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Rare Earth Elements in China: Growth, Strategy and Implications

National Institute of Advanced Studies

Bangalore, India

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Executive Summary

Rare earth elements (REEs) or rare earth metals are a collection of seventeen chemical elements in the periodic table, namely scandium, yttrium, and the fifteen lanthanides. Scandium and yttrium are considered rare earth elements since they tend to occur in the same ore deposits as the lanthanides and exhibit similar chemical properties.

This paper is designed to evaluate the importance of rare earth elements. The study explores China's role in the supply-demand equation and price mechanism at large and, its implications. It also examines the history of rare earth elements and China's current monopoly over the industry, including possible repercussions and strategic implications if rare earth supply were to be disrupted. The study provides insights into how widely traded these minerals are and China's positions in the international trade both in terms volume and value. The study investigates who are the major customers and analyses the various trade restrictions imposed by China. The study capitulate instructive and actionable data for considering how China's decreasing exports, fresh technological uses, and rising prices are setting up an unprecedented discussion on the REEs.

Rare earths are critical component of many high technology goods such as hybrid vehicles, mobile telephones, computers, televisions and energy efficient lights. Although rare earths have relatively a high unit value, the impact of their cost has little, if any impact on the selling price of the final item because they are present in minute concentrations. RE elements are also considered as strategically important because of its uses in defense and essential components to products with high growth potential-electronics and technology industries, energy efficiency and greenhouse gas reduction. Rare earth elements are important ingredients in lasers, superconducting magnets, batteries for hybrid automobiles; Makers of hybrid cars use these elements in their lanthanum nickel magnets to give them greater rechargeable capabilities. Portable x-ray units can function much more effectively with thulium. Erbium-doped fiber optic cables can amplify the speed of communication. Night vision goggles and rangefinder equipment use rubidium to increase accuracy and visibility. Radar uses the samarium cobalt magnet to withstand stresses as it has the highest temperature rating of any rare earth magnet.

China's dominance in the RE supply chain is directly related to Beijing's consistent and long term planning, which dates back to as early as the 1950s. However, the Chinese RE industry greatly advanced when Xu Guangxian (also known as "The Father of Chinese Rare Earths Chemistry") developed the Theory of Countercurrent Extraction-which is applicable for the separation of a mixture with more than ten components such as rare earths-in the 1970s. Since then, China's REO output has increased rapidly from slightly over 1,000 tonnes in 1978 to 11,860 tonnes in 1986, when a production spike at the giant Bayan-obo mine first propelled China past the United States as the world's leading producer of REO. Meanwhile, Beijing has continuously invested heavily in technological innovations through key national R&D programs, in order to gain a decisive advantage in the rare earth supply chain including mining, separation, refining, forming and manufacturing.

Most rare earth elements throughout the world are found in deposits of the minerals bastnaesite and monazite. Bastnaesite deposits in the United States and China account for the largest concentrations of REEs, while monazite deposits in Australia, South Africa, China, Brazil, Malaysia, and India account for the second largest concentrations of REEs. Bastnaesite occurs as a primary mineral, while monazite is found in primary deposits of other ores and typically recovered as a byproduct. Over 90% of the world's economically recoverable rare earth elements are found in primary mineral deposits i.e., in bastnaesite ores. China supplies approximately 95% of global demand and consumes about 60% of the global supply, but its reserves of rare earths are finite.

The Chinese government has indicated that if the exploitation of these resources is not controlled, they could be exhausted in 20-30 years. These valuable resource endowments are not evenly distributed in China and about 83% of the resources are located in Baiyunebo (Baotou, Inner Mongolia), 8% in Shandong province, 3% in Sichuan province (light rare earth deposits of La, Ce, Pr, Nd Sm, Eu). 3 percent of the deposits located in Jiangxi province are middle and heavy rare earth deposits (Middle: Gd, Tb, Dy, Ho, Heavy: Er, Tm, Yb, Lu, Sc, Y). In comparison, while most of the global supply of heavy REs (e.g. yttrium) originates in the "ion adsorption clay" ores of Southern China, the proven reserves of heavy REs in the 7 Southern Chinese provinces are a mere 1.5 Mt. Since heavy REs are considered more strategically valuable, significant efforts have been made by Beijing in recent years to crack down rampant illegal mining in Southern China.

In fact, there are very few companies outside China producing the metals. Inner Mongolia Baotou Steel Rare Earth Hi-Tech Co. is China's single largest producer of the metals. China rare earth extraction know how is currently unparalleled, the necessary production capacities, infrastructure and distribution channels all exist and, on top of that, the country benefits from fairly lax environment and work place safety regulations and low labour costs. China, which once focused on exporting rare earths in their raw forms, has shifted its end goal from production to innovation. In the 1970s, China was just exporting rare earth mineral concentrates. By the 1990s, it began producing magnets, phosphors and polishing powders. Now, it is making finished products like electric motors, batteries, LCDs, mobile phones and so on.

There are few basic features of Chinese supply that we can derive from the above analysis. The facts include, China still hold more than 25 million tonnes of rare earth oxide reserves, excessive secondary processing capacity and easy availability of cheap processing chemicals, and heavy investment in research and technology. Moreover, the supply of Chinese heavy rare earth are finite with 15- 20 years of mine life, Chinese are rigorously regulating the mines on environmental grounds. After China gained decisive advantage in the RE supply chain, Beijing's restrictions on REO production and exports in recent years have been primarily motivated by the strong political desire for resource conservation.

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

Just as worldwide demand for REO is growing so too is China's own demand. Data from the Chinese society of Rare earths (CSRE) show that the country's consumption has grown rapidly since 2004 and reached over 70,000 tonnes in 2008. Growth in demand from China will continue to outpace the rest of the world. By the year of 2015, it is estimated that the global demand of rare earths is expected to reach 210 thousand tonnes. It can be concluded that Rare Earth Materials has become a major growth point of China rare earth industry. China, Japan and the United States are the largest consumers of rare earth metals. With the growing demand for 'green' products, the demand for rare earth metals is only expected to increase. The annual growth in demand is expected to hover around 10%. China started a program wherein it not only mined and produced these rare earth elements but also manufactured the finished goods. So, not only does the country produce 97% of the world's REEs but also uses approximately 70% of that material to build products domestically. Thus, China came to dominate the entire industry. 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. This demand as no doubt been and will continue to be fueled by heavy investments in clean energy.

In China, rare earths were mainly consumed in traditional areas of metallurgy, machinery, petroleum industry, chemical industry, light industry, textile industry, agriculture, in new materials like magnets, phosphors, hydrogen storage, catalysts for automobile exhaust and polishing powder. There was a dramatic change in the consumption structure, the consumption of rare earths in new materials increased very fast since 2004. In 1988, the consumption of rare earths in new materials was only 1%, but in 2007, it was 53%. In 2008, it was claimed that about 60% of rare earths was consumed in new materials in China. China's consumption of rare earth elements is also expected to increase dramatically as more and more foreign companies move their production sites to China to take advantage of the lower cost of rare earths and therefore reduce their overall production costs. This is part of China's larger strategy to maintain a tight hold on the industry.

Rare earth elements are needed for China's expansion of its own military needs (aircraft carriers, nuclear-powered submarines, and ballistic missiles). Home-grown production needs will further cut exports already reduced to crippling levels. Not surprisingly, these measures have raised real concerns outside of China regarding the future availability of the refined products created from REMs. The rare earth supply chain for the sleep paralyzed Western defense industries is now being held hostage by the Chinese who want to keep the rare earth metals for their own rapidly expanding markets. Rare earth prices remained static for decades due to plentiful supplies, lulling the high-tech industry into a false sense of security. After Beijing cut export quotas by 70 percent for the second half of 2010, prices of some rare earths has gone up, as much as 850 percent. Due to the extensive management of rare earth resource exploitation and scattered distribution of the rare earth industry, many foreign importers used the opportunity to force down the price. When the global demand for rare earth materials increases year by year, China exported 6,100 tonnes of medium-end and low-end rare earth products in 1990; the average price was 13,600 USD/ton. In 2009, China exported 36,100 tonnes of rare earth smelting and separation products, rising by 16.67% YOY. The export value amounted to USD 310 million and the average price was only 8,959 USD/ton (China Research and Intelligence, 2010). Low prices for rare earth elements from China, contributed to cuts at the Mountain Pass mine in the United States, one of the main source of supply for many years, before it closed in 2002. They also discouraged most entrants to the industry until the last two years, when prices began to climb because of strong demand.

In 2009, China exported a total of 38573.02 tonnes but the total of all the rare earths exported to 46 countries added up to 40982.13 tonnes. The quantity and the percentage share of the top 10 customers of China is indicated in the below table. United States was the largest importer of Chinese rare earths by quantity and imported around 14700 tonnes of rare earths, these accounted for 38% of the Chinese exports. Japan imported around 10500 tonnes and its share amounted to 27%. North America (mainly the United States) and Asia each account for around 36% of the Chinese rare earth exports by quantity. Around 24% is exported to Europe.

Until recently, the global dependency on China for rare earths was a well-kept secret. But word started to spread fast after Beijing cut export quotas by 70 per cent for the second half of 2010, sending prices of some oxides - the purified form of rare earth elements - up as much as

850 per cent. The need for alternative supplies from outside China suddenly became obvious. The Chinese dominance has raised concerns within industry regarding prices and lead times for critical defense hardware. With demand increasing, the problem of purchasing and shipping REEs for products is concurrently growing.

The impact of Chinese interventions in the domestic industry such as implicit assistance to domestic downstream processors of the targeted products and thus providing them a competitive advantage will have an impact on the prices. China is seeking sustainability and prices will respond to market demand and supply from a sustainable base. Estimates from Chinese government reports shows that the "Chinese price" for rare earths is about ¼ of the price that would result from an environmentally sound, worker friendly, profitable operation. This means that the "real" price of rare earths is about four times higher than the current China price. An entire set of "green" industries have grown up over the past ten years in reliance on that China price. The danger is that as the China price is phased out, many of these green industries will prove to be unprofitable. A primary example of this risk is the electric car. Since the China price for rare earths is virtually certain to be phased out very quickly, this risk is quite real. However, technological change often brings sharp changes in demand, which, in turn, may lead to strong price volatility. An example is the tantalum capacitor industry. Two-thirds of world tantalum production is used in electronic components. When the tantalum price increased sharply in the late 1990s, the electronics industry encouraged capacitor designers to improve their niobium capacitors and multiple ceramics capacitors in order to replace the tantalum components. The demand for tantalum, and its price, fell sharply as a result.

To control the supply China has introduced a number of measures such as imposing 15 percent of taxes on light rare earths oxides and neodymium metal and, 25 percent tax on heavy rare earths and other metals. Government has recommended that the management of rare earth mines should be consolidated under three four main enterprises and has stepped up efforts to restructure the rare earth industry and has introduced favorable policies, and is encouraging acquisitions and mergers to restructure the sector. According to plans, the Chinese government will bring down the number of rare earth companies from 90 to 20 within 2015. These measures will have short – medium term repercussions in the international market and industrial applications.

For China rare earth is the wild card now. The Chinese government has stated that its reserves of rare earths are finite and, therefore, they will be developed for the prime benefit of China's manufacturing industry. To help generate manufacturing jobs and move up the value chain, a series of measures has been implemented to "conserve resources and to maximize the benefits" of its rare earths endowment. 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.

1. Introduction

Rare earth elements (REEs) or rare earth metals are a collection of seventeen chemical elements in the periodic table, namely scandium, yttrium, and the fifteen lanthanides. Scandium and yttrium are considered rare earth elements since they tend to occur in the same ore deposits as the lanthanides and exhibit similar chemical properties.

This paper is designed to evaluate the importance of rare earth elements. The study explores China's role in the supply-demand equation and price mechanism at large and, its implications. It also examines the history of rare earth elements and China's current monopoly over the industry, including possible repercussions and strategic implications if rare earth supply were to be disrupted. The study provides insights into how widely traded these minerals are and China's positions in the international trade both in terms volume and value. The study investigates who are the major customers and analyses the various trade restrictions imposed by China. The study capitulate instructive and actionable data for considering how China's decreasing exports, fresh technological uses, and rising prices are setting up an unprecedented discussion on the REEs.

REEs were first discovered in 1787 by Lieutenant Carl Axel Arrhenius, a Swedish army officer. Since then there has

Table 1: What are the rare earth elements?

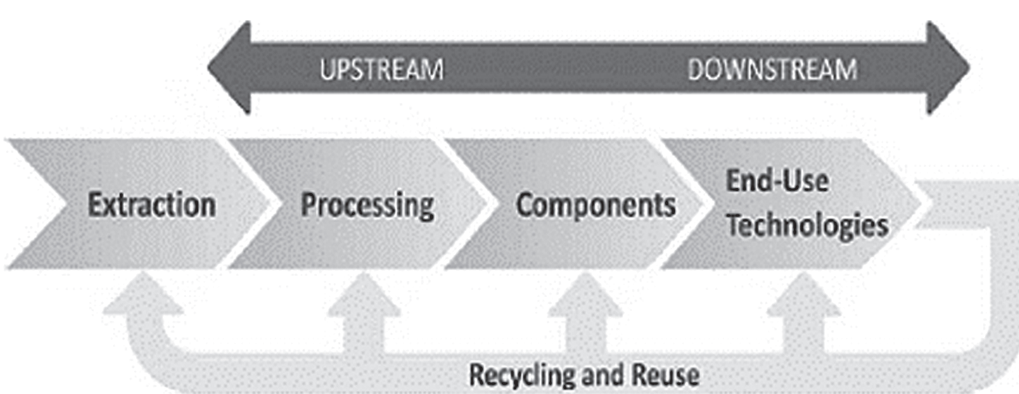
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Ai	Si	P	S	CI	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	**	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Ti	Pb	Bi	Po	At	Rn
Fr	Ra	**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn						
		La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
		Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cr	Es	Fm	Md	No	Lr	

* The author is thankful to Dr. Prahlada, Dr. K.D. Naik, Dr. S Sankaran and Dr. Anuradha Reddy for their valuable suggestions and comments. Suggestions from Prof. Rajaram Nagappa, Prof. S. Chandrashekar, Prof. Lalitha Sundaresan, Dr. Manav Guha, Prof. Ramani are gratefully acknowledged and thanks are due to other ISSSP faculties for their encouragement and help. I also would like to thank Shruthi Shivabasavaiah for her editorial assistance.

been a great deal of interest in their chemical properties and potential uses. From about the 1940s to the 1990s, REEs attracted great interest in both the U.S. and China's academic and scientific communities. Today, however, there are only a small handful of scientists who truly focus on REEs in the U.S. China, on the other hand, could be setting itself up to become a superpower in technological innovation through its near monopoly and its vast efforts in research and development of REEs (Hurst Cindy, 2010).

Despite their name, rare earth elements (with the exception of the highly unstable promethium) are relatively plentiful in the Earth's crust, with cerium being the 25th most abundant element at 68 parts per million (similar to copper). However, because of their geochemical properties, rare earth elements are not often found in concentrated and economically exploitable forms or ores. It was the very scarcity of these minerals (previously called "earths") that led to the term "rare earth". The first such mineral discovered was gadolinite, a compound of cerium, yttrium, iron, silicon and other elements. Cerium, for example, ranks number 26 in abundance among the elements and is five times as common as lead. And even the scarcest of rare earths, Thulium, is more abundant than gold or platinum. Because the elements share similar chemical properties, most REEs deposits contain a large number of all 17 elements in varying- albeit small- concentrations. In addition, rare earths are often of low quality, which has made the material uneconomical to mine, and also because the elements are usually found within a cocktail of rare earths that need to be separated in laborious process.

Figure 1: Basic materials supply chain



Elemental materials are extracted from the earth via mining. Next, they are processed via separation and refining to obtain the desired composition or purity. Materials may be extracted either as major products, where ore is directly processed to extract the key materials or they may be co-products or byproducts of other mining operations. The co-production and by-production processes create complex relationships between the availability and extraction costs of different materials, which may cause supply curves and market prices to vary in ways not captured by simple supply and demand relationships (DoE, US, 2010). Processed materials are used to manufacture component parts that are ultimately assembled into end-use technologies. The generic supply chain also shows the potential for recycling and reusing materials from finished applications, though materials can be reclaimed at any stage of the supply chain and reused either upstream or downstream (DoE, US, 2010).

Rare earths are a critical component of many high technology goods such as hybrid vehicles, mobile telephones, computers, televisions and energy efficient lights. Although rare earths have relatively a high unit value, the impact of their cost has little, if any impact on the selling price of the final item because they are present in minute concentrations. RE elements are also considered as strategically important because of its uses in defense and essential components to products with high growth potential-electronics and technology industries, energy efficiency and greenhouse gas reduction. Rare earth elements are important ingredients in lasers, superconducting magnets, batteries for hybrid automobiles; Makers of hybrid cars use these elements in their lanthanum nickel magnets to give them greater rechargeable capabilities. Portable x-ray units can function much more effectively with thulium. Erbium-doped fiber optic cables can amplify the speed of communication. Night vision goggles and rangefinder equipment use rubidium to increase accuracy and visibility. Radar uses the samarium cobalt magnet to withstand stresses as it has the highest temperature rating of any rare earth magnet.

Even with a threefold increase in REE demand over the past ten years, demand is expected to increase even further, by anywhere from 8 to 790 percent over the next five years (Kientz R, 2010). While REEs have been produced for almost a century, the companies supplying them have changed. In the mid-twentieth century, almost all rare earth mining was done at Mountain Pass, California. Today, more than 97 percent of mining and refinement is done in China. The shift occurred mainly due to the elaborative separation and refining processes, which is labor intensive, and raises safety and environmental concerns. Not only do the Chinese mine most of rare earths today, they possess 36 percent of world reserves (Hedrick. J B, 2010:129).

China's dominance in the RE supply chain is directly related to Beijing's consistent and long term planning, which dates back to as early as the 1950s. However, the Chinese RE industry greatly advanced when Xu Guangxian (also known as "The Father of Chinese Rare Earths Chemistry") developed the Theory of Countercurrent Extraction-which is applicable for the separation of a mixture with more than ten components such as rare earths-in the 1970s. Since then, China's REO output has increased rapidly from slightly over 1,000 tonnes in 1978 to 11,860 tonnes in 1986, when a production spike at the giant Bayan-obo mine first propelled China past the United States as the world's leading producer of REO. Meanwhile, Beijing has continuously invested heavily in technological innovations through key national R&D programs, such as the 863 and 973 projects, in order to gain a decisive advantage in the rare earth supply chain including mining, separation, refining, forming and manufacturing (Hurst Cindy, 2010:6).

According to China's Ministry of Science and Technology, the objective of these program was to "advance in key technological fields that concern the national economy and national security; and to achieve 'leapfrog' development in key high-tech fields and take strategic positions in order to provide high-tech support to fulfill strategic objectives in China's modernization process". In 1992 the late Chinese Prime Minister Deng Xiaoping famously stated, "the Middle East has oil, and China has rare earths", since then, China has not only remained the world's largest REO producer, but has also successfully moved its manufacturers up the supply chain (Hurst Cindy, 2010). Since 1990, domestic consumption of REO for high value-added product manufacturing in China has increased at 13 percent annually, reaching 73,000 tonnes in 2009 (Song and Hong, 2010). State-run labs in China have consistently been involved in research and development of REEs for over fifty years. The Rare Earth Materials Chemistry and Applications which is affiliated with Peking University and focused on rare earth separation techniques and, the lab based at Changchun Institute of Applied Chemistry. Additional labs concentrating on rare earth elements include the Baotou Research Institute of Rare Earths, the largest rare earth research institution in the world, established in 1963, and the General Research Institute for Nonferrous Metals established in 1952(Hurst Cindy, 2010:9). This long term outlook and investment has yielded significant results for China's rare earth industry.

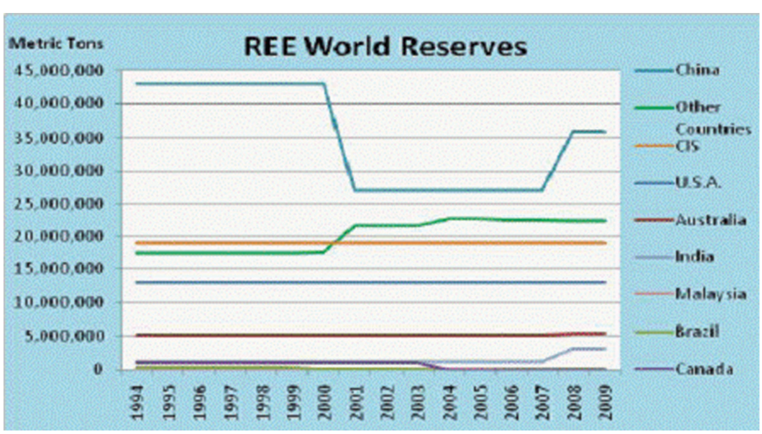
2. Reserves, Production and Supply

2.1 Rare Earth Element - Reserves

Reserves are the resources that could be economically extracted or produced at the time of determination. The term reserves need not signify that extraction facilities are in place and operative.

Globally, the four principal high-yield REE-bearing minerals are bastnäsite, monazite, xenotime and ion absorption clays. A mineral deposit that does not fall in any of these four categories typically requires more metallurgical testing to establish the mineralogy and processing steps. The rare earth content of each deposit is essential to estimating the deposit's profitability. It determines how the ore will be processed and how complicated it will be to separate the rare earth elements from each other. Most rare earth elements throughout the world are found in deposits of the minerals bastnaesite and monazite. Bastnaesite deposits in the United States and China account for the largest concentrations of REEs, while monazite deposits in Australia, South Africa, China, Brazil,

Figure 2: REE world reserves



Source: United States Geological Survey Mineral and Commodity Summaries

Malaysia, and India account for the second largest concentrations of REEs. Bastnaesite occurs as a primary mineral, while monazite is found in primary deposits of other ores and typically recovered as a byproduct. Over 90% of the world's economically recoverable rare earth elements are found in primary mineral deposits i.e., in bastnaesite ores (Marc Humphries, 2010).

According to the US Geological survey, total known reserves word wide amounted roughly 99 million tonnes at the end of 2009, which would last 800 years, provided production remained unchanged at the current level of approximately 124 thousand tonnes compared with its peak of 137 thousand tonnes in 2006, rare earth out put has thus come down some 9 per cent.

There are three primary criteria, among others, that determine the economic feasibility of a potential rare earth mine: tonnage, grade and the cost of refining the rare earth mineral. A mine may be economically viable (and therefore attractive to investors) if a low-grade (<5%) ore occurred with large tonnage and familiar mineralogy or if high-grade ore occurred with familiar mineralogy. Heavy rare earths (atomic numbers 65–71), such as terbium and dysprosium, along with yttrium (atomic number 39), are somewhat more scarce and often concentrated in ionic adsorption clay and xenotime, commonly found in southeastern China (Hedrick James B, 1997:471).

China supplies approximately 95% of global demand and consumes about 60% of the global supply, but its reserves of rare earths are finite. The Chinese government has indicated that if the exploitation of these resources is not controlled, they could be exhausted in 20-30 years. These valuable resource endowments are not evenly distributed in China and about 83% of the resources are located in Baiyunebo (Baotou, Inner Mongolia), 8% in Shandong province, 3% in Sichuan province (light rare earth deposits of La, Ce, Pr, Nd Sm, Eu). 3 percent of the deposits located in Jiangxi province are middle and heavy rare earth deposits (Middle: Gd, Tb, Dy, Ho, Heavy: Er, Tm, Yb, Lu, Sc, Y). In comparison, while most of the global supply of heavy REs (e.g. yttrium) originates in the "ion adsorption clay" ores of Southern China, the proven reserves of heavy REs in the 7 Southern Chinese provinces are a mere 1.5 Mt (Huatai United Securities, 2010). Since heavy REs are considered more strategically valuable, significant efforts have been made by Beijing in recent years to crack down rampant illegal mining in Southern China.

Table 2: The world wide resreves of rare earth elements as of 2009

Country	Reserves (Million Metric Tonnes)	% of total	ReserveBase* (Million Metric Tonnes)	% of total
United States	13.0	13	14	9.3
China	**36**	**36**	**89**	**59.3**
Russia & CIS	19	19	21	14
Australia	5.4	5	5.8	3.9
India	**3.1**	**3**	**1.3**	**1**
Brazil	Small			
Malaysia	Small			
Others	22.0	22	23	12.5
Total	**99.0**		**154.0**	

Source: Marc Humphries 2010

*Reserve Base is defined by USGS to include reserves(both economic and marginally economic)plus some subeconomic resources(with potential for becoming economic reserves).

Reserves of medium and heavy rare earths may only last 15 to 20 years at the current rate of production, which could lead to China being forced to imports supplies. Medium and heavy rare earth, also known as ion-adsorbed-type rare earth, is more valuable than the lighter variety. It is used in advanced areas such as missiles. China's verified reserves of ion-adsorbed-type rare earth stood at 8 million tonnes in 2008, while reserves of light rare earth totaled 50 to 60 million, according to data from the Ministry of Land and Resources.

Fujian, the province with the country's third richest rare earth reserve, is building an integrated rare earth industrial park near one of the country's most productive heavy rare earth mineral deposits. Located at south Changting, the 10 sq km park with an investment of 6 billion yuan ($905 million) is expected to be ready by 2015, according to the Chinese Society of Rare Earth.

China's rare earth resources are widely distributed throughout the country. The scattered distribution makes it difficult to carry out efficient oversight of the industry. The 2009-2015 Plan aims to create 'large rare earth districts' to simplify management of China's rare earth resources. The new plan will divide China's industry into three large districts -south, north, and west. The southern district would comprise of Jiangxi, Guangdong, Fujian, Hunan, and Guangxi; the northern district would be centered on Inner

Mongolia and Shandong and the western district would consolidate mines located in Sichuan (Hurst Cindy, 2010). China is also reported to have around 84 deposits /mines of rare earths, spread over 18 provinces. The proposed consolidated rare earth districts will most likely be under the direction of one company. If successful, the new consolidation could dramatically affect China's ability to control the flow of rare earths. During this consolidation process there may be unexpected supply shortages because of shutdowns or increased availability of products due to new efficiencies. The details of the number of mines operating in various provinces are indicated in table 3.

Interestingly, the data suggests that China has controlled output successfully since 2006 as it sought to consolidate the domestic industry into a handful of players. China has long lagged behind the U.S. technologically. However, as of the early 1990s, China's vast rare earth resources have propelled the country into the number one position in the industry. Additionally, China has set out on an expansive effort to increase its overall technological innovation, effort which includes the use of rare earth elements. China's academic focus on rare earth elements could one day give the country a decisive advantage over technological innovation.

2.2 Production of Rare Earth Elements

In fact, there are very few companies outside China producing the metals. Inner Mongolia Baotou Steel Rare Earth Hi-Tech Co. is China's single largest producer of the metals. China rare earth extraction

Table 3: Rare earth deposits/mines in China

Province	No. of Mines	Province	No. of Mines
Fujian	3	Jiangxi	8
Gansu	1	Jilin	1
Guangdong	17	Liaoning	2
Guangxi	7	Shandong	2
Guizhou	3	Shanxi	1
Hainan	6	Sichuan	4
Hebei	3	Xinjiang	1
Hubei	3	Yunan	3
Hunan	12	Not Known	**2**
Inner Mongolia	5	**Total**	**84**

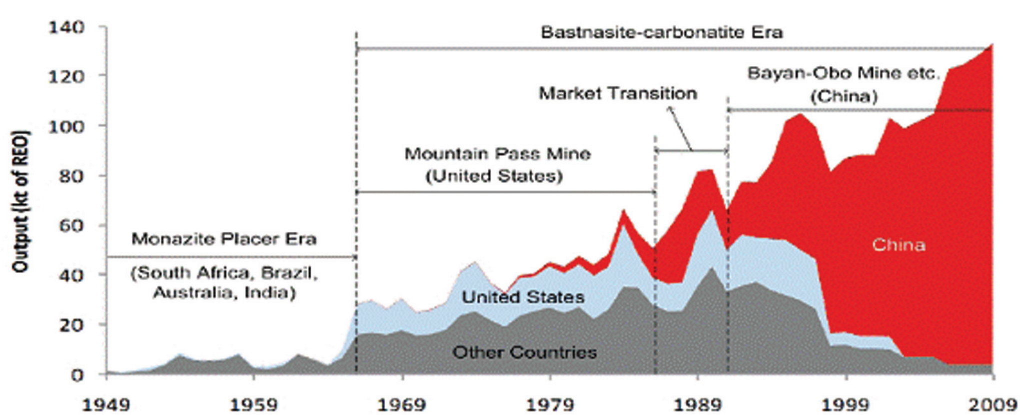
Source: Greta J. Orris and Richard I. Grauch (2002) know how is currently unparalleled, the necessary production capacities, infrastructure and distribution channels all exist and, on top of that, the country benefits from fairly lax environment and work place safety regulations and low labour costs. China, which once focused on exporting rare earths in their raw forms, has shifted its end goal from production to innovation. In the 1970s, China was just exporting rare earth mineral concentrates. By the 1990s, it began producing magnets, phosphors and polishing powders. Now, it is making finished products like electric motors, batteries, LCDs, mobile phones and so on.

REE Production Trends

The significant cost advantage for Chinese producers, which has crushed almost all overseas competitors, is not only driven by low labor costs, but also unintentionally reinforced by Beijing's policy failures in regulating the resource extraction sector as a whole, and the RE industry in particular. To keep pace with its booming economy, Beijing promulgated the so-called "Let Water Flow Rapidly" (*You Shui Kuai Liu*) policy in 1981 to stimulate a rapid spike in resource demand without appropriate considerations of environmental protection, safety and sector consolidation. The lack of entrance standards and patent enforcement led to a proliferation of small scale and technologically backward mines and separation plants.

Media reports have often pegged China's rare earth cost advantage on poor environmental standards, which are a problem in the chaotic mining operations

Figure 3: Chinese rare earth industry in the international context



Source: United States Geological Survey, formatted by CSIS in Southern China (Tu Kevin J, 2010). But the truth, according to experts, is that China's largest source of rare earths does not even come from a rare earth mine. Rather, it comes out of the tailings (or waste material) from the giant Baotou iron ore mine in the province of Inner Mongolia in Northern China. A cheap processing method is used to covert them into high-purity product. As production from these sources continued to ramp up in the 1990s, there was massive overcapacity built in China, and prices collapsed. The Chinese government introduced the first export quotas in 1999. In less than one decade, the permanent magnet market experienced a complete shift in leadership. Whereas in 1998, 90 percent of the world's magnet production was in the United States, Europe, and Japan, today, rare earth magnets are sold almost exclusively by China or using Chinese rare earth oxides. China is now facing the possibility that reserves of medium and heavy rare earths might run dry within 15 to 20 years if the current rate of production is maintained.

The table 4 reveals that the production in Bayan Obo remains the largest REE industry in China contributing almost half of the total production. The production has been constant between the periods 2006 and 2008 ranging between 125- 140 thousand tonnes. China has greatly reduced the production of REE to 110-130 thousand tonnes by the end of 2010 and also restricted the exports through various quota systems which will be discussed in detail in section four. The table also provides the estimated level of REE production in China for the year 2014, increased production of 80-100 thousand tones in Bayan Obo and 160-170 thousand tonnes of total production.

Table 4: Chinese production of rare earth chemical concentrates 2004-14

Year	Bayan Obo Bastnasite	Sichuan Bastnasite	Ion Adsorption clays	Monazite	Total
2004	42-48,000	20-24,000	28-32,000	-	9-100,000
2006	45-55,000	22-26,000	40-50,000	8-12,000	125-140,000
2008	60-70,000	10-15,000	45-55,000	8-12,000	125-140,000
2010	55-65,000	10-15,000	35-45,000	4-8,000	110-130,000
2014	80-100,000	20-40,000	40-50,000	8-12,000	160-170,000

Note: Illegal or uncontrolled mining and processing is not included. It has amounted to 10-20,000t pa REO over the last 3-5 years

Source: IMCOA, CREIC, Baogang Rare Earth Hi-Tech, Sichuan RE Association, GRIREM

2.3 Supply of Rare Earth Elements

The supply of a material is a function of resources, reserves and production. "Resources" include identified and undiscovered resources. Production generally occurs in countries with large resources and reserves, but exceptions exist. In some cases, small reserve holders may also produce the material, while countries with no reserves could be a major refinery producer of imported primary or raw material.

There was still more than enough supply reaching other markets and there was no real talk of a problem in the sector until the past couple of years, when growing global demand for rare earths highlighted the fact that China had put everyone else out of business. Comments from Chinese government officials started to suggest that they view the industry as more strategic than ever before, and were intent on securing more supply for domestic use. They started taking measures to consolidate domestic supply and reduce smuggling. Analysts are of the opinion that by 2012, the rest of the world could face a major supply crisis because of China's reduced or zero supply. The demand-supply is expected to touch 30,000–40,000 tonnes by 2012 in the absence of any new large supplier (David Anthony, 2010). The growing economy of China is creating a worldwide risk to supply and China's growing consumption limits its exports of rare earths. China insists that it requires the high supplies to meet the demands of its clean energy and high-tech sectors.

Most of the rare earth enterprises locate around the large rare earth mines, such as Baotou city, Sichuan province and Ganzhou city. There are about 24 enterprises for rare earth concentrate production, and 100 rare earth enterprises for smelting separation production in China. Most of the REE supply originated from the Baotou plant was about 55000t and the total supply from China were about 103300t in 2010. The global supply increased to 15000 in 2010 from the 2005 level of 10500t to meet the increasing demand from the automotive and technology sectors.

The table 5 reveals a number of developments in production and supply of rare earths by 2014 and shows that a 10 percent increase in production at Baotou plant from 2010 to14 and full production quota to be utilized at Sichuan with production of 20000t. The supply from Iconic clay regions will be reduced to 30000t by 2014 with a little increase in supply from recycling in China. Chinese restrictions on supply in 2010 have triggered many countries too look for alternative sources and by 2014 a number countries will be in a position to

Table 5: Chinese REE supply compare to other countries in 2010 and 2014 (forecast)

Chinese Supply Sources	QTY 2010	QTY 2014.est	Non Chinese Supply	QTY 2010	QTY 2014.est
Baotou ♦ By product of iron ore mine ♦ Moving to higher grade iron, with lower impurities and Rare Earths ♦ Tailing facilities near capacity	55000t	60000t	India ♦ Subsidiary of Indian AEA ♦ Toyota Tsusho bought trading firm with Japanese Distribution	3000t	12000t
			Russia & CIS ♦ Limited expansion capacity ♦ By product of Mg production	4000t	
Sichuan ♦ Target to increase value added ♦ Capacity expected to increase	10000t	20000t	Australia, Mount Weld		22000t
Iconic clay regions ♦ Reportedly 14 yrs of resources ♦ Large amount of illegal mining ♦ Government action taking effect	35000t	30000t	USA-Mountain pass ♦ Reprocessing stockpiles ♦ Requires apprx. US$530 million rebuild	3000t	20000t
Recycling	3300t	4000t	Recycling ♦ Magnet swarf ♦ Batteries-future potential	1500t	1800t
Total	103300t	114000t	Total	11500t	55800t

Source: Lynas Corp, 2010

supply some amount of rare earth as the data shows that the mount weld mine in Australia is expected to supply about 22000t and mountain pass in California is expected to supply 20000 tonnes along with supplies from Russia, CIS countries and India. One of the largest growth areas is expected to be the production of hybrid vehicles, such as the Toyota Prius. Each hybrid car contains 16 kg of rare earths, predominantly in its batteries and electric motors (Lun Joe, 2006).

The table also shows that the supply from recycling in China increases marginally from 3300t in 2010 to 4000t in 2014 and from 1500t to 1800t in global supply. The reuse and recycling capacity currently limited as recovery of manufacturing waste and measurable recovery from aftermarket products are yet to develop. Also recycling them is often difficult and expensive, because they are often mixed with other materials when products are made. And there is little economic incentive to recycle, since rare earth elements are available raw on the world market at comparatively low prices. However, improved designs for recycling coupled with larger streams of materials could eventually allow for the economical recycling and reuse of magnetic materials.

Table 6 shows that most of the oxides are produced at different mine sites in China. The industry in Malaysia is largely dependent on the ores from Australia. Most analysts believe China will eventually change its quota system to restrict the rare earths individually. Because China has an abundance of light rare earths available through the Bayan Obo project in Mongolia, changing the quota system would likely trigger a sudden flood of cerium and lanthanum on to the market. Even with new mines coming online within the next five years, analysts are forecasting a shortage of heavy rare earths terbium and dysprosium by 2015, and a very tight supply of light rare earths neodymium and praseodymium. Of note is that nearly all rare earth deposits contain the radioactive material thorium and the cost of treating and storing thorium is an important factor in evaluating the economics of a mine. This may be particularly true to the rare earth

Table 6: Rare earths types and contents of major contributing source minerals supplying REEs to the global market (percentage of total rare earth oxides)

		LIGHT				MEDIUM			HEAVY								
TYPE	Location (s)	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Y
Currently Active:																	
Bastnasite	Byan obo Inner Mongolia	23	50	6.2	18.5	0.8	0.2	0.7	0.1	0.1	0	0	0	0	0	0
Xenomite	Lahat, perak, Malaysia	1.2	3.1	0.5	1.6	1.1	0	3.5	0.9	8.3	2.0	6.4	1.1	6.8	1	61
Rare earth laterite	Xunwu, Jianxi China	43.4	2.4	9.0	31.7	3.9	0.5	3.0	0	0	0	0	0	0.3	0.1	8
Ion adsorption clays	Longnan,Jianxi, China	1.8	0.4	0.7	3.0	2.8	0.1	6.9	1.3	6.7	1.6	4.9	0.7	2.5	0.4	65
Loparite	Lovozerskaya, Russia	28	57.5	3.8	8.8	0	0.1	0	0.1	0.1	0	0	0	0	0	0
Various	India	23	46	5	20	4	0	0	0	0	0	0	0	0	0	0

Source: U.S Department of Energy (2010) production in Kerala, India where the deposits of thorium is very high. In general, each rare earth ore body is unique and requires a site-specific processing system. As a result, production costs vary from deposit to deposit based on ore content and mineralogy.

The development of increased stockpiling of REE in China has gained momentum in recent years with assertion of government authority in recent years over mining regions. The Chinese stockpiling, under the direction of the Ministry of Land and Resources, began with a pilot project in early 2010 in China's primary mining region of Baotou in Inner Mongolia. At least 10 storage facilities are being built and managed by the world's largest producer of rare-earth metals; government-controlled Baotou Steel Rare-Earth (Group) Hi-Tech Co. Chinese state media reports say stockpiles may eventually top 100,000 metric tonnes (James T. Areddy, 2011). The move to build reserves comes as China's supply of rare-earth metals to the rest of the world already is shrinking despite growing demand for the elements. In response to Chinese restrictions on supply the high-tech-focused nations of U.S, The European Union, Japan and South Korea, all of which are dependent on China for rare-earth supplies, have highlighted stockpiling strategies.

There are few basic features of Chinese supply that we can derive from the above analysis. The facts include, China still hold more than 25 million tonnes of rare earth oxide reserves, excessive secondary processing capacity and easy availability of cheap processing chemicals, and heavy investment in research and technology. Moreover, the supply of Chinese heavy rare earth are finite with 15- 20 years of mine life, Chinese are rigorously regulating the mines on environmental grounds. After China gained decisive advantage in the RE supply chain, Beijing's restrictions on REO production and exports in recent years have been primarily motivated by the strong political desire for resource conservation.

3. Demand and Industrial Applications of Rare Earth Elements

The two major drivers of demand for mineral commodities are the rate of overall economic growth, (stable or decline) and the state of development for principal material applications (e.g., clean energy technologies). Demand for key materials in clean energy technologies compete for available supply with demand for the same materials in other applications.[1] With 1.3 billion people and the fastest growing economy in the world, China is faced with the challenging task of ensuring it has adequate natural resources to sustain economic growth. There is also a growing school of thought that China is not actually able, at present, to use all of the materials allocated for domestic use only. "Out of a production level of perhaps 100,000 tonnes of total rare earth oxides in past years," the bulk of that material has ended up being purchased by end-users in first-world nations (US DOE, 2010).

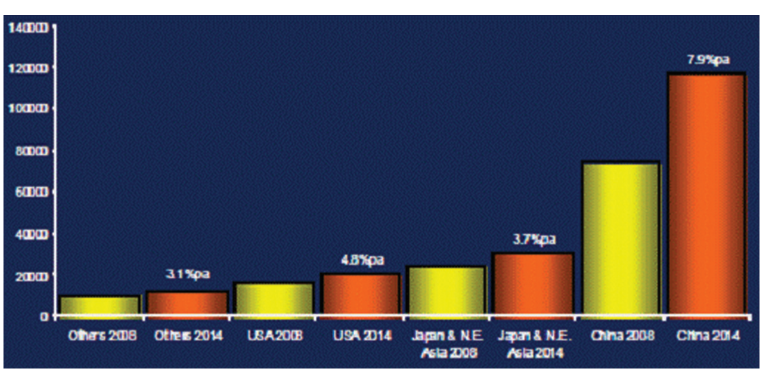
World demand for rare earth elements are estimated at 134,000 tonnes per year, with global production around 124,000 tonnes annually. The difference is covered by above-ground stocks or inventories. World demand is projected to rise to 180,000 tonnes annually by 2012, while it is unlikely that new mine output will close the gap in the short term. By 2014, global demand for rare earth elements may exceed 200,000 tonnes per year. China's output may reach 160,000 tonnes per year (up from 130,000 tonnes in 2008) in 2014. An additional capacity

[1] Generally and with respect to the key materials, demand for end-use items for building use (e.g., phosphors for lighting) or construction tend to be more cyclical, whereas those that enter big-ticket consumer items such as cars tend to be more volatile and sensitive to short-term economic movements. Uses that enter portable devices and personal consumer goods (e.g., batteries for portable electronics) tend to experience more stable demand. Regional factors are important also: China's and India's rapid economic growth have had and will continue to have a huge impact on global demand for mineral commodities (Eggert RG, 2010).

shortfall of 40,000 tonnes per year may occur. This potential shortfall has raised concerns in the major rare earth consuming countries. New mining projects could easily take 10 years for development. In the long run, however, the USGS expects that reserves and undiscovered resources are large enough to meet demand. This expected growth, coupled with the recent export cuts from China, has end users of rare earths scrambling for supplies.

Just as world wide demand for REO is growing, so too is China's own demand. Data from the Chinese society of Rare earths (CSRE) show that the country's consumption has grown rapidly since 2004 and reached over 70,000 tonnes in 2008. Growth in demand from China will continue to outpace the rest of the world. By the year of 2015, it is estimated that the global demand of rare earths is expected to reach 210 thousand tonnes; China's domestic demand will be 138,000 tonnes. By 2020, China's domestic demand is expected to reach 190,000 tonnes, including 130,000 tonnes consumed in high-tech fields, account for 68% of global total consumption. It can be concluded that Rare Earth Materials has become a major growth point of China rare earth industry (Chen Zhanheng, 2010). China, Japan and the United States are the largest consumers of rare earth metals. With the growing demand for 'green' products, the demand for rare earth metals is only expected to increase. The annual growth in demand is expected to hover around 10%. China started a program wherein it not only mined and produced these rare earth elements but also manufactured the finished goods. So,

Figure 4: Forecast global demand for rare earths by market in 2014 (t REO ±15%)



Source IMCOA, Roskill, 2010

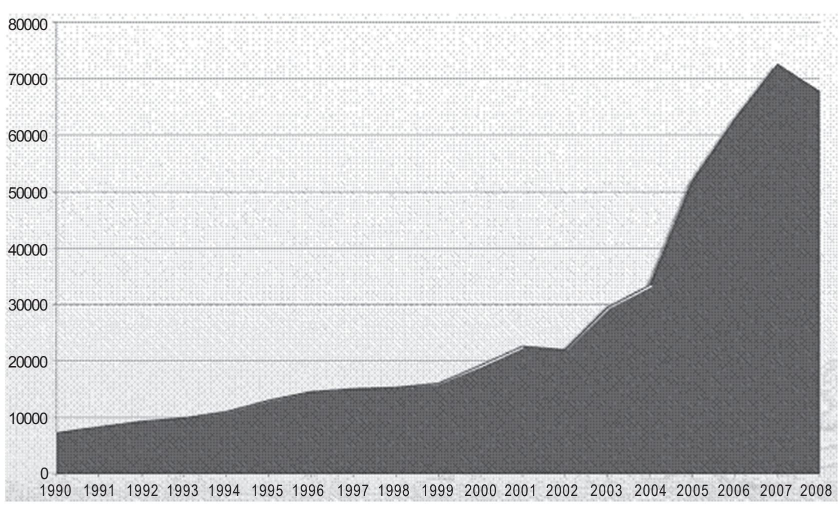
not only does the country produce 97% of the world's REEs but also uses approximately 70% of that material to build products domestically. Thus, China came to dominate the entire industry.

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. This demand as no doubt been and will continue to be fueled by heavy investments in clean energy.

The Figure shows the Chinese consumption of rare earths from 1990 to 2008. It can be noticed that the consumption of rare earths in China increased rapidly since 2004. During the last 20 years from 1990 to 2008, China annual consumption increased from 1 thousand tonnes to 72.6 thousand tonnes, it was a tremendous increase of 72.6 times. The consumption was 67.68 thousand tonnes in 2008, a slight decrease compared with that in 2007. The main reason for this tremendous growth is that ever increasing production of manufacturing items in china such wind mills, solar panels, electronic commodities.

High-technology and environmental applications of the rare earth elements have grown dramatically in diversity and importance over the past four decades. Many of these applications are highly specific and substitutes for REE's are inferior or unknown. REE's have acquired a level of technological significance much

Figure 5: Chinese consumption of rare earths from 1990 to 2008



Source: Chen Zhanheng, 2010

greater than expected from their relative obscurity. These uses range from mundane (lighter flints, glass polishing) to high-tech (phosphors, lasers, magnets, batteries, magnetic refrigeration) to futuristic (high-temperature superconductivity, safe storage and transport of hydrogen for a post-hydrocarbon economy). The rare earth elements are essential for a diverse and expanding array of high-technology applications (Quantum Rare Earth Development Corp, 2011).

The table 7 depicts the REE products and their applications. Dysprosium and terbium are alloyed into rare earths magnets to make them capable of operating at elevated temperatures. At current alloying levels, dysprosium and terbium make up about 5% of the metal used in these car battery magnets. The majority of applications depend on the rare earth magnets. China exported 10,000 tonnes of rare earth magnets worth $400 million and 34,600 tonnes of other rare earth products worth $500 million in 2008. The rare earths market represented approximately USD 1.25 billion in 2008. Over the past decade, market growth has been in the range of 8-11% per year, with the exception of the correction in 2001/02 due to the fall in technology markets and the global economic crisis. While the global financial and economic crisis in 2009 reduced consumption of REE, the industry growth

Table 7: Major products and applications of rare earth products

Rare Earths	Products	Industrial applications
Nd, Pr, Sm, Tb, Dy	Magnets	Demand for large magnets for permanent magnet motors in HEVs, EVs, and Maglev trains, also increased demand for HDDs and ODDs, mobile phones, MP3 playes, cameras, VCMs
La, Ce, Pr, Nd	Battery alloy	Rising demand for HEVs
Eu, Y, Tb, La, Dy, Ce, Pr, Gd	Phosphors	Increased use of energy efficient fluresent lights, also growing demand for LCDs, PDPs
La, Ce, Pr, Nd	Fluid cracking catalysts	Increased use of catalysts in processing heavy crude and tar sands
Ce, La, Nd	Auto catalysts	Tighter NOx and Sox standards – offset to some extent by increased use of zirconia in the wash coat
Ce, La, Nd	Polishing powders	Increased demand for mechano- chemical polishing of electronic components, and some types of LCd screens
La,Ce, Pr, Nd,Y	Ceramics	Growth in use of multi-layer ceramic capacitors, use of PSZ in advanced applications

Notes: HEV = Hybrid Electric Vehicle, EV = Electric Vehicle

HDD = Hard Disc Drive; ODD = Optical Disc Drive; VCM = Voice Coul Motor; LCD = Liquid Crystal Display; CRT = Cathode Ray Tube; PSZ = Partially Stabilised Zirconia returned to 8-11% in late 2010 (Kingsnorth D, 2010).

Table 8 reveals a number features of rare earth demand in 2008. The Chinese demand constitutes about 67 percent of global demand followed by Japan and North East Asian countries and USA. Magnets, metal alloys and catalysts were in high demand compare other applications and these are highly used in industrial applications of hybrid vehicles, electronic vehicles, hard disc drive, optical disc drive, voice coul motor, liquid crystal display, cathode ray tubes and petroleum refining industries. The demand for magnets was equal to21 percent followed by 20 percent demand for catalysts and about 18 percent demand for metal alloys. Magnets phosphors and metal alloys are the largest end uses for rare earths by value.

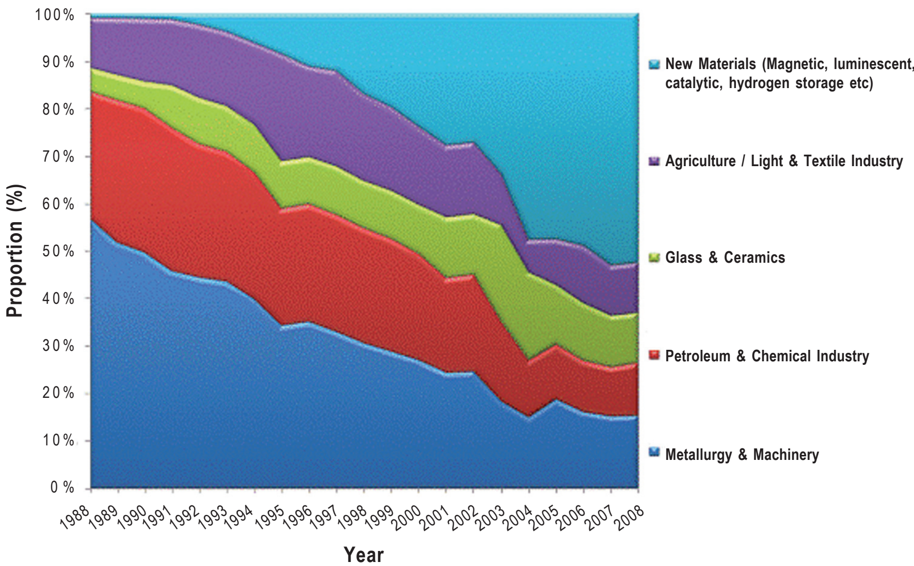
In China and globally, REEs have experienced fast growth in advanced technology sectors including luminescent (phosphors), magnetic, catalytic and hydrogen storage technologies. The demand by clean energy technology sectors is largely a result of the ramp-up of clean energy technology manufacturing and use by the United States, other Organization for Economic Co-operation and Development (OECD) nations and China. Magnets dominated REE usage by weight in 2008, with catalysts claiming the second-highest usage and metal alloys accounting for the third highest (Kingsnorth and Chegwidden 2010). REE consumption has grown most rapidly in China. China's 2005 REO demand exceeded half of global demand for the first time and more than tripled in absolute terms between 2000 and 2008 (Chen Z 2010).

Table 8: Global rare earths demand in 2008 in tonnes and by value

Application	China	Japan & NE Asia	USA	Others	Total	Volume %	Total value %
Catalysts	9000	3000	9500	3500	25000	20%	5%
Glass	7500	2000	1000	1500	12000	10%	2%
Polishing	8000	4500	1000	1500	15000	12%	4%
Metal Alloys	15500	4500	1250	1000	22500	18%	14%
Magnets	21000	3500	750	1000	26250	21%	37%
Phosphors	5500	2500	500	500	9000	7%	31%
Ceramics	2500	2500	1250	750	7000	6%	4%
Other	5000	2000	250	250	7500	6%	3%
Total	74000	24500	15500	10000	124000	100%	US$6.75b

Source: Roskill, IMCOA, 2010 and author's calculations

Figure 6: China: consumption structure of rare earths from 1988 to 2008



Source: The Chinese Society of Rare Earth, Nomura International Hong Kong

In China, rare earths were mainly consumed in traditional areas of metallurgy, machinery, petroleum industry, chemical industry, light industry, textile industry, agriculture, in new materials like magnets, phosphors, hydrogen storage, catalysts for automobile exhaust and polishing powder. There was a dramatic change in the consumption structure, the consumption of rare earths in new materials increased very fast since 2004. In 1988, the consumption of rare earths in new materials was only 1%, but in 2007, it was 53%. In 2008, it was claimed that about 60% of rare earths was consumed in new materials in China. China's consumption of rare earth elements is also expected to increase dramatically as more and more foreign companies move their production sites to China to take advantage of the lower cost of rare earths and therefore reduce their overall production costs. This is part of China's larger strategy to maintain a tight hold on the industry.

In 2009, China produced about 7,200 tonnes of rare earth fluorescent powder, ranking the world Top. The three-band fluorescent lamp industry consumed 75% of rare earth luminescent materials as the major application area of luminescent materials. The three-band fluorescent lamp with the advantages of energy saving and long lifespan will gradually replace the incandescent lamp. In 2009, China produced over 3 billion three-band fluorescent lamps. If 80% of the incandescent lamps are replaced, 3 billion three-band fluorescent lamps will be needed every year. Hence, the annual demand for fluorescent powder is about 10,000 tonnes. By 2015, the total demand for three-band fluorescent powder will be about 60,000 tonnes.

In 2008, the consumption of rare earth polishing powder in the world was 20,000 tonnes, including 8,000 tonnes for LCD. In recent years, with the booming of the LCD industry, high-performance polishing powder has achieved fast development. Presently, the production capacity of rare earth polishing powder in China exceeded 150 million tonnes. It is forecast that China's annual production capacity of rare earth polishing powder will reach 20,000 tonnes in 2010. In 2009, the rare earth consumed in Chinese petrochemical catalytic cracking sector was about 7,500 tonnes. It is forecast that China's crude oil processing volume will maintain over 500 million tonnes in 2015-2020. The rare earth for FCC catalysts will exceed 10,000 tonnes. Besides, with the considerable growth of the demand for rare earth catalytic materials in the fields of fuel cell, water pollution control, air purification, etc., China's total demand for rare earth catalytic materials will exceed 17,000 tonnes in 2015-2020 (China Research and Intelligence, 2010).

Because of their ability to readily give up and accept electrons, the rare earth elements have become uniquely indispensable in many electronic, optical, magnetic and catalytic applications. From iPods to catalytic converters, from wind power generators to computer disc drives and hybrid electric vehicles - Rare Earth applications are ubiquitous and critical for the overall economic well being of any country. China is most interested in supplying its domestic needs first. Because there's such a wide range of products that use rare earth elements, its domestic REE-product industry is growing rapidly. China's doing everything it can to bring new investment into the country and develop new industries to use this material; for example, it will sell REEs to local industries at a much cheaper price than it sells the same material to sources outside of China. In that sense, it's trying to do everything it can to increase the country's internal need.

The data released by Lynas Corp shows that global supplies of rare-earth elements will fall short of demand, which will grow by an average of 9 percent annually to the year 2014. The largest growth rate will be in demand for magnets

Table 9: Global rare earths demand in tonnes 2010 & 2014

Application	Demand tonnes	Volume (%)	Value (%)	Demand tonnes 2014	Growth rate p.a. (%)	Value (%)
Magnets	35000	26%	38%	55100	12%	42%
Battery Alloys	18600	14%	10%	32500	15%	13%
Metallurgy ex battery	11700	9%	7%	12700	2%	5%
Auto Catalysts	9000	7%	5%	12200	8%	4%
Fluid cracking Catalysts	21300	16%	11%	24900	4%	9%
Polishing	19100	14%	10%	28000	10%	10%
Glass	7800	6%	4%	7800	0%	3%
Phosphors	7900	6%	10%	10800	8%	10%
Others	5700	4%	5%	6100	6%	5%
Total	136 100	100%	US$7.8 bln	190100	9%	11.2 b

Source: Lynas Corp, 2010

and battery alloys which would be 12 percent and 15 percent respectively by 2014. Total demand for the group of elements, used in products such as industrial magnets, flat-screen TVs, and military weapons systems, is likely to grow to 190,100 metric tonnes in 2014, from 136,100 tonnes in 2010. For example, permanent magnet demand is expected to grow by 10%-16% per year through 2014. Demand for rare earths in auto catalysts and petroleum cracking catalysts is expected to increase between 6% and 8% each year over the same period. Demand increases are also expected for rare earths in flat panel displays, hybrid vehicle engines, and defense and medical applications. The global demand in value terms will grow from US$7.8 billion in 2010 to 11.2 billion in 2014.

3.1 Consumption and Industrial Applications

The rare earth elements as a group have magnetic, chemical and spectroscopic properties that have led to their application in wide range of end-uses. These metals are utilized in a broad range of manufacturing areas that include materials, machineries and electronics. These are the raw materials for high value added products. Although often needed only in small quantities, these metals are increasingly essential to the development of technologically sophisticated products. They play a critical role in the development of innovative 'environmental technologies' to boost energy efficiency and reduce greenhouse gas emissions. Demand for rare earths, often referred to as "industrial vitamins," will only increase. Several clean energy technologies-including wind turbines, electric vehicles, photovoltaic cells and fluorescent lighting-use materials at risk of supply disruptions in the short term. Those risks will generally decrease in the medium and long term.

Clean energy technologies currently constitute about 20 percent of global consumption of critical materials. As clean energy technologies are deployed more widely in the decades ahead, their share of global consumption of critical materials will likely grow. Green energy technology is expected to become the largest consumer of rare earth elements in the future. In 2009 China was the world's top investor in clean energy technology at over $34 billion. Since 2005, the country's wind generation capacity has increased by more than 100% a year. The government's renewable energy policy aims to procure 15% of the country's energy from non-carbon sources by 2020, twice the proportion of 2005. In 2009, China became the largest manufacturer of wind turbines in the world, with 17 of its 40 turbine manufacturers being state-owned, 12 private Chinese firms, and 11 joint ventures or foreign owned (The Pew Charitable Trusts, 2010).

The country has doubled its installed wind power capacity every year since 2006 and is now the world's largest producer of wind turbine. By 2020, China is expected to boost its wind power capacity to 100 Giga watts (GW) or more, up from 12 GW in 2008. The annual growth rate will be about 20 percent (China Daily, 2009). Similarly, the Global Wind Energy Council (GWEC) forecasts that the global installed wind capacity in 2011 will climb to 409 GW, up from 158.5 GW at the end of 2009. The additional 250.5 GW will require 167,000 tonnes of REMs. China has announced that in the next ten years it will "construct some 133 giga watts of wind turbine generated electricity." Around two tonnes of neodymium is needed for each wind turbine and NdFeB magnets are a critical component for some models of the new generation wind-powered turbines.

Hydrogen-fuel based cars, for example, require platinum-based catalysts; electric-hybrid cars need lithium batteries; and rhenium super alloys are an indispensable input for modern aircraft production. In 2009, China produced 19,000 tonnes of rare earth hydrogen storage materials. They consumed 7,900 tonnes of rare earth, accounting for 11% of the total rare earth consumption. Since November 2009, China has become the largest auto market in the world. China's automobile industry has been in rapid development since the early 1990s. In 2009, China produced 13.79 million units of automobile. The Chinese are also investing big in electric cars, hybrid cars and the underlying industry. The Chinese are already one of the largest producers of lithium-ion batteries and as the main application in car batteries; lithium-ion demand is growing fast. Rare earth hydrogen storage materials are major raw materials for the production of nickel-hydrogen battery. As nickel-hydrogen battery shows positive development prospects in the electric tool and electric vehicle sectors, it is forecast that China's hybrid electric vehicle market will acquire explosive growth after 2010 and the annual growth rate will reach 12% (China Research and Intelligence, 2010).

According to Reuters, global sales of hybrid electric cars are forecast to reach 3 million units in 2015 with a total REM requirement of 33,000 tonnes. One of the largest growth areas is expected to be the production of hybrid vehicles, such as the Toyota Prius. Each hybrid car contains 16 kg of rare earths, predominantly in its batteries and electric motors. It is estimated that the motor in the average Prius hybrid uses about 193 grams, or about 7 ounces, of neodymium and 24 grams of dysprosium, while the fully electric Nissan Leaf uses about 421 grams of neodymium and 56 grams of dysprosium.

The Chinese government, determined to become a world leader in green technology, and plans to invest billions of dollars over the next few years to develop electric and hybrid vehicles. A group of 16 big state-owned companies had already agreed to form an alliance to do research and development, and creates standards for electric and hybrid vehicles. The plan aims to put more than a million electric and hybrid vehicles on the road over the next few years in what is already the world's biggest and fastest growing auto market. The announcement, analysts say, is another example of how China seeks to marshal resources and tackle industries and new markets. The plan also underlines what China describes as its growing commitment to combating pollution and reducing carbon emissions.

The Chinese government announced it will spend $14.7 billion through 2020 on alternative drive train vehicles, with the bulk of the money going towards all-electric vehicles. Pike Research, projects that between 2010 and 2015, China will have 1.85 million hybrids and EVs sold, with 1 million EVs on the road. In the U.S. more than 2.3 million hybrids will be sold during that time, and 840,000

Table 10: Annual sales of Toyota prius worldwide and by region (in thousands)

Year	World	Japan	North America	U.S.	Europe	Other
1997	0.3	0.3				
1998	17.7	17.7				
1999	15.2	15.2				
2000	19.0	12.5	5.8	5.6	0.7	0.01
2001	29.5	11.0	16.0	15.6	2.3	0.2
2002	28.1	6.7	20.3	20.1	0.8	0.2
2003	43.2	17.0	24.9	24.6	0.9	0.4
2004	125.7	59.8	55.9	54.0	8.1	1.9
2005	175.2	43.7	109.9	107.9	18.8	2.9
2006	185.6	48.6	109.0	107.0	22.8	5.3
2007	281.3	58.3	183.8	181.2	32.2	7.0
2008	285.7	73.1	163.3	158.6	41.5	7.7
2009	404.2	208.9	144.3	139.7	42.6	8.4
Jan-Sept2010	401.3	254.2	105.9	103.3	35.5	5.8
Total	2,011	826.9	939.1	917.5	206.1	39.7

Source: Toyota Corporation

plug-in and all-electric vehicles. At the 2010 Beijing Motor Show, more than 20 electric vehicles were on display, most of which came from native automakers. As of May 2010, at least 10 all-electric models have been reported to be on track for volume-production. The first mass produced plug-in hybrid car (BYD F3DM), all-electric minivan (Luxgen 7 MPV EV) and all-electric long-range bus (500 km range Zonda Bus) are Chinese (Gartner John , 2010).

Many of the rare earth metals are also used in sectors such as semi-conductors. The semiconductor industry is dominated by Chinese Taipei, South Korea, United States, and Japan. The role of the semi-conductor industry is one of a technology enabler: the semiconductor industry is widely recognized as a key driver for economic growth throughout the electronics value chain. The semiconductor market represented USD213 billion in 2004 and the industry was one enabling factor in the generation of USD1200 billion in electronic systems business and USD 5000 billion in services, representing close to 10% of world GDP that year. The semi-conductor industry is also a high-growth industry, experiencing 13% growth on average per annum over the last 20 years (Korinek, J. and J. Kim, 2010).

There are numerous examples that point to China's anticipated increase in rare earth consumption. For example, at the end of July 2008, China had 600 million cell phone users. Less than one year later, by the end of March 2009, China had 670 million cell phone users (Xinhuanet, 2009). China's mobile phone industry has high growth rate, raising its share on the global mobile phone market. During 2007, 600 million mobile phones were made in China which accounted for over 50% of the global production. The domestic sales of cell phone made a breakthrough of 100 million in China in 2006. In 2007, the domestic sales of cell phone in china were 190 million, increased by 74%. For year of 2007, sales volume had reached about 23 billion USD, increased by 17% as compared with 2006. The export volume of China's cell phones added up to a record high of 385 million in 2006, increased by 69.3% as compared with 2005. In 2007, this figure reached 483 million, increased by 125.45% as compared with 2006. As far as 2006, the export volume had reached 31.214 billion USD, increased by 52.47% as compared with 2005. The export volume of 2007 was 35.6 billion dollars, increased by 114.01% as compared with 2006 (Pr-inside, 2008).

The rare earth metals are critical for the production of smart bombs, laser targeting systems in tanks, and silent technology used in helicopter blades. The rare earth metals of most concern to the military and the Defense Department are neodymium, samarium, and yttrium. Neodymium is an essential metal in a magnetic alloy which was developed separately by General Motors in Detroit and Sumitomo Special Metals Co. in Japan in the 1980s. Now it is used in speaker magnets, disk drives, motors, and, more importantly, in missile weapons systems like the Joint Direct Attack Munition (JDAM). Neodymium is also used in magnets for hybrid-electric motors being developed to cut fuel use in U.S. Navy destroyers. Samarium is needed for magnets being used by Lockheed Martin Corp.'s SPY-1 radar systems on Aegis destroyers. China is the only supplier in the world for yttrium which is needed for the laser gun sights in the General Dynamics Abrams tank (RC Zar, 2010).

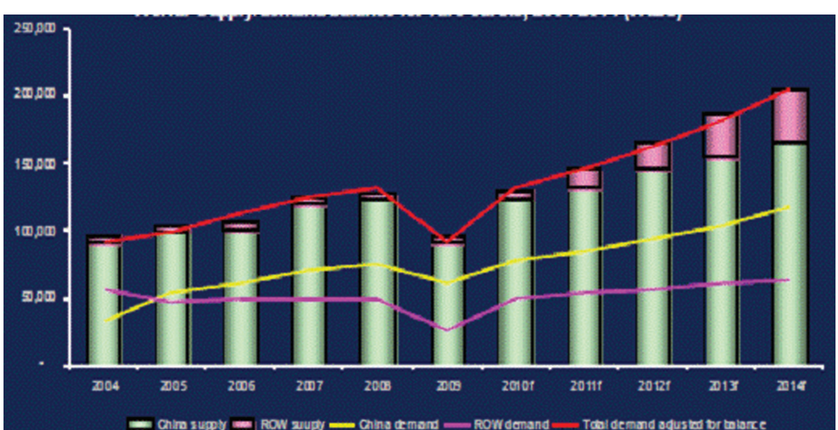
The DDG-51 Hybrid Electric Drive Ship Program uses neodymium iron boron magnets which help power the guided destroyers. Night vision goggles and rangefinder equipment use rubidium to increase accuracy and visibility. The Aegis Spy-1 Radar uses the samarium cobalt magnet to withstand stresses as it has the highest temperature rating of any rare earth magnet. Even with a threefold increase in REE demand over the past ten years, demand is expected to increase even further, by anywhere from 8 to 790 percent over the next five years (Kientz R, 2010).

Rare earth elements are needed for China's expansion of its own military needs (aircraft carriers, nuclear-powered submarines, and ballistic missiles). Home-grown production needs will further cut exports already reduced to crippling levels. Not surprisingly, these measures have raised real concerns outside of China regarding the future availability of the refined products created from REMs. The rare earth supply chain for the sleep paralyzed Western defense industries is now being held hostage by the Chinese who want to keep the rare earth metals for their own rapidly expanding markets.

4. Global Demand-Supply Interface by 2014

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. 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. While new or reopened mines outside of china are expected to increase global production, resulting in an over all surplus, shortfalls are expected in certain elements, particularly in Neodymium and Europium, and the heavy rare earths Terbium, Dysprosium, and Yttrium. Demand for rare-earth metals is likely to increase between 10 percent and 20 percent each year, analysts say, thanks to growing demand for elements like neodymium, which is used in making hybrid electric vehicles and generators for wind turbines.

Figure 7: World supply/demand balance for rare earths, 2004-2014 (t REO)



Source: Roskill, IMCOA, CREIC, Neo Materials Technology

World demand for rare earth elements are estimated at 134,000 tonnes per year, with global production around 124,000 tonnes annually. The difference is covered by above-ground stocks or inventories. World demand is projected to rise to 180,000 tonnes annually by 2012, while it is unlikely that new mine output will close the gap in the short term. By 2014, global demand for rare earth elements may exceed 200,000 tonnes per year. China's output may reach 160,000 tonnes per year (up from 130,000 tonnes in 2008) in 2014 (Marc Humphries, 2010). An additional capacity shortfall of 40,000 tonnes per year may occur. New production from ROW could meet increased demand to 2014-but will the "balance" be right? This brings spotlight on the absolute necessity for other countries get to full-scale rare earth production sufficient to meet global demand and to deploy a complete mining-to-magnets manufacturing supply chain as soon as possible outside China.

The above table shows that the global demand REO in 2014 will be around 180-190,000t a little less than the global supply of 190-210,000t. However some individual oxides will be in short of supply particularly the heavy rare earths like Terbium, Dysprosium and Yttrium, their proportion to the total demand is comparatively less, although their importance to some the applications are very important. Since supply of these elements is going to be so tight, the prices for Tb, Dy and Y will remain strong. Neodymium iron boron permanent magnet is the leading product among rare earth magnetic materials. With the development of new application areas, it is forecast that the global neodymium iron boron industry will maintain the growth rate of 15% in the coming five years, whereas Chinese neodymium iron

Table 11: Forecast supply and demand for selected rare earths in 2014

Rare Earth Oxide	Demand @ tpa REO	%	Supply @ tpa REO	%
Lanthanum	50-55000t	28.4%	52-57000t	26.9%
Cerium	60-65000t	36.5%	80-85000t	40.2%
Neodymium	34900t	19.4%	33000t	16.3%
Terbium	400-500t	0.3%	400-500t	0.2%
Dysprosium	1900-2300t	1.1%	1800-2000t	0.9%
Yttrium	10-14000t	6.7%	9-13000t	5.7%
Total	180-190,000t	100%	190-210,000t	100%

IMCOA, 2009

boron industry will maintain the growth rate of 20% and the global demand for Neodymium will outstrip the global supply with a thousand tonnes marginal difference in 2014.

The rare earth content of NdFeB magnets varies by manufacturer and application. An electric drive vehicle may use up to a kilogram (kg) of Nd, while each wind turbine may contain several hundred kilograms. Rare earth PMs may also incorporate praseodymium (Pr), which can be substituted for or combined with Nd. Dysprosium (Dy) or terbium (Tb) may also be added to the inter metallic alloy to increase the temperature at which the magnet can operate before losing its magnetic. The cumulative demand for Nd and other REEs in these clean energy technologies is a function of both the material content per individual product and the total number of products sold. Therefore, aggressive technology penetration rates envisioned under many worldwide clean energy strategies could significantly increase global demand for Nd, Pr, Dy and Tb (London I.M. 2010).

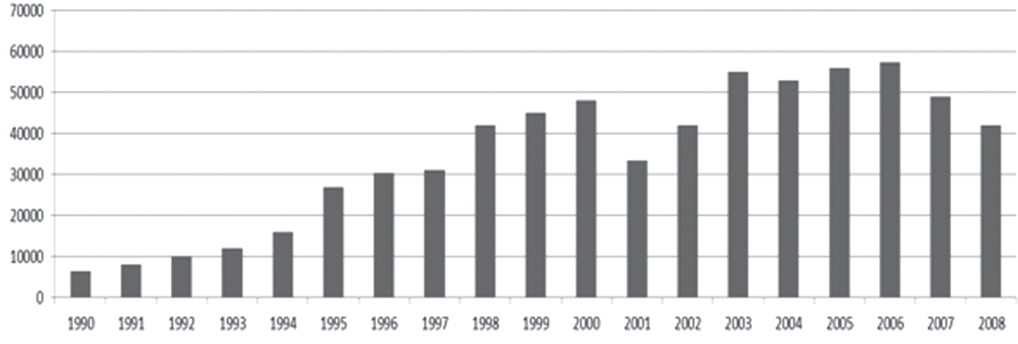
Chinese economy will continue to grow or near double digit rates for the foreseeable future and disposable income for automobiles, personal electronics, etc driving significant internal RE demand. China is already the largest auto market and will produce 500,000 electric vehicles in 2011 and, leads in wind power generation. So to meet this increasing demand for REEs, China has employed a number of controls to date such as, production limits, export quotas, export tariffs, stockpiling, closing of separation plants and even literally blowing up illegal mines (REITA, 2011).

5. International Trade in Rare Earth Elements

The section examines the trade in rare earths and importance and Chinese export restrictions. Rare earths were traded freely and at a discounted price on the global market before the mid-2000s. Since 2005, however, China-the world's leading RE producer- gradually tightened export restrictions on rare earth oxide (REO).China has become the largest country of rare-earth deposits, producer, consumer and exporter and, there is a growing demand-supply gap because of a dearth of any other major supplying nation. China's imposition of export quotas on several rare earth metals, on the grounds that it needs the higher quantities for its clean energy and high-tech sectors, is squeezing an already starved market. China wants rare-earths companies to add value by making more technologically advanced products rather than exporting the raw material. While it has cut foreign sale quotas of the minerals, there are no restrictions on exports of finished products.

Figure 8, shows the gross volume in tonnes of exports of REEs which grew from 6500 tonnes in 1990 to 57,400 tonnes in 2006 and declined to 49,000 tones in 2007, and 42,000 tonnes in 2008, respectively. It indicates that the

Figure 8: Gross volume of exports from 1979 to 2008



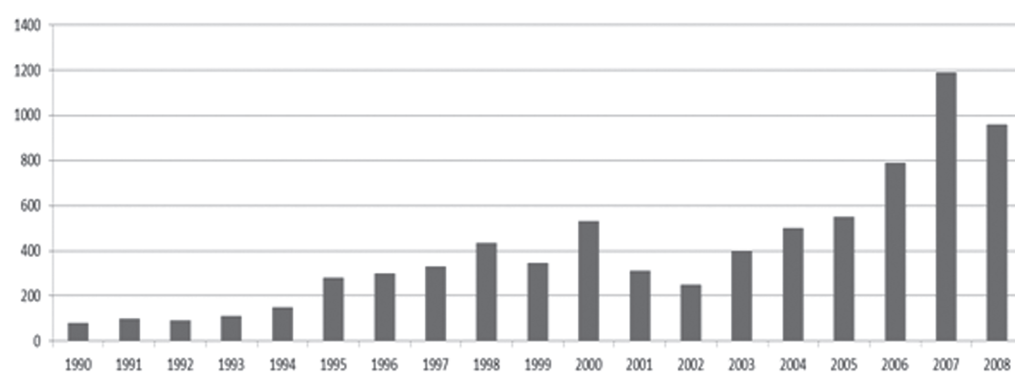
Source: Reitausa.org, 2010

gross volume of exports had been in a growth trend until 2006, and then declined in 2007 and 2008 mainly because of the global financial crisis which had very badly affected the major rare earth consuming countries such as U.S, Japan and Europe. Although, China began to control exports of rare earth products with quota administration since 1999, the total exports did not decrease generally, until 2007 except a decline in 2001.

Figure 9, explains the gross value of exports in million U.S dollar from 1990 to 2008. The total exports in value terms also grew outstandingly, reaching to peak level at about, USD 1.2 billion, in 2007, while the export value was just 80 million in 1990. From 1998 to 2005, the annual average of gross value for exports was about USD 420 million, and the annual average of gross volume for exports was about 46,946.63 tonnes, namely 8.98 USD/Kg. In 2007, the price was about 24 USD/Kg, which exuberantly increased in the last months of 2010 to USD 60/kg, and above.

Rare earth prices remained static for decades due to plentiful supplies, lulling the high-tech industry into a false sense of security. After Beijing cut export quotas by 70 percent for the second half of 2010, prices of some rare earths has gone up, as much as 850 percent. Due to the extensive management of rare earth resource exploitation and scattered distribution of the rare earth industry, many foreign importers used the opportunity to force down the price. When the global demand for rare earth materials increases year by year, China exported 6,100 tonnes of medium-end and low-end rare earth products in 1990; the average price was 13,600 USD/ton. In 2009, China exported 36,100 tonnes of rare earth smelting and separation products,

Figure 9: Gross value of exports from 1979 to 2008



Source: Reitausa.org, 2010

rising by 16.67% YOY. The export value amounted to USD 310 million and the average price was only 8,959 USD/ton (China Research and Intelligence, 2010). Low prices for rare earth elements from China, contributed to cuts at the Mountain Pass mine in the United States, one of the main source of supply for many years, before it closed in 2002. They also discouraged most entrants to the industry until the last two years, when prices began to climb because of strong demand.

The data from UNComtrade data base shows that in 2009, a total of 43 countries reported exports of rare earths. The entire exports were valued at 427.75 million US$ and 61232.32 tonnes of rare earths were exported by the 43 countries. The details of the top ten exporting countries by volume in tonnes and value in million US$ in 2009 have shown in table 13. China including Hong Kong and Macao exported about 39 thousand tonnes with a share of more than 64 percent in 2009 followed by Japan exported 5904 tonnes with a share of 9.64 percent and Russia exported around 4619 tonnes in 2009. Estonia and U.S were in the fourth and fifth position respectively in terms export volumes. Analysis of exports in value terms shows that China including Hong Kong and Macao accounted for slightly more than 50% of the share of rare earths exports by value. China was followed by Japan with a share of around 23% and Germany with a share of around 5%. China therefore continued to be the dominant exporter of rare earths both in terms of volume and by value and China for all purposes continues to be an

Table 12: Top ten exporters of rare earths by volume and value in 2009 (Million US$)

Reporter	Exp Qty (Tonnes)	% Share by Qty Tonnes	Country	Export Value	% Exports by Value
China+HK+Macao	39201.67	64.02	China+HK+Macao	240.97	50.97
Japan	5904.61	9.64	Japan	107.35	22.71
Russia Federation	4619.61	7.54	Germany	22.44	4.75
Estonia	2678.85	4.37	USA	15.36	3.25
USA	1332.50	2.18	France	14.02	2.96
France	1246.13	2.04	Norway	13.64	2.89
Austria	2578.62	4.21	Italy	11.80	2.50
Kazakhstan	1053.32	1.72	Estonia	10.38	2.20
Germany	657.55	1.07	Russia Federation	9.92	2.10
United Kingdom	555.85	0.91	United Kingdom	6.62	1.40

Source: UN Comtrade data base

effective monopolistic supplier of rare earths.

The details of the top ten importing countries by quantity and value in million US$ in 2009 are placed at table 13. In 2009 a total quantity of 69638.07 tonnes of rare earths were imported by a total of 91 countries. United Sates was the top importers of rare earths in terms of quantity with Japan and Germany occupying second and third positions. United Sates accounted for 23.57% of the world's share of rare earth imports by quantity which was equal to 16416 tonnes. Japan imported 13490 tonnes and accounted 19.37 percent of the total imports. Germany imported 8000 tonnes followed by France importing 6985 tonnes. The entire imports were valued at 608.48 million US$ 69638.07 tonnes of rare earths were imported by the 91 countries. Japan was the largest importer of rare earths in 2009 by value terms, followed by USA, Thailand and Germany respectively. Japan accounted for 25% of the world's rare earth imports.

The difference in quantity between total rare earths exported and imported amounts to 8405 tonnes. This difference is very large and cannot be explained away as statistical error. One possible reason could be the belief that rare earths are smuggled from China. Illicit exports are typically in the form of REE mixed with steel and exported as steel composites. The process is reversed in the country recovering the REE's (British Geological Survey, 2010). In case the smuggled REE's are accounted for at the receiving country either deliberately or inadvertently, then some portion of this discrepancy of around 8000 tonnes could be partially explained.

Table 13: Top ten importers of rare earths by quantity and by value in 2009

Reporter	Trade Qty Tonnes	% Imports Qty	Reporter	Value US $ Million	% Imports by Value
USA	16416.371	23.57	Japan	152.12	25.00
Japan	13490.908	19.37	USA	115.03	18.90
Germany	8218.155	11.80	Thailand	67.51	11.09
France	6985.406	10.03	Germany	51.76	8.51
Austria	4456.6	6.40	France	40.57	6.67
Estonia	4124.822	5.92	China+HK	38.19	6.28
China+HK	4039.644	5.80	S. Korea	24.90	4.09
S. Korea	2632.811	3.78	Austria	21.62	3.55
Brazil	1314.483	1.89	Malaysia	11.29	1.86
Russia	1195.176	1.72	Italy	10.00	1.64

Source: UN Comtrade data base

5.1 China's Exports and Imports

In 2009, China exported a total of 38573.02 tonnes but the total of all the rare earths exported to 46 countries added up to 40982.13 tonnes. The quantity and the percentage share of the top 10 customers of China is indicated in the below table. United States was the largest importer of Chinese rare earths by quantity and imported around 14700 tonnes of rare earths, these accounted for 38% of the Chinese exports. Japan imported around 10500 tonnes and its share amounted to 27%. North America (mainly the United States) and Asia each account for around 36% of the Chinese rare earth exports by quantity. Around 24% is exported to Europe.

China's exports were valued at 239.37 million US$ in 2009. The details of the top ten customers of China in million US$ in 2009 are depicted in table 15. The largest importer of rare earths from China was Japan with around 76 million US $, followed by the United Sates with around 67 million US$. Japan and the United Sates accounted for nearly 61% of the exports of rare earths from China. About 30% of the exports are accounted by Hong Kong, France, Germany, South Korea and Netherlands.

5.2 Rare Earth Export Control by China

Several objectives motivate implementing export restrictions on strategic raw materials. In some cases, these can be understood as a response to market imperfections. The question remains, however, whether export

Table 14: China's top 10 customers by quantity and value in 2009

Partner	Qty in Tonnes	% Share	Partner	Trade Value million US$	% Share
USA	14764.6	38.28	Japan	76.66	32.29
Japan	10519.71	27.27	USA	67.48	28.43
France	4391.593	11.39	Hong Kong	21.75	9.16
Hong Kong	2658.938	6.89	France	20.45	8.61
Italy	1509.58	3.91	Germany	15.58	6.56
Austria	1465.062	3.80	Rep. of Korea	8.40	3.54
Germany	1034.877	2.68	Netherlands	7.60	3.20
Australia	979.646	2.54	Italy	5.51	2.32
U.K	594.76	1.54	U.Kingdom	2.67	1.12
Netherlands	494.23	1.28	Other Asia	2.65	1.12

Source: UN Comtrade data base

restrictions are the most effective tool to achieve the desired outcomes. As many of these raw materials are produced in a limited number of countries, export restrictions that are imposed in one country may motivate other countries to follow if importers massively move to buy their raw materials. The restrictions imposed by the first country then lose their effectiveness. This can in principle lead to a situation of competitive policy practices – and of higher and higher export taxes.

Many export restrictions are put into place for environmental reasons or to preserve natural resources. In other cases, export restrictions are imposed in order to encourage supply of raw materials to domestic producers of downstream semi-processed goods. On 23rd September 2010, exports of rare earth elements (REEs) from China to Japan apparently stopped due to a dispute over maritime boundaries. This use of economic leverage to influence policy raised concerns about the impact of China's strategic hold on these precious metals. REEs have long been considered the "enhancers" of global products and are used to manufacture defense and commercial high-technology items. Their availability today, however, could be jeopardized since China controls over 97 percent of their production and refinement (CSIS, 2010).

Until recently, the global dependency on China for rare earths was a well-kept secret. But word started to spread fast after Beijing cut export quotas by 70 per cent for the second half of 2010, sending prices of some oxides - the purified form of rare earth elements - up as much as 850 per cent. The need for alternative supplies from outside China suddenly became obvious. The Chinese dominance has raised concerns within industry regarding prices and lead times for critical defense hardware. With demand increasing, the problem of purchasing and shipping REEs for products is concurrently growing.

In the first week of July 2010, China announced a number of changes affecting the rare earths sector. These changes included a reduction in the total amount of rare earths that may be exported from China besides other measures (Gareth P Hatch, 2010). China has passed the "2009-2015 Rare Earth Industry Development Plan". According to the document, in the next six years, no new rare earth mining permit will be approved. The separation of newly formed rare earth smelting companies will be strictly reviewed. China has officially cited environmental issues as one of the key factors for its recent regulation on the industry, but non-environmental motives have also been imputed to China's rare earth policy. According to The Economist, "Slashing their exports of rare-earth metals...is all about moving Chinese manufacturers up the supply chain, so they can sell valuable finished goods to the world rather than lowly raw materials" (The Economist, 2010). Foreign companies also taking part in this business of value additions. One possible example is the division of General Motors which deals with miniaturized magnet research, which shut down its US office and moved its entire staff to China in 2006. A news release in December 2010 announced that one Japanese company had moved its magnet-producing industry to China to take advantage of cheaper prices and more certain supplies. This is what the Chinese are trying to do; it's just good business.

5.3 Chinese Rare Earth Export Quotas

China practices the quota license administration on the export of rare earth products since 1998 citing the need for environmental management and resource conservation. In recent years, Chinese government cuts down the volume of export enterprises, export quotas and annual exploitation volume of rare earth ores. The Beijing government argues that its curbs are for environmental reasons and to guarantee supplies to Chinese clean-energy firms it is trying to promote internationally. But it has also said its dominance as a producer should give it more control over global prices. China's Commerce Ministry allotted 14,446 tonnes of quotas to 31 companies, which was 11.4 percent less than the 16,304 tonnes it allocated to 22 companies in the first half of 2010 quotas a year ago. While industrial users of the minerals in industrialized countries face tighter supplies and higher prices, China's export curbs have created opportunities to open mines or revive dormant production in Canada, Australia and the United States. China cut its export quotas for rare earths by 35 percent in the first round of permits for 2011, threatening to extend a global shortage of the minerals needed for smart phones, hybrid cars and guided missiles.

Export quotas have been falling continuously since 2005. The plan to restrict rare earth exports were reportedly commenced in 2005-06.The aim was to restrict rare earth production in China to around 80000 tonnes (People's Daily, 2009). But the decline between 2008 and 2009 was quite drastic. There is wide-scale concern that China may soon restrict or even ban the export of particular rare earths. There has been much speculation about China's future policy on rare earths. However it is quite clear that China has been systematically and methodically

Table 15: Chinese export quota and demand from rest of the world (ROW): 2005–2010. (tonnes REO)

Year	Domestic Companies	Foreign Companies	Total	Change	ROW Demand
2005	48,048t	17,657t	65,609t	-	46,000t
2006	45,752t	16,069t	61,821t	-6%	50,000t
2007	43574t	16,069t	59,643t	-4%	50,000t
2008	40,987t	15,834t	56,939t	-5.5%	50,000t
2009	33,300t	16845t	50,145t	-12%	25,000t
2010	16304t for 1st half	5978t for 1st half 2010	30,258t	-40%	48,000t

Sources: Kingsnorth, 2010, Hatch 2010

reducing quotas (Kara Hudai et all, 2010).

In 2010, it cuts down the export quota to 30,258 tonnes, including 22,512 tonnes for domestic enterprises and 7,746 tonnes for foreign enterprises. The data shows that the export quotas for 2010 have been reduced by 40% compared with 2009. This is a far greater reduction than forecast that the reductions would be of the order of 6-7% in the coming years. The impact of the change will have far reaching consequences, particularly outside of China. Chinese rare earth export quotas for 2010 are now significantly less than rest of the world (ROW) consumption having a gap of 18,000 tonnes. The quota for 2010 was 30,258t REO compared with ROW demand of 50000t. Total ROW production capacity is currently 10-12,000t at best, which indicates a shortfall of 10-15,000 t at least in 2010. China announced in December 2010 that it will cut its export quotas for rare-earth minerals by more than 11 percent in the first half of 2011, further shrinking supplies of metals needed to make a range of high-tech products. The move comes on the heels of a 40 percent slash in the export quota on such minerals in 2010. The export restraints have inflamed trade ties with the United States, European Union and Japan in particular (Tom Miles, 2011).

But a further reduction in quotas for 2011 issued late 2010 would be consistent with recent Chinese policy. The Chinese government typically makes a main allocation of quotas near the end of the year, followed by a smaller, supplemental allocation in the summer. But the supplemental allocation issued last July was down 72 percent from a year earlier, as Chinese officials called for making sure that their own industries had ample supplies and that heavily polluting illegal mines should be closed. According to the revised "2009 to 2015 Development Plan of the Rare Earth Industry" prepared by the MIIT, the annual REO export level from China will be restricted below 35 kt between 2009 and 2015. If the aforementioned targets can be strictly enforced, the existing stockpiles outside China are expected to be exhausted over time, which will further strengthen China's competitiveness. With the current quota system, China does not distinguish between the individual rare earth oxides but limits the total tonnage of exports across the board. That has led to Chinese companies exporting as much as possible of the high-value heavy rare earths like dysprosium, instead of low-value light rare earths like cerium.

5.4 Other Export Restrictions

Export restrictions are applied to many of the rare earth metals originating from China. Export restrictions come in a variety of forms. They include quantitative restrictions (quotas), export taxes, duties and charges and mandatory minimum export prices. In so far as they can affect export volumes, the reduction of VAT rebates as well as stringent export licensing requirements may also be considered forms of export restrictions. As discussed before China has announced several cuts in export quotas of rare earth metals and raised export taxes to as high as 25 percent, from zero to 15 percent previously (IER , 2011).

Export Taxes on Rare Earth Exports from China

In late 2006, the Chinese government introduced a tax on rare earth exports of 10%, which was increased to 15% on selected rare earths in 2007. Effective from 1 January 2008, export taxes were raised to the following levels

China has added a 15- to 25-percent export duty on rare earth exports and 41 rare earth products have been listed in the category of prohibited processing trade. Rare earth exporters, including

Table 16: Chinese export taxes on rare earths

Materials	Tax (%)
Europium, terbium, dysprosium, yttrium as oxides, carbonates or chlorides	25%
All other rare earth oxides, carbonates and chlorides	15%
Neodymium metal	15%
All other rare earth metals	25%
Ferro rare earth alloys	20%

10 foreign companies, are facing stricter supervision on their qualification. The move is an increase from the 15 percent temporary export tax on neodymium, used in batteries for hybrid cars including Toyota Motor Corp.'s Prius. Lanthanum, also used in hybrids, and cerium, used for polishing semiconductors, were not taxed in 2010, and will be taxed at 25 percent in 2011, the Chinese ministry reported in December 2010. China's export tax for dysprosium will be kept at 25 percent next year, and the same with terbium, according to the statement of China's finance ministry.

In 2007, China withdrew the refund of VAT (16%) on exports of unimproved rare earths, while the refund on higher value-added exports such as magnets and phosphors remains in place. The effect of this decision, combined with the export tax regime above, is that non-Chinese rare earth processors such as cerium polishing powder producers and rare earth magnet producers pay 31% more for rare earth raw materials (plus transport and storage costs) than their Chinese counterparts.

In other cases, export restrictions are imposed in order to encourage supply of raw materials to domestic producers of downstream semi-processed goods. In the years prior to the 2008 downturn Chinese exports of rare earth compounds were declining while exports of metals and alloys were increasing slightly.

In 2008 and 2009, China began implementing regulations to place greater controls on the rare earth industry. For example, the Ministry of Land and Resources implemented a regulation in 2009 that would "protect and make rational use of China's superior natural resources," in particular, tungsten, antimony, and rare earth ores. According to the regulation, the Ministry of Land and Resources is suspending any applications nationwide for survey or mining licenses for rare earth ores. The goal for controlling the rare earth industry in China is "to prevent over-exploitation and blind competition, and to advance the effective protection and scientific, rational use of these superior mineral resources." The Chinese argue that the REM industry is unsustainable and is rife with environmental externalities that ultimately take a toll on the public. They maintain that export restrictions are in place to reflect the true price of REMs and their ecological costs, while protecting the environment from overexploitation and illegal mining operations (ICTSD, 2010). Most of the analysts argue that, if China causes a shortage of rare earths, it will be a temporary shortage, since the rising prices for rare earth elements will serve as an incentive for others to enter the market, leading to greater supply. The United States, for example, has 13 percent of known rare earth reserves and could get back into the production and refining business. Still, there will be a lag before new production becomes available, and it could easily come from an equally troubling source. After China, Russia has the next largest reserves (19 percent), and it is at least as likely (if not more so) to play games with export restrictions, and have more lax safety and environmental standards as well (New York Times, 2010). Countries that rely on Rare Earth Metals (REMs) for manufacturing are lashing out at China after Beijing officially announced a further 35 percent reduction in export quotas. The cut, which will affect exports for the first half of 2011, follows a 72 percent reduction in REM exports in the second half of 2010.

6. REE Pricing and Price Movements

Despite the rising demand and the historical high prices reached by many commodities, mine capacity expansions and new mine production capacity have not kept pace. Overall, the price of minerals is driven by multiple physical, financial and political factors. When deciphering price data and trends, it is helpful to know whether there is a market surplus or deficit and the extent of the imbalance. Physical parameters (e.g., stock changes, closures of old mines and the start-up of new ones) are in turn influenced by general economic conditions and financial forecasts (e.g., inflation and exchange rates) that inform investor sentiments. Unanticipated shocks- such as monopolistic or oligopolistic pricing (e.g., export quotas); geopolitics and natural disasters- also play a role in affecting physical and financial parameters.

6.1 Negotiated Pricing and Metal Exchanges

Most rare, precious, minor and specialty metals and their alloys are traded through bilateral contracts based on negotiated pricing between parties. The fragmented nature of some of these markets and the remoteness of some producers has resulted in traders playing a dominant role. Regionally, traders account for a large part of the specialty metal supply coming out of regions such as China, the former Soviet Union and Africa. The nature of the process limits price disclosure in these markets and the prices of specialty metals quoted by traders and consultants vary widely in their reliability (U.S Department of Energy, 2010). To understand the price behavior and volatility of key materials, it is also important to examine the ways in which these commodities are bought and sold, in conjunction with whether they are produced as a co- or byproduct of other specialty metals (e.g., REEs) or a by-product of a major metal. Both aspects influence the price behavior and volatility of a mineral. The influences of these factors can be gleaned from a comparison between the historical price trends of commodities produced as a byproduct of metals traded on major exchanges and

Table 17: Purchase option and source of price information for REEs

Minerals	Purchase option	Source of price info
Rare Earth Elements	Negotiated purchase, not traded on metal exchanges and therefore no spot market; however, illegally traded REEs are sold through less formal channels and may possibly be sold on the spot markets	Trade journals, based on information from producers, consumers and traders

commodities mainly transacted through bi-lateral contracts.

For now, the demand/supply equation has been wildly swayed, and prices have rocketed. It has been widely reported that the Chinese authorities plan to implement a 'fully unified pricing mechanism' in order to control the price of rare earths throughout the country. On closer inspection, the proposed mechanism seems to apply only to the Fujian, Guangdong, Hunan and Jiangxi provinces, and the Guangxi autonomous region, at this time. These five jurisdictions are adjacent to one another in the southeast of China, an area whose elution deposited/ ion-absorbed clays are rich in the heavy rare earth elements. Inner Mongolia and other northern jurisdictions, which predominantly produce light rare earths, do not appear to be covered by the announcement. It would thus appear that the change is an attempt by the authorities to specifically control the prices of the more valuable heavy rare earths (Gareth P Hatch, 2010). Some would argue that China is already well in control of rare earth pricing with more than 90 percent market share, Chinese firms already control prices.

Are the Chinese looking to actively manipulate the price of rare earths? To assume that 'the Chinese', in some unified conspiracy, are working to throttle back rare earth supply and raise prices would be incorrect and there are certainly some Chinese rare earth companies that recognize they will get the best pricing for material outside China, and would love to use their expertise to help establish operations outside China. This would allow these Chinese companies to more directly reap the benefit of worldwide demand. Problems associated with future pricing of rare earths will affect different parts of the supply chain differently. Supply risks, at least in the short-to-medium term, are less associated with the prospect of increasing prices because in most cases the cost of these elements is a small part of the final product manufacturing cost. However, in the last 6-12 months the price of many rare earth elements has increased by approximately

300-700%, which in some cases has had a more significant impact on the price of the final product.

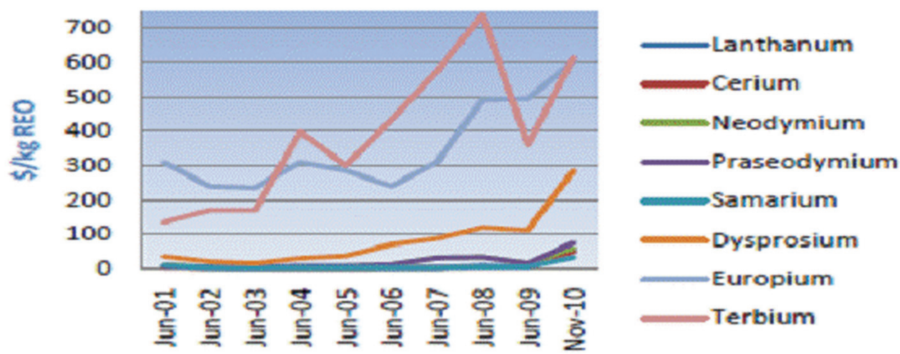
6.2 Rare Earths Price Movements

Rare earth prices remained static for decades due to plentiful supplies, lulling the high-tech industry into a false sense of security. After Beijing cut export quotas by 70 percent for the second half of 2010, prices of some rare earths gone up as much as 850 percent. When the global demand for rare earth materials increases year by year, China exported 6,100 tonnes of medium-end and low-end rare earth products in 1990; the average price was 13,600 USD/ton. In 2009, China exported 36,100 tonnes of rare earth smelting and separation products, rising by 16.67% YOY. The export value amounted to USD 310 million and the average price was only 8,959 USD/ton (China Research and Intelligence, 2010:3). Low prices for rare earth elements from China contributed to cuts at the Mountain Pass mine in U.S one of the main source of supply for many years before it closed in 2002. They also discouraged most entrants to the industry until the last two years, when prices began to climb because of strong demand.

2008 marked the peak in China's rare earth industry. However, in 2009, due to the economic downturn, demand fell sharply. Prices fell due to oversupply on the international market and price wars among Chinese suppliers, in particular smaller players. Since 2005, the Chinese government has been imposing export quotas on many of the rare earth metals, resulting in reduced global supply. Higher prices are a natural result of such supply restrictions. The latest data reveals that, China's exports of rare earth metals burst through the $100,000-per-tonne mark for the first time in February 2011, up almost nine fold from a year before, while the volume of trade stayed far below historical averages and each tonne fetched a mere $14,405 on average. The apparent price rises have averaged $10,000 per tonne per month but accelerated in February 2011, galloping ahead by $34,000 per tonne, according to Reuters calculations based on data from China's Customs office (Tom Miles, 2011). The explosion in export values has coincided with a collapse in volumes coming out of China, the source of almost the entire world's rare earth supplies, which has cut export quotas of the 17 rare earth metals and raised tariffs on exports.

Figure 10 illustrates the historical average prices of individual rare earth oxides between 2001 and 2010. REE prices have raised threefold overall since 2001. This period covers the 2001 recession, which had lingering effects until 2003, and the 2008– 2009 recession. Two things to note are that the heavier rare

Figure 10: REO prices from 2001–2010



Source: Lynas Corp 2010

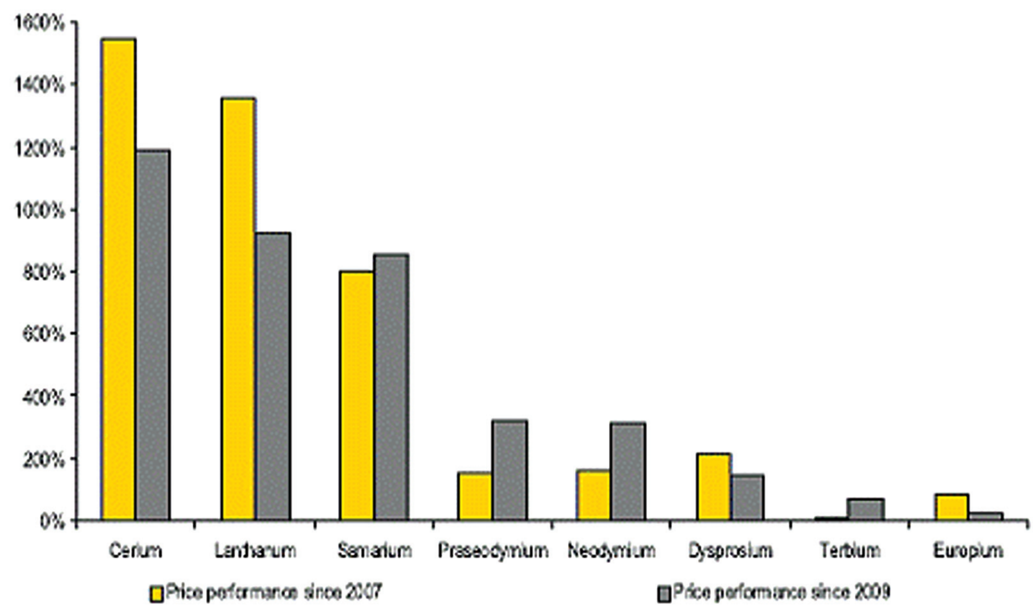
earths (e.g., dysprosium, terbium and europium) are relatively more expensive, and that prices have risen fairly steadily since 2003 due to China's rising domestic demand and escalating export controls. The price jumps from 2009–2010 can perhaps be attributed to a reduction in China's rare earth export quota. The export quota which is for total rare earth exports, resulted in higher prices for REO exports. This led to an unexpected fall in China's export of LREEs which are generally lower priced. As a result of the greater scarcity of light rare earths, the price of LREEs rose much more than the HREEs. Rare earth oxide and rare earth metal prices track closely, with the prices for metals always higher (though relatively more so for some rare earth elements than others) (British Geological Survey, 2010).

After soaring in recent years, rare earth prices have virtually skyrocketed in 2010. Cerium, for example, jumped from on average USD 3.88 per kg in 2009 to USD 50 per kg at beginning of November 2010, while the average price of lanthanum increased tenfold between 2009 and 2010. Terbium and Europium, on the other hand, recorded relatively modest increases of only 7% and 23%. Unlike the conventional metals, rare earths are not traded at the exchange. As a result, pricing is highly obscure, and there is no way for either producers or consumers to hedge prices. Neodymium prices quintupled at the same time to $23 a pound and slumped before almost fully recovering last quarter of 2010. The price of neodymium oxide, also used in magnets in BlackBerrys, has surged more than four- fold to $88.5 a kilogram from $19.12 in 2009 because of rising demand and reduced supply from China, according to Sydney-based Lynas Corp., which is building a A$550 million ($542 million) rare earths mine in Western Australia.

As discussed before the two heavy rare earths, dysprosium and terbium are in short supply, mainly because they have emerged as the miracle ingredients of green energy products. Tiny quantities of dysprosium can make magnets in electric motors lighter by 90 percent, while terbium can help cut the electricity usage of lights by 80 percent. According to a new United States Energy Department report, the most important of these for clean energy is dysprosium. Its price is now $132 a pound compared with $6.50 a pound in 2003. Terbium prices quadrupled from 2003 to 2008, peaking at $407 a pound, before slumping in the global economic crisis to $205 a pound.

While the long-term price of the light rare earths remains open for debate, the quotas will continue to tighten the supply of heavy rare earths like terbium and dysprosium, sending prices soaring. Dysprosium oxide, used in hybrid vehicles, lasers and nuclear reactors, is already selling for $284 a kg and that is projected to rise to over $400 in the next couple of years, according to Asian Metals. The rising prices have been a cause for concern in importing nations, which have become reliant on affordable REMs from China. The recent controversy over

Figure 11: Rare earth prices have multiplied over a short period of time.



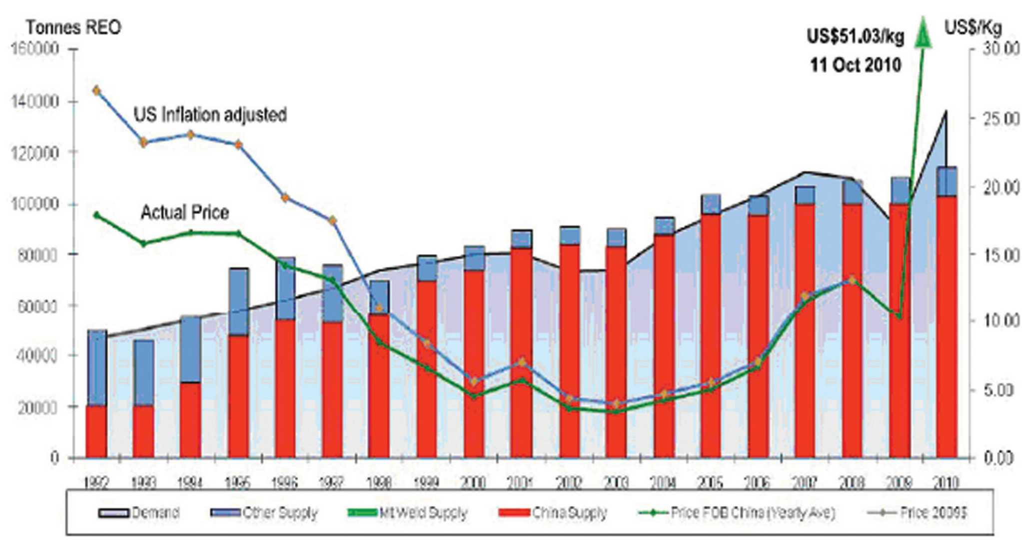
Source: Lynas Corp, Commerzbank Corporates and markets

China's clampdown has prompted prices such as cerium oxide to climb by 700 percent in less than a year. In light of China's virtual monopoly of the REM market, critics have argued that the country is simply flexing its economic muscle.

The figure 12 shows that the prices dropped continuously as supply from China increased substantially up to 2000. The 1992 was the year when Deng Xiaoping famously stated, "the Middle East has oil, and China has rare earths", since then, China has not only remained the world's largest REO producer, but has also successfully moved its manufacturers up the supply chain. During this period rare earth investment at state, provincial and local levels also increased as china dominated the market. When the prices were fallen too short at the international market, the mountain pass mine in California the main supplier of REEs till early 1990s was unable to cope with the escalating cost and finally shut down its operation in 2002 also during this decade the major buyers of rare earths such as U.S, Japan and Europe switched the purchase to China.

During 2000 to 2006 prices again went down; however from 2003, the price started to increase slightly and it is unlikely to be seen the prices again at this level. The major drivers that had an impact on setting the prices on this period were the high level of competition within China and handful of

Figure 12: Historic supply, demand and pricing



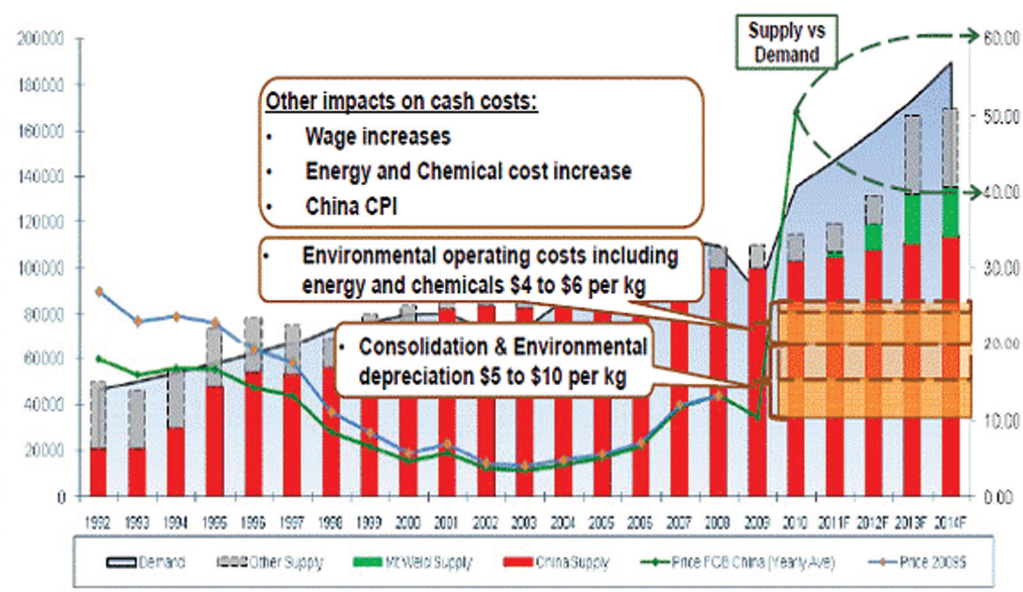
Source: Lynas Corp, 2010

powerful buyers in Japan, USA and Europe. During this period the number of producers in China reduced from 600 to 150 companies by mergers and acquisition and there were little regulation from government side and there were no investment in environmental compliance within the Chinese rare earth Industry. This period also witnessed reducing supply from other countries along with over all demand growing from 2003 onwards after sluggishness in demand from 2000 to 2003.

The figure also shows that from 2003 onwards the prices started to increase again and there was a steep rise in prices in 2007-2008 due to changing market conditions in China. The major drivers of the price during this time were the temporary crack down on environmental standards which resulted in the temporary closure of multiple producers. Cost increasing in China due to the start of environmental compliance, as well labour, energy and chemical costs increasing and tightening between demand and supply also contributed in increasing prices.

In 2009 the price moved down mainly because of the demand sharply dropped due to global financial crisis while global supply almost remained at the same level. However as the economies started to

Figure13: Future outlook and price drivers
Structural change in industry has commenced



Source: Lynas Corp, 2010

recover and by the end of 2009 the prices started to increase again not only because of the global recovery but a number internal policies that China adopted related to rare earth industry. China started the consolidation of production and marketing channels that restricted Chinese supply and demand recovering strongly after GFC induced the prices to increase inside China and consequently increasing the international prices.

The figure 13 shows the future trend in demand, supply and prices up to 2014. There would be a number of factors that affects the price movements both in Chinese domestic market and international level. Assuming current trends continue, new projects are developed and there is a 'balance' in supply and demand for individual rare earths through extra supply. The Challenges for 2014 will be the tight supply and 'balance' between demand supply will still be an issue; so prices for Tb, Dy and Y will remain strong. And other issues include, can the rare earths industry in China be successfully controlled? And will the first of the new non-Chinese projects be successfully built and commissioned?

The impact of Chinese interventions in the domestic industry such as implicit assistance to domestic downstream processors of the targeted products and thus providing them a competitive advantage will have an impact on the prices. China is seeking sustainability and prices will respond to market demand and supply from a sustainable base. Estimates from Chinese government reports shows that the "Chinese price" for rare earths is about ¼ of the price that would result from an environmentally sound, worker friendly, profitable operation. This means that the "real" price of rare earths is about four times higher than the current China price. An entire set of "green" industries have grown up over the past ten years in reliance on that China price. The danger is that as the China price is phased out, many of these green industries will prove to be unprofitable. A primary example of this risk is the electric car. Since the China price for rare earths is virtually certain to be phased out very quickly, this risk is quite real (Steve Dickinson, 2010). However, technological change often brings sharp changes in demand, which, in turn, may lead to strong price volatility. An example is the tantalum capacitor industry. Two-thirds of world tantalum production is used in electronic components. When the tantalum price increased sharply in the late 1990s, the electronics industry encouraged capacitor designers to improve their niobium capacitors and multiple ceramics capacitors in order to replace the tantalum components. The demand for tantalum, and its price, fell sharply as a result.

7. Conclusions

For China rare earth is the wild card now. The Chinese government has stated that its reserves of rare earths are finite and, therefore, they will be developed for the prime benefit of China's manufacturing industry. To help generate manufacturing jobs and move up the value chain, a series of measures has been implemented to "conserve resources and to maximize the benefits" of its rare earths endowment. 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.

China has officially cited environmental issues as one of the key factors for its recent regulation on the industry, but non-environmental motives have also been imputed to China's rare earth policy. According to The Economist, "Slashing their exports of rare-earth metals…is all about moving Chinese manufacturers up the supply chain, so they can sell valuable finished goods to the world rather than lowly raw materials (The Economist, 2010). Although often needed only in small quantities, these metals are increasingly essential to the development of technologically sophisticated products. They play a critical role in the development of innovative "environmental technologies" to boost energy efficiency and reduce greenhouse gas emissions. Hydrogen-fuel based cars, for example, require platinum-based catalysts; electric-hybrid cars need lithium batteries; and rhenium super alloys are an indispensable input for modern aircraft production. In addition, there are few substitutes available in the short-term for these raw materials.

The study finds that, a major ongoing issue for the rare earths industry is the balance. Due to the absurdity between the supply and demand of individual rare earths, there always exists a situation in which there is a shortfall of some rare earths while others are in surplus. On the basis of known analyses of major resources it is considered that some of the 'heavy' rare earths are more likely to be in short supply in the future.

Although production of some strategic minerals is very concentrated, this does not necessarily suggest that future production will be similarly geographically restrained. The future production situation is mixed. For some strategic minerals, the reserve base is more geographically concentrated than the present production. For others, the raw materials are more widely dispersed. In the case of some of the most concentrated raw materials, particularly those largely found in China, such as rare earths, the future reserves are less concentrated than present production would suggest.

Since early 90s, Chinese rare earth producers have had an unregulated approach to the supply in the international market. This has been exploited by a concentrated number of buyers who have collaborated to force prices down. As China gradually increased its bargaining power by restricting supply with tightening market, rare earth prices have improved significantly over the years. Whilst the next 5 to 10 years, global demand will surpass supply, China Rare Earth export quotas will play a critical element in the supply chain of rare earths out side China.

There are few basic features of Chinese supply that we can derive from the above analysis. The main aspects include, China still hold more than 36 million tonnes of rare earth oxide reserves, excessive secondary processing capacity and easy availability of cheap processing chemicals, and heavy investment in research and technology. However the supply of Chinese heavy rare earth is finite with 15- 20 years of mine life and Chinese are rigorously regulating the mines on environmental grounds.

To control the supply China has introduced a number of measures such as imposing 15 percent of taxes on light rare earths oxides and neodymium metal and, 25 percent tax on heavy rare earths and other metals. Government has recommended that the management of rare earth mines should be consolidated under three four main enterprises and has stepped up efforts to restructure the rare earth industry and has introduced favorable policies, and is encouraging acquisitions and mergers to restructure the sector. According to plans, the Chinese government will bring down the number of rare earth companies from 90 to 20 within 2015. These measures will have short – medium term repercussions in the international market and industrial applications.

There is no rare earth source that can match the Baotou tailings dump, these deposits can be found all over the world. China's actions have put this issue firmly on the radar screen and countries are getting serious about developing new sources. Several new overseas mine projects are in the pipeline but few are likely to be able to compete with China on prices. Besides, it would require at least a decade before new mines can make an impact on the global market and the study shows that China will continue to control the global market for some time to come.

China's control over rare earth elements has the potential to increase foreign dependence on China for finished goods. China has adopted various policies to further develop the rare earth industry at its roots. China's vision is to increase industrial utilization of rare earth elements and control the market of rare earth applications.

China recognized the strategic value of its RE resources long before the days of Deng Xiaoping. With skill, patience and investment China has transformed the Rare Earth industry into what it is today. Government support of advanced curricula in RE sciences has produced thousands of technical professionals employed in RE industry today.

China's moves are creating panic in the rare earth sector and its efforts to monopolize the sector will backfire since the nation's policy makers seem to have failed to realize that such high-handed measures are uniting the rest of the world against China. Business partners and prospective investors will insist on tougher terms of contract or develop other ways to protect their business interests.

Most of the analysts argue that, if China causes a shortage of rare earths, it will be a temporary shortage, since the rising prices for rare earth elements will serve as an incentive for others to enter the market, leading to greater supply. The United States, for example, has 13 percent of known rare earth reserves and could get back into the production and refining business. Still, there will be a lag before new production becomes available, and it could easily come from an equally troubling source. After China, Russia has the next largest reserves (19 percent), and it is at least as likely (if not more so) to play games with export restrictions, and have more lax safety and environmental standards as well.

According to Financial Times, China wants to forge a new phase of globalization where many of the roads – financial, commercial and perhaps eventually political- converge on Beijing. China is not seeking a rupture with the international economic system (although some foreign companies are fearful of a technology grab). But it is looking to mould more of the rules, institutions and economic relationships that are at the core of the global economy. It is trying to forge post-American globalization.

While China says its deposits of rare-earth minerals account for only about a third of the global total, the country mines most of the world's marketed supply, which has raised concerns that China could deplete the supply too quickly. The move to build reserves comes as China's supply of rare-earth metals to the rest of the world already is shrinking despite growing demand for the elements. In response to Chinese restrictions on supply the high-tech-focused nations of U.S, The European Union, Japan and South Korea, all of which are dependent on China for rare-earth supplies, have highlighted stockpiling strategies.

High-technology and environmental applications of the rare earth elements have grown dramatically in diversity and importance over the past four decades. Many of these applications are highly specific and substitutes for REE's are inferior or unknown. REE's have acquired a level of technological significance much greater than expected from their relative anonymity.

If new supplies of rare earths do not come online within the next 10 years, a global shortage would likely to affect new energy industry such as wind turbine, solar panels, electric vehicle production and electronics. According to the U.S government report, the issue even carries national security implications because of the rare earth content in many advanced military weapons, the economic threat of depending on a single country and getting new sources of supply into production is not that easy. Rare earth elements are needed for China's expansion of its own military needs (aircraft carriers, nuclear-powered submarines, and ballistic missiles). Home-grown production needs will further cut exports already reduced to crippling levels. Not surprisingly, these measures have raised real concerns outside of China regarding the future availability of the refined products created from REMs.

China has been strategically motivated in the development of many new high tech applications which have helped quadruple the size of the RE market since 1990. Chinese economy will continue to grow near double digit rates for the foreseeable future and disposable income for automobiles, personal electronics, etc will drive the internal demand for REs significantly. China is already overtaken U.S as the largest auto market and expected to produce 500,000 electric vehicles in 2011and also leads in wind power generation. So to meet this increasing demand for REEs, China will gradually reduce the exports.

So to summarize

- China's RE reserves are finite.
- Chinese internal demand for RE

materials and technologies is forecasted to continue growing at double digit rates for the foreseeable future.

- These conditions will continue to drive Chinese policies to limit RE production and exports to better manage its precious natural resource.
- China already produces 80% of global requirement for fully dense RE permanent magnets and 100% of the global RE metal requirement for all RE permanent magnets (fully dense and bonded) produced.
- Prospects of the Chinese expanding RE raw material output beyond its own internal demand only appears to make sense if China can leverage this increased production to bring more downstream manufacturing into the country (more magnets, motors and motor assemblies for example)

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1. Introduction

Rare earth elements (REEs) or rare earth metals are a collection of seventeen chemical elements in the periodic table, namely scandium, yttrium, and the fifteen lanthanides. Scandium and yttrium are considered rare earth elements since they tend to occur in the same ore deposits as the lanthanides and exhibit similar chemical properties.

This paper is designed to evaluate the importance of rare earth elements. The study explores China's role in the supply-demand equation and price mechanism at large and, its implications. It also examines the history of rare earth elements and China's current monopoly over the industry, including possible repercussions and strategic implications if rare earth supply were to be disrupted. The study provides insights into how widely traded these minerals are and China's positions in the international trade both in terms volume and value. The study investigates who are the major customers and analyses the various trade restrictions imposed by China. The study capitulate instructive and actionable data for considering how China's decreasing exports, fresh technological uses, and rising prices are setting up an unprecedented discussion on the REEs.

REEs were first discovered in 1787 by Lieutenant Carl Axel Arrhenius, a Swedish army officer. Since then there has

Table 1: What are the rare earth elements?

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Ai	Si	P	S	CI	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	**	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Ti	Pb	Bi	Po	At	Rn
Fr	Ra	**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn						
		La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
		Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cr	Es	Fm	Md	No	Lr	

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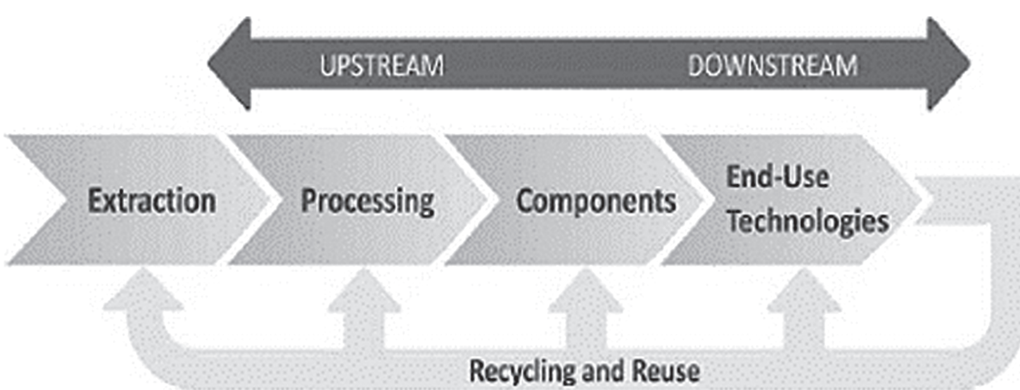
been a great deal of interest in their chemical properties and potential uses. From about the 1940s to the 1990s, REEs attracted great interest in both the U.S. and China's academic and scientific communities. Today, however, there are only a small handful of scientists who truly focus on REEs in the U.S. China, on the other hand, could be setting itself up to become a superpower in technological innovation through its near monopoly and its vast efforts in research and development of REEs (Hurst Cindy, 2010).

Despite their name, rare earth elements (with the exception of the highly unstable promethium) are relatively plentiful in the Earth's crust, with cerium being the 25th most abundant element at 68 parts per million (similar to copper). However, because of their geochemical properties, rare earth elements are not often found in concentrated and economically exploitable forms or ores. It was the very scarcity of these minerals (previously called "earths") that led to the term "rare earth". The first such mineral discovered was gadolinite, a compound of cerium, yttrium, iron, silicon and other elements. Cerium, for example, ranks number 26 in abundance among the elements and is five times as common as lead. And even the scarcest of rare earths, Thulium, is more abundant than gold or platinum. Because the elements share similar chemical properties, most REEs deposits contain a large number of all 17 elements in varying- albeit small- concentrations. In addition, rare earths are often of low quality, which has made the material uneconomical to mine, and also because the elements are usually found within a cocktail of rare earths that need to be separated in laborious process.

Figure 1: Basic materials supply chain



Elemental materials are extracted from the earth via mining. Next, they are processed via separation and refining to obtain the desired composition or purity. Materials may be extracted either as major products, where ore is directly processed to extract the key materials or they may be co-products or byproducts of other mining operations. The co-production and by-production processes create complex relationships between the availability and extraction costs of different materials, which may cause supply curves and market prices to vary in ways not captured by simple supply and demand relationships (DoE, US, 2010). Processed materials are used to manufacture component parts that are ultimately assembled into end-use technologies. The generic supply chain also shows the potential for recycling and reusing materials from finished applications, though materials can be reclaimed at any stage of the supply chain and reused either upstream or downstream (DoE, US, 2010).

Rare earths are a critical component of many high technology goods such as hybrid vehicles, mobile telephones, computers, televisions and energy efficient lights. Although rare earths have relatively a high unit value, the impact of their cost has little, if any impact on the selling price of the final item because they are present in minute concentrations. RE elements are also considered as strategically important because of its uses in defense and essential components to products with high growth potential-electronics and technology industries, energy efficiency and greenhouse gas reduction. Rare earth elements are important ingredients in lasers, superconducting magnets, batteries for hybrid automobiles; Makers of hybrid cars use these elements in their lanthanum nickel magnets to give them greater rechargeable capabilities. Portable x-ray units can function much more effectively with thulium. Erbium-doped fiber optic cables can amplify the speed of communication. Night vision goggles and rangefinder equipment use rubidium to increase accuracy and visibility. Radar uses the samarium cobalt magnet to withstand stresses as it has the highest temperature rating of any rare earth magnet.

Even with a threefold increase in REE demand over the past ten years, demand is expected to increase even further, by anywhere from 8 to 790 percent over the next five years (Kientz R, 2010). While REEs have been produced for almost a century, the companies supplying them have changed. In the mid-twentieth century, almost all rare earth mining was done at Mountain Pass, California. Today, more than 97 percent of mining and refinement is done in China. The shift occurred mainly due to the elaborative separation and refining processes, which is labor intensive, and raises safety and environmental concerns. Not only do the Chinese mine most of rare earths today, they possess 36 percent of world reserves (Hedrick. J B, 2010:129).

China's dominance in the RE supply chain is directly related to Beijing's consistent and long term planning, which dates back to as early as the 1950s. However, the Chinese RE industry greatly advanced when Xu Guangxian (also known as "The Father of Chinese Rare Earths Chemistry") developed the Theory of Countercurrent Extraction-which is applicable for the separation of a mixture with more than ten components such as rare earths-in the 1970s. Since then, China's REO output has increased rapidly from slightly over 1,000 tonnes in 1978 to 11,860 tonnes in 1986, when a production spike at the giant Bayan-obo mine first propelled China past the United States as the world's leading producer of REO. Meanwhile, Beijing has continuously invested heavily in technological innovations through key national R&D programs, such as the 863 and 973 projects, in order to gain a decisive advantage in the rare earth supply chain including mining, separation, refining, forming and manufacturing (Hurst Cindy, 2010:6).

According to China's Ministry of Science and Technology, the objective of these program was to "advance in key technological fields that concern the national economy and national security; and to achieve 'leapfrog' development in key high-tech fields and take strategic positions in order to provide high-tech support to fulfill strategic objectives in China's modernization process". In 1992 the late Chinese Prime Minister Deng Xiaoping famously stated, "the Middle East has oil, and China has rare earths", since then, China has not only remained the world's largest REO producer, but has also successfully moved its manufacturers up the supply chain (Hurst Cindy, 2010). Since 1990, domestic consumption of REO for high value-added product manufacturing in China has increased at 13 percent annually, reaching 73,000 tonnes in 2009 (Song and Hong, 2010). State-run labs in China have consistently been involved in research and development of REEs for over fifty years. The Rare Earth Materials Chemistry and Applications which is affiliated with Peking University and focused on rare earth separation techniques and, the lab based at Changchun Institute of Applied Chemistry. Additional labs concentrating on rare earth elements include the Baotou Research Institute of Rare Earths, the largest rare earth research institution in the world, established in 1963, and the General Research Institute for Nonferrous Metals established in 1952(Hurst Cindy, 2010:9). This long term outlook and investment has yielded significant results for China's rare earth industry.

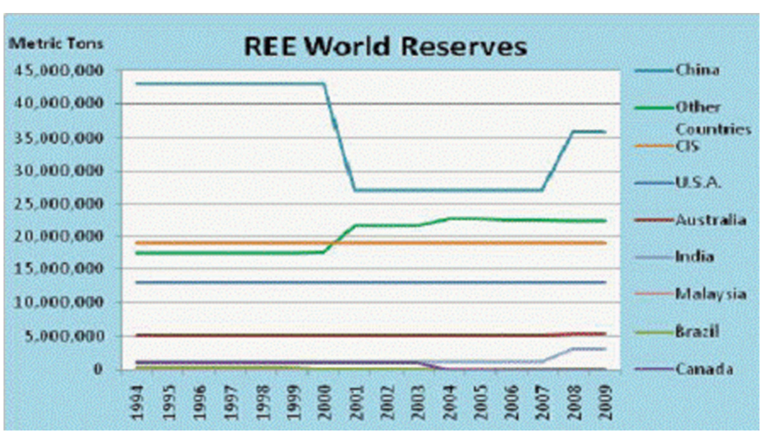
2. Reserves, Production and Supply

2.1 Rare Earth Element - Reserves

Reserves are the resources that could be economically extracted or produced at the time of determination. The term reserves need not signify that extraction facilities are in place and operative.

Globally, the four principal high-yield REE-bearing minerals are bastnäsite, monazite, xenotime and ion absorption clays. A mineral deposit that does not fall in any of these four categories typically requires more metallurgical testing to establish the mineralogy and processing steps. The rare earth content of each deposit is essential to estimating the deposit's profitability. It determines how the ore will be processed and how complicated it will be to separate the rare earth elements from each other. Most rare earth elements throughout the world are found in deposits of the minerals bastnaesite and monazite. Bastnaesite deposits in the United States and China account for the largest concentrations of REEs, while monazite deposits in Australia, South Africa, China, Brazil,

Figure 2: REE world reserves



Source: United States Geological Survey Mineral and Commodity Summaries

Malaysia, and India account for the second largest concentrations of REEs. Bastnaesite occurs as a primary mineral, while monazite is found in primary deposits of other ores and typically recovered as a byproduct. Over 90% of the world's economically recoverable rare earth elements are found in primary mineral deposits i.e., in bastnaesite ores (Marc Humphries, 2010).

According to the US Geological survey, total known reserves word wide amounted roughly 99 million tonnes at the end of 2009, which would last 800 years, provided production remained unchanged at the current level of approximately 124 thousand tonnes compared with its peak of 137 thousand tonnes in 2006, rare earth out put has thus come down some 9 per cent.

There are three primary criteria, among others, that determine the economic feasibility of a potential rare earth mine: tonnage, grade and the cost of refining the rare earth mineral. A mine may be economically viable (and therefore attractive to investors) if a low-grade (<5%) ore occurred with large tonnage and familiar mineralogy or if high-grade ore occurred with familiar mineralogy. Heavy rare earths (atomic numbers 65–71), such as terbium and dysprosium, along with yttrium (atomic number 39), are somewhat more scarce and often concentrated in ionic adsorption clay and xenotime, commonly found in southeastern China (Hedrick James B, 1997:471).

China supplies approximately 95% of global demand and consumes about 60% of the global supply, but its reserves of rare earths are finite. The Chinese government has indicated that if the exploitation of these resources is not controlled, they could be exhausted in 20-30 years. These valuable resource endowments are not evenly distributed in China and about 83% of the resources are located in Baiyunebo (Baotou, Inner Mongolia), 8% in Shandong province, 3% in Sichuan province (light rare earth deposits of La, Ce, Pr, Nd Sm, Eu). 3 percent of the deposits located in Jiangxi province are middle and heavy rare earth deposits (Middle: Gd, Tb, Dy, Ho, Heavy: Er, Tm, Yb, Lu, Sc, Y). In comparison, while most of the global supply of heavy REs (e.g. yttrium) originates in the"ion adsorption clay"ores of Southern China, the proven reserves of heavy REs in the 7 Southern Chinese provinces are a mere 1.5 Mt (Huatai United Securities, 2010). Since heavy REs are considered more strategically valuable, significant efforts have been made by Beijing in recent years to crack down rampant illegal mining in Southern China.

Table 2: The world wide resreves of rare earth elements as of 2009

Country	Reserves (Million Metric Tonnes)	% of total	ReserveBase* (Million Metric Tonnes)	% of total
United States	13.0	13	14	9.3
China	**36**	**36**	**89**	**59.3**
Russia & CIS	19	19	21	14
Australia	5.4	5	5.8	3.9
India	**3.1**	**3**	**1.3**	**1**
Brazil	Small			
Malaysia	Small			
Others	22.0	22	23	12.5
Total	**99.0**		**154.0**	

Source: Marc Humphries 2010

*Reserve Base is defined by USGS to include reserves(both economic and marginally economic)plus some subeconomic resources(with potential for becoming economic reserves).

Reserves of medium and heavy rare earths may only last 15 to 20 years at the current rate of production, which could lead to China being forced to imports supplies. Medium and heavy rare earth, also known as ion-adsorbed-type rare earth, is more valuable than the lighter variety. It is used in advanced areas such as missiles. China's verified reserves of ion-adsorbed-type rare earth stood at 8 million tonnes in 2008, while reserves of light rare earth totaled 50 to 60 million, according to data from the Ministry of Land and Resources.

Fujian, the province with the country's third richest rare earth reserve, is building an integrated rare earth industrial park near one of the country's most productive heavy rare earth mineral deposits. Located at south Changting, the 10 sq km park with an investment of 6 billion yuan ($905 million) is expected to be ready by 2015, according to the Chinese Society of Rare Earth.

China's rare earth resources are widely distributed throughout the country. The scattered distribution makes it difficult to carry out efficient oversight of the industry. The 2009-2015 Plan aims to create 'large rare earth districts' to simplify management of China's rare earth resources. The new plan will divide China's industry into three large districts -south, north, and west. The southern district would comprise of Jiangxi, Guangdong, Fujian, Hunan, and Guangxi; the northern district would be centered on Inner

Mongolia and Shandong and the western district would consolidate mines located in Sichuan (Hurst Cindy, 2010). China is also reported to have around 84 deposits /mines of rare earths, spread over 18 provinces. The proposed consolidated rare earth districts will most likely be under the direction of one company. If successful, the new consolidation could dramatically affect China's ability to control the flow of rare earths. During this consolidation process there may be unexpected supply shortages because of shutdowns or increased availability of products due to new efficiencies. The details of the number of mines operating in various provinces are indicated in table 3.

Interestingly, the data suggests that China has controlled output successfully since 2006 as it sought to consolidate the domestic industry into a handful of players. China has long lagged behind the U.S. technologically. However, as of the early 1990s, China's vast rare earth resources have propelled the country into the number one position in the industry. Additionally, China has set out on an expansive effort to increase its overall technological innovation, effort which includes the use of rare earth elements. China's academic focus on rare earth elements could one day give the country a decisive advantage over technological innovation.

2.2 Production of Rare Earth Elements

In fact, there are very few companies outside China producing the metals. Inner Mongolia Baotou Steel Rare Earth Hi-Tech Co. is China's single largest producer of the metals. China rare earth extraction

Table 3: Rare earth deposits/mines in China

Province	No. of Mines	Province	No. of Mines
Fujian	3	Jiangxi	8
Gansu	1	Jilin	1
Guangdong	17	Liaoning	2
Guangxi	7	Shandong	2
Guizhou	3	Shanxi	1
Hainan	6	Sichuan	4
Hebei	3	Xinjiang	1
Hubei	3	Yunan	3
Hunan	12	Not Known	**2**
Inner Mongolia	5	**Total**	**84**

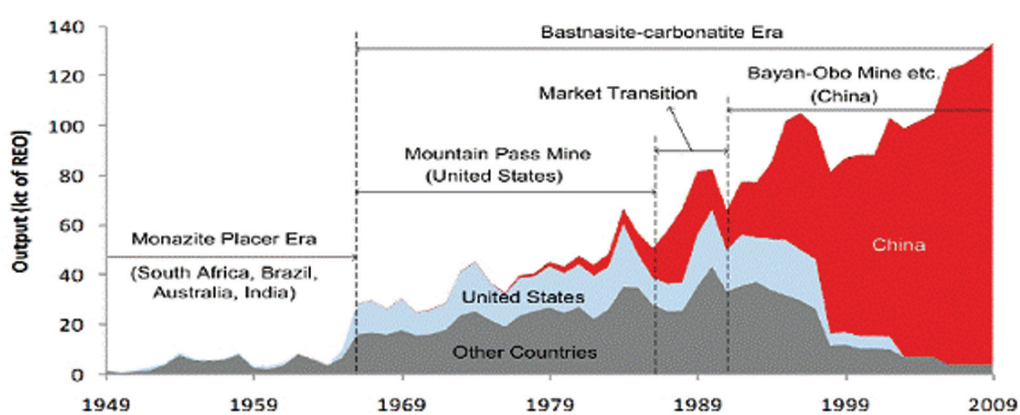
Source: Greta J. Orris and Richard I. Grauch (2002) know how is currently unparalleled, the necessary production capacities, infrastructure and distribution channels all exist and, on top of that, the country benefits from fairly lax environment and work place safety regulations and low labour costs. China, which once focused on exporting rare earths in their raw forms, has shifted its end goal from production to innovation. In the 1970s, China was just exporting rare earth mineral concentrates. By the 1990s, it began producing magnets, phosphors and polishing powders. Now, it is making finished products like electric motors, batteries, LCDs, mobile phones and so on.

REE Production Trends

The significant cost advantage for Chinese producers, which has crushed almost all overseas competitors, is not only driven by low labor costs, but also unintentionally reinforced by Beijing's policy failures in regulating the resource extraction sector as a whole, and the RE industry in particular. To keep pace with its booming economy, Beijing promulgated the so-called "Let Water Flow Rapidly" (*You Shui Kuai Liu*) policy in 1981 to stimulate a rapid spike in resource demand without appropriate considerations of environmental protection, safety and sector consolidation. The lack of entrance standards and patent enforcement led to a proliferation of small scale and technologically backward mines and separation plants.

Media reports have often pegged China's rare earth cost advantage on poor environmental standards, which are a problem in the chaotic mining operations

Figure 3: Chinese rare earth industry in the international context



Source: United States Geological Survey, formatted by CSIS in Southern China (Tu Kevin J, 2010). But the truth, according to experts, is that China's largest source of rare earths does not even come from a rare earth mine. Rather, it comes out of the tailings (or waste material) from the giant Baotou iron ore mine in the province of Inner Mongolia in Northern China. A cheap processing method is used to covert them into high-purity product. As production from these sources continued to ramp up in the 1990s, there was massive overcapacity built in China, and prices collapsed. The Chinese government introduced the first export quotas in 1999. In less than one decade, the permanent magnet market experienced a complete shift in leadership. Whereas in 1998, 90 percent of the world's magnet production was in the United States, Europe, and Japan, today, rare earth magnets are sold almost exclusively by China or using Chinese rare earth oxides. China is now facing the possibility that reserves of medium and heavy rare earths might run dry within 15 to 20 years if the current rate of production is maintained.

The table 4 reveals that the production in Bayan Obo remains the largest REE industry in China contributing almost half of the total production. The production has been constant between the periods 2006 and 2008 ranging between 125- 140 thousand tonnes. China has greatly reduced the production of REE to 110-130 thousand tonnes by the end of 2010 and also restricted the exports through various quota systems which will be discussed in detail in section four. The table also provides the estimated level of REE production in China for the year 2014, increased production of 80-100 thousand tones in Bayan Obo and 160-170 thousand tonnes of total production.

Table 4: Chinese production of rare earth chemical concentrates 2004-14

Year	Bayan Obo Bastnasite	Sichuan Bastnasite	Ion Adsorption clays	Monazite	Total
2004	42-48,000	20-24,000	28-32,000	-	9-100,000
2006	45-55,000	22-26,000	40-50,000	8-12,000	125-140,000
2008	60-70,000	10-15,000	45-55,000	8-12,000	125-140,000
2010	55-65,000	10-15,000	35-45,000	4-8,000	110-130,000
2014	80-100,000	20-40,000	40-50,000	8-12,000	160-170,000

Note: Illegal or uncontrolled mining and processing is not included. It has amounted to 10-20,000t pa REO over the last 3-5 years

Source: IMCOA, CREIC, Baogang Rare Earth Hi-Tech, Sichuan RE Association, GRIREM

2.3 Supply of Rare Earth Elements

The supply of a material is a function of resources, reserves and production. "Resources" include identified and undiscovered resources. Production generally occurs in countries with large resources and reserves, but exceptions exist. In some cases, small reserve holders may also produce the material, while countries with no reserves could be a major refinery producer of imported primary or raw material.

There was still more than enough supply reaching other markets and there was no real talk of a problem in the sector until the past couple of years, when growing global demand for rare earths highlighted the fact that China had put everyone else out of business. Comments from Chinese government officials started to suggest that they view the industry as more strategic than ever before, and were intent on securing more supply for domestic use. They started taking measures to consolidate domestic supply and reduce smuggling. Analysts are of the opinion that by 2012, the rest of the world could face a major supply crisis because of China's reduced or zero supply. The demand-supply is expected to touch 30,000–40,000 tonnes by 2012 in the absence of any new large supplier (David Anthony, 2010). The growing economy of China is creating a worldwide risk to supply and China's growing consumption limits its exports of rare earths. China insists that it requires the high supplies to meet the demands of its clean energy and high-tech sectors.

Most of the rare earth enterprises locate around the large rare earth mines, such as Baotou city, Sichuan province and Ganzhou city. There are about 24 enterprises for rare earth concentrate production, and 100 rare earth enterprises for smelting separation production in China. Most of the REE supply originated from the Baotou plant was about 55000t and the total supply from China were about 103300t in 2010. The global supply increased to 15000 in 2010 from the 2005 level of 10500t to meet the increasing demand from the automotive and technology sectors.

The table 5 reveals a number of developments in production and supply of rare earths by 2014 and shows that a 10 percent increase in production at Baotou plant from 2010 to14 and full production quota to be utilized at Sichuan with production of 20000t. The supply from Iconic clay regions will be reduced to 30000t by 2014 with a little increase in supply from recycling in China. Chinese restrictions on supply in 2010 have triggered many countries too look for alternative sources and by 2014 a number countries will be in a position to

Table 5: Chinese REE supply compare to other countries in 2010 and 2014 (forecast)

Chinese Supply Sources	QTY 2010	QTY 2014.est	Non Chinese Supply	QTY 2010	QTY 2014.est
Baotou ♦ By product of iron ore mine ♦ Moving to higher grade iron, with lower impurities and Rare Earths ♦ Tailing facilities near capacity	55000t	60000t	India ♦ Subsidiary of Indian AEA ♦ Toyota Tsusho bought trading firm with Japanese Distribution	3000t	12000t
			Russia & CIS ♦ Limited expansion capacity ♦ By product of Mg production	4000t	
Sichuan ♦ Target to increase value added ♦ Capacity expected to increase	10000t	20000t	Australia, Mount Weld		22000t
Iconic clay regions ♦ Reportedly 14 yrs of resources ♦ Large amount of illegal mining ♦ Government action taking effect	35000t	30000t	USA-Mountain pass ♦ Reprocessing stockpiles ♦ Requires apprx. US$530 million rebuild	3000t	20000t
Recycling	3300t	4000t	Recycling ♦ Magnet swarf ♦ Batteries-future potential	1500t	1800t
Total	103300t	114000t	Total	11500t	55800t

Source: Lynas Corp, 2010

supply some amount of rare earth as the data shows that the mount weld mine in Australia is expected to supply about 22000t and mountain pass in California is expected to supply 20000 tonnes along with supplies from Russia, CIS countries and India. One of the largest growth areas is expected to be the production of hybrid vehicles, such as the Toyota Prius. Each hybrid car contains 16 kg of rare earths, predominantly in its batteries and electric motors (Lun Joe, 2006).

The table also shows that the supply from recycling in China increases marginally from 3300t in 2010 to 4000t in 2014 and from 1500t to 1800t in global supply. The reuse and recycling capacity currently limited as recovery of manufacturing waste and measurable recovery from aftermarket products are yet to develop. Also recycling them is often difficult and expensive, because they are often mixed with other materials when products are made. And there is little economic incentive to recycle, since rare earth elements are available raw on the world market at comparatively low prices. However, improved designs for recycling coupled with larger streams of materials could eventually allow for the economical recycling and reuse of magnetic materials.

Table 6 shows that most of the oxides are produced at different mine sites in China. The industry in Malaysia is largely dependent on the ores from Australia. Most analysts believe China will eventually change its quota system to restrict the rare earths individually. Because China has an abundance of light rare earths available through the Bayan Obo project in Mongolia, changing the quota system would likely trigger a sudden flood of cerium and lanthanum on to the market. Even with new mines coming online within the next five years, analysts are forecasting a shortage of heavy rare earths terbium and dysprosium by 2015, and a very tight supply of light rare earths neodymium and praseodymium. Of note is that nearly all rare earth deposits contain the radioactive material thorium and the cost of treating and storing thorium is an important factor in evaluating the economics of a mine. This may be particularly true to the rare earth

Table 6: Rare earths types and contents of major contributing source minerals supplying REEs to the global market (percentage of total rare earth oxides)

		LIGHT				MEDIUM			HEAVY								
TYPE	Location (s)	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Y
Currently Active:																	
Bastnasite	Byan obo Inner Mongolia	23	50	6.2	18.5	0.8	0.2	0.7	0.1	0.1	0	0	0	0	0	0
Xenomite	Lahat, perak, Malaysia	1.2	3.1	0.5	1.6	1.1	0	3.5	0.9	8.3	2.0	6.4	1.1	6.8	1	61
Rare earth laterite	Xunwu, Jianxi China	43.4	2.4	9.0	31.7	3.9	0.5	3.0	0	0	0	0	0	0.3	0.1	8
Ion adsorption clays	Longnan,Jianxi, China	1.8	0.4	0.7	3.0	2.8	0.1	6.9	1.3	6.7	1.6	4.9	0.7	2.5	0.4	65
Loparite	Lovozerskaya, Russia	28	57.5	3.8	8.8	0	0.1	0	0.1	0.1	0	0	0	0	0	0
Various	India	23	46	5	20	4	0	0	0	0	0	0	0	0	0	0

Source: U.S Department of Energy (2010) production in Kerala, India where the deposits of thorium is very high. In general, each rare earth ore body is unique and requires a site-specific processing system. As a result, production costs vary from deposit to deposit based on ore content and mineralogy.

The development of increased stockpiling of REE in China has gained momentum in recent years with assertion of government authority in recent years over mining regions. The Chinese stockpiling, under the direction of the Ministry of Land and Resources, began with a pilot project in early 2010 in China's primary mining region of Baotou in Inner Mongolia. At least 10 storage facilities are being built and managed by the world's largest producer of rare-earth metals; government-controlled Baotou Steel Rare-Earth (Group) Hi-Tech Co. Chinese state media reports say stockpiles may eventually top 100,000 metric tonnes (James T. Areddy, 2011). The move to build reserves comes as China's supply of rare-earth metals to the rest of the world already is shrinking despite growing demand for the elements. In response to Chinese restrictions on supply the high-tech-focused nations of U.S, The European Union, Japan and South Korea, all of which are dependent on China for rare-earth supplies, have highlighted stockpiling strategies.

There are few basic features of Chinese supply that we can derive from the above analysis. The facts include, China still hold more than 25 million tonnes of rare earth oxide reserves, excessive secondary processing capacity and easy availability of cheap processing chemicals, and heavy investment in research and technology. Moreover, the supply of Chinese heavy rare earth are finite with 15- 20 years of mine life, Chinese are rigorously regulating the mines on environmental grounds. After China gained decisive advantage in the RE supply chain, Beijing's restrictions on REO production and exports in recent years have been primarily motivated by the strong political desire for resource conservation.

3. Demand and Industrial Applications of Rare Earth Elements

The two major drivers of demand for mineral commodities are the rate of overall economic growth, (stable or decline) and the state of development for principal material applications (e.g., clean energy technologies). Demand for key materials in clean energy technologies compete for available supply with demand for the same materials in other applications.[1] With 1.3 billion people and the fastest growing economy in the world, China is faced with the challenging task of ensuring it has adequate natural resources to sustain economic growth. There is also a growing school of thought that China is not actually able, at present, to use all of the materials allocated for domestic use only. "Out of a production level of perhaps 100,000 tonnes of total rare earth oxides in past years," the bulk of that material has ended up being purchased by end-users in first-world nations (US DOE, 2010).

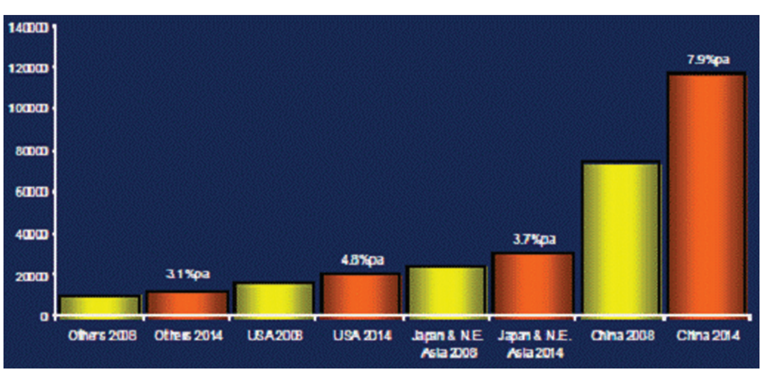
World demand for rare earth elements are estimated at 134,000 tonnes per year, with global production around 124,000 tonnes annually. The difference is covered by above-ground stocks or inventories. World demand is projected to rise to 180,000 tonnes annually by 2012, while it is unlikely that new mine output will close the gap in the short term. By 2014, global demand for rare earth elements may exceed 200,000 tonnes per year. China's output may reach 160,000 tonnes per year (up from 130,000 tonnes in 2008) in 2014. An additional capacity

[1] Generally and with respect to the key materials, demand for end-use items for building use (e.g., phosphors for lighting) or construction tend to be more cyclical, whereas those that enter big-ticket consumer items such as cars tend to be more volatile and sensitive to short-term economic movements. Uses that enter portable devices and personal consumer goods (e.g., batteries for portable electronics) tend to experience more stable demand. Regional factors are important also: China's and India's rapid economic growth have had and will continue to have a huge impact on global demand for mineral commodities (Eggert RG, 2010).

shortfall of 40,000 tonnes per year may occur. This potential shortfall has raised concerns in the major rare earth consuming countries. New mining projects could easily take 10 years for development. In the long run, however, the USGS expects that reserves and undiscovered resources are large enough to meet demand. This expected growth, coupled with the recent export cuts from China, has end users of rare earths scrambling for supplies.

Just as world wide demand for REO is growing, so too is China's own demand. Data from the Chinese society of Rare earths (CSRE) show that the country's consumption has grown rapidly since 2004 and reached over 70,000 tonnes in 2008. Growth in demand from China will continue to outpace the rest of the world. By the year of 2015, it is estimated that the global demand of rare earths is expected to reach 210 thousand tonnes; China's domestic demand will be 138,000 tonnes. By 2020, China's domestic demand is expected to reach 190,000 tonnes, including 130,000 tonnes consumed in high-tech fields, account for 68% of global total consumption. It can be concluded that Rare Earth Materials has become a major growth point of China rare earth industry (Chen Zhanheng, 2010). China, Japan and the United States are the largest consumers of rare earth metals. With the growing demand for 'green' products, the demand for rare earth metals is only expected to increase. The annual growth in demand is expected to hover around 10%. China started a program wherein it not only mined and produced these rare earth elements but also manufactured the finished goods. So,

Figure 4: Forecast global demand for rare earths by market in 2014 (t REO ±15%)



Source IMCOA, Roskill, 2010

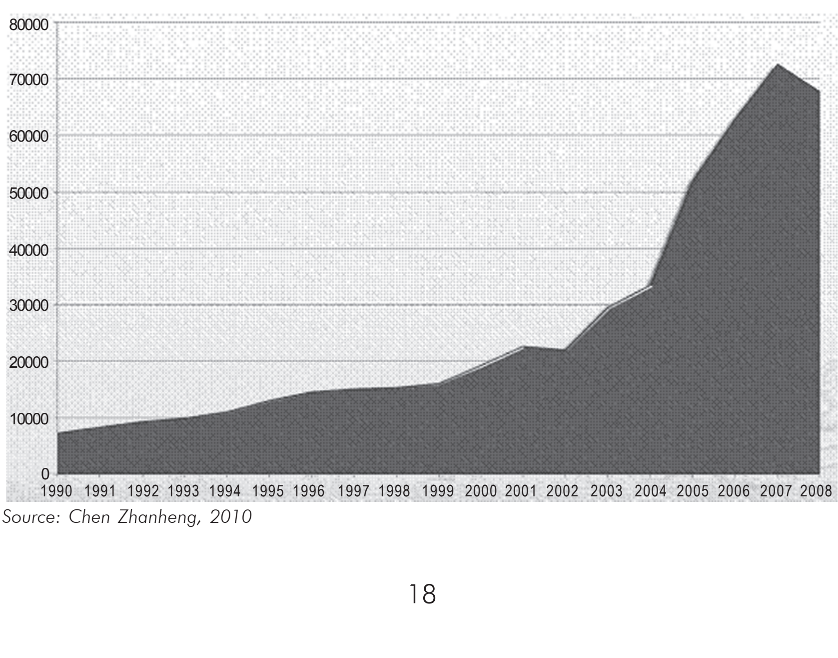
not only does the country produce 97% of the world's REEs but also uses approximately 70% of that material to build products domestically. Thus, China came to dominate the entire industry.

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. This demand as no doubt been and will continue to be fueled by heavy investments in clean energy.

The Figure shows the Chinese consumption of rare earths from 1990 to 2008. It can be noticed that the consumption of rare earths in China increased rapidly since 2004. During the last 20 years from 1990 to 2008, China annual consumption increased from 1 thousand tonnes to 72.6 thousand tonnes, it was a tremendous increase of 72.6 times. The consumption was 67.68 thousand tonnes in 2008, a slight decrease compared with that in 2007. The main reason for this tremendous growth is that ever increasing production of manufacturing items in china such wind mills, solar panels, electronic commodities.

High-technology and environmental applications of the rare earth elements have grown dramatically in diversity and importance over the past four decades. Many of these applications are highly specific and substitutes for REE's are inferior or unknown. REE's have acquired a level of technological significance much

Figure 5: Chinese consumption of rare earths from 1990 to 2008



Source: Chen Zhanheng, 2010

greater than expected from their relative obscurity. These uses range from mundane (lighter flints, glass polishing) to high-tech (phosphors, lasers, magnets, batteries, magnetic refrigeration) to futuristic (high-temperature superconductivity, safe storage and transport of hydrogen for a post-hydrocarbon economy). The rare earth elements are essential for a diverse and expanding array of high-technology applications (Quantum Rare Earth Development Corp, 2011).

The table 7 depicts the REE products and their applications. Dysprosium and terbium are alloyed into rare earths magnets to make them capable of operating at elevated temperatures. At current alloying levels, dysprosium and terbium make up about 5% of the metal used in these car battery magnets. The majority of applications depend on the rare earth magnets. China exported 10,000 tonnes of rare earth magnets worth $400 million and 34,600 tonnes of other rare earth products worth $500 million in 2008. The rare earths market represented approximately USD 1.25 billion in 2008. Over the past decade, market growth has been in the range of 8-11% per year, with the exception of the correction in 2001/02 due to the fall in technology markets and the global economic crisis. While the global financial and economic crisis in 2009 reduced consumption of REE, the industry growth

Table 7: Major products and applications of rare earth products

Rare Earths	Products	Industrial applications
Nd, Pr, Sm, Tb, Dy	Magnets	Demand for large magnets for permanent magnet motors in HEVs, EVs, and Maglev trains, also increased demand for HDDs and ODDs, mobile phones, MP3 playes, cameras, VCMs
La, Ce, Pr, Nd	Battery alloy	Rising demand for HEVs
Eu, Y, Tb, La, Dy, Ce, Pr, Gd	Phosphors	Increased use of energy efficient fluresent lights, also growing demand for LCDs, PDPs
La, Ce, Pr, Nd	Fluid cracking catalysts	Increased use of catalysts in processing heavy crude and tar sands
Ce, La, Nd	Auto catalysts	Tighter NOx and Sox standards – offset to some extent by increased use of zirconia in the wash coat
Ce, La, Nd	Polishing powders	Increased demand for mechano- chemical polishing of electronic components, and some types of LCd screens
La,Ce, Pr, Nd,Y	Ceramics	Growth in use of multi-layer ceramic capacitors, use of PSZ in advanced applications

Notes: HEV = Hybrid Electric Vehicle, EV = Electric Vehicle

HDD = Hard Disc Drive; ODD = Optical Disc Drive; VCM = Voice Coul Motor; LCD = Liquid Crystal Display; CRT = Cathode Ray Tube; PSZ = Partially Stabilised Zirconia returned to 8-11% in late 2010 (Kingsnorth D, 2010).

Table 8 reveals a number features of rare earth demand in 2008. The Chinese demand constitutes about 67 percent of global demand followed by Japan and North East Asian countries and USA. Magnets, metal alloys and catalysts were in high demand compare other applications and these are highly used in industrial applications of hybrid vehicles, electronic vehicles, hard disc drive, optical disc drive, voice coul motor, liquid crystal display, cathode ray tubes and petroleum refining industries. The demand for magnets was equal to21 percent followed by 20 percent demand for catalysts and about 18 percent demand for metal alloys. Magnets phosphors and metal alloys are the largest end uses for rare earths by value.

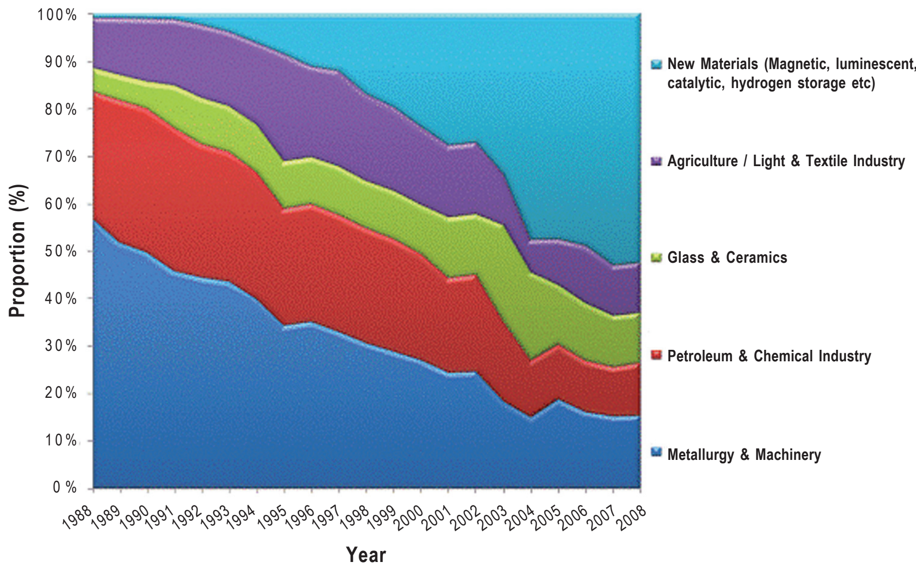
In China and globally, REEs have experienced fast growth in advanced technology sectors including luminescent (phosphors), magnetic, catalytic and hydrogen storage technologies. The demand by clean energy technology sectors is largely a result of the ramp-up of clean energy technology manufacturing and use by the United States, other Organization for Economic Co-operation and Development (OECD) nations and China. Magnets dominated REE usage by weight in 2008, with catalysts claiming the second-highest usage and metal alloys accounting for the third highest (Kingsnorth and Chegwidden 2010). REE consumption has grown most rapidly in China. China's 2005 REO demand exceeded half of global demand for the first time and more than tripled in absolute terms between 2000 and 2008 (Chen Z 2010).

Table 8: Global rare earths demand in 2008 in tonnes and by value

Application	China	Japan & NE Asia	USA	Others	Total	Volume %	Total value %
Catalysts	9000	3000	9500	3500	25000	20%	5%
Glass	7500	2000	1000	1500	12000	10%	2%
Polishing	8000	4500	1000	1500	15000	12%	4%
Metal Alloys	15500	4500	1250	1000	22500	18%	14%
Magnets	21000	3500	750	1000	26250	21%	37%
Phosphors	5500	2500	500	500	9000	7%	31%
Ceramics	2500	2500	1250	750	7000	6%	4%
Other	5000	2000	250	250	7500	6%	3%
Total	74000	24500	15500	10000	124000	100%	US$6.75b

Source: Roskill, IMCOA, 2010 and author's calculations

Figure 6: China: consumption structure of rare earths from 1988 to 2008



Source: The Chinese Society of Rare Earth, Nomura International Hong Kong

In China, rare earths were mainly consumed in traditional areas of metallurgy, machinery, petroleum industry, chemical industry, light industry, textile industry, agriculture, in new materials like magnets, phosphors, hydrogen storage, catalysts for automobile exhaust and polishing powder. There was a dramatic change in the consumption structure, the consumption of rare earths in new materials increased very fast since 2004. In 1988, the consumption of rare earths in new materials was only 1%, but in 2007, it was 53%. In 2008, it was claimed that about 60% of rare earths was consumed in new materials in China. China's consumption of rare earth elements is also expected to increase dramatically as more and more foreign companies move their production sites to China to take advantage of the lower cost of rare earths and therefore reduce their overall production costs. This is part of China's larger strategy to maintain a tight hold on the industry.

In 2009, China produced about 7,200 tonnes of rare earth fluorescent powder, ranking the world Top. The three-band fluorescent lamp industry consumed 75% of rare earth luminescent materials as the major application area of luminescent materials. The three-band fluorescent lamp with the advantages of energy saving and long lifespan will gradually replace the incandescent lamp. In 2009, China produced over 3 billion three-band fluorescent lamps. If 80% of the incandescent lamps are replaced, 3 billion three-band fluorescent lamps will be needed every year. Hence, the annual demand for fluorescent powder is about 10,000 tonnes. By 2015, the total demand for three-band fluorescent powder will be about 60,000 tonnes.

In 2008, the consumption of rare earth polishing powder in the world was 20,000 tonnes, including 8,000 tonnes for LCD. In recent years, with the booming of the LCD industry, high-performance polishing powder has achieved fast development. Presently, the production capacity of rare earth polishing powder in China exceeded 150 million tonnes. It is forecast that China's annual production capacity of rare earth polishing powder will reach 20,000 tonnes in 2010. In 2009, the rare earth consumed in Chinese petrochemical catalytic cracking sector was about 7,500 tonnes. It is forecast that China's crude oil processing volume will maintain over 500 million tonnes in 2015-2020. The rare earth for FCC catalysts will exceed 10,000 tonnes. Besides, with the considerable growth of the demand for rare earth catalytic materials in the fields of fuel cell, water pollution control, air purification, etc., China's total demand for rare earth catalytic materials will exceed 17,000 tonnes in 2015-2020 (China Research and Intelligence, 2010).

Because of their ability to readily give up and accept electrons, the rare earth elements have become uniquely indispensable in many electronic, optical, magnetic and catalytic applications. From iPods to catalytic converters, from wind power generators to computer disc drives and hybrid electric vehicles - Rare Earth applications are ubiquitous and critical for the overall economic well being of any country. China is most interested in supplying its domestic needs first. Because there's such a wide range of products that use rare earth elements, its domestic REE-product industry is growing rapidly. China's doing everything it can to bring new investment into the country and develop new industries to use this material; for example, it will sell REEs to local industries at a much cheaper price than it sells the same material to sources outside of China. In that sense, it's trying to do everything it can to increase the country's internal need.

The data released by Lynas Corp shows that global supplies of rare-earth elements will fall short of demand, which will grow by an average of 9 percent annually to the year 2014. The largest growth rate will be in demand for magnets

Table 9: Global rare earths demand in tonnes 2010 & 2014

Application	Demand tonnes	Volume (%)	Value (%)	Demand tonnes 2014	Growth rate p.a. (%)	Value (%)
Magnets	35000	26%	38%	55100	12%	42%
Battery Alloys	18600	14%	10%	32500	15%	13%
Metallurgy ex battery	11700	9%	7%	12700	2%	5%
Auto Catalysts	9000	7%	5%	12200	8%	4%
Fluid cracking Catalysts	21300	16%	11%	24900	4%	9%
Polishing	19100	14%	10%	28000	10%	10%
Glass	7800	6%	4%	7800	0%	3%
Phosphors	7900	6%	10%	10800	8%	10%
Others	5700	4%	5%	6100	6%	5%
Total	136 100	100%	US$7.8 bln	190100	9%	11.2 b

Source: Lynas Corp, 2010

and battery alloys which would be 12 percent and 15 percent respectively by 2014. Total demand for the group of elements, used in products such as industrial magnets, flat-screen TVs, and military weapons systems, is likely to grow to 190,100 metric tonnes in 2014, from 136,100 tonnes in 2010. For example, permanent magnet demand is expected to grow by 10%-16% per year through 2014. Demand for rare earths in auto catalysts and petroleum cracking catalysts is expected to increase between 6% and 8% each year over the same period. Demand increases are also expected for rare earths in flat panel displays, hybrid vehicle engines, and defense and medical applications. The global demand in value terms will grow from US$7.8 billion in 2010 to 11.2 billion in 2014.

3.1 Consumption and Industrial Applications

The rare earth elements as a group have magnetic, chemical and spectroscopic properties that have led to their application in wide range of end-uses. These metals are utilized in a broad range of manufacturing areas that include materials, machineries and electronics. These are the raw materials for high value added products. Although often needed only in small quantities, these metals are increasingly essential to the development of technologically sophisticated products. They play a critical role in the development of innovative 'environmental technologies' to boost energy efficiency and reduce greenhouse gas emissions. Demand for rare earths, often referred to as "industrial vitamins," will only increase. Several clean energy technologies-including wind turbines, electric vehicles, photovoltaic cells and fluorescent lighting-use materials at risk of supply disruptions in the short term. Those risks will generally decrease in the medium and long term.

Clean energy technologies currently constitute about 20 percent of global consumption of critical materials. As clean energy technologies are deployed more widely in the decades ahead, their share of global consumption of critical materials will likely grow. Green energy technology is expected to become the largest consumer of rare earth elements in the future. In 2009 China was the world's top investor in clean energy technology at over $34 billion. Since 2005, the country's wind generation capacity has increased by more than 100% a year. The government's renewable energy policy aims to procure 15% of the country's energy from non-carbon sources by 2020, twice the proportion of 2005. In 2009, China became the largest manufacturer of wind turbines in the world, with 17 of its 40 turbine manufacturers being state-owned, 12 private Chinese firms, and 11 joint ventures or foreign owned (The Pew Charitable Trusts, 2010).

The country has doubled its installed wind power capacity every year since 2006 and is now the world's largest producer of wind turbine. By 2020, China is expected to boost its wind power capacity to 100 Giga watts (GW) or more, up from 12 GW in 2008. The annual growth rate will be about 20 percent (China Daily, 2009). Similarly, the Global Wind Energy Council (GWEC) forecasts that the global installed wind capacity in 2011 will climb to 409 GW, up from 158.5 GW at the end of 2009. The additional 250.5 GW will require 167,000 tonnes of REMs. China has announced that in the next ten years it will "construct some 133 giga watts of wind turbine generated electricity." Around two tonnes of neodymium is needed for each wind turbine and NdFeB magnets are a critical component for some models of the new generation wind-powered turbines.

Hydrogen-fuel based cars, for example, require platinum-based catalysts; electric-hybrid cars need lithium batteries; and rhenium super alloys are an indispensable input for modern aircraft production. In 2009, China produced 19,000 tonnes of rare earth hydrogen storage materials. They consumed 7,900 tonnes of rare earth, accounting for 11% of the total rare earth consumption. Since November 2009, China has become the largest auto market in the world. China's automobile industry has been in rapid development since the early 1990s. In 2009, China produced 13.79 million units of automobile. The Chinese are also investing big in electric cars, hybrid cars and the underlying industry. The Chinese are already one of the largest producers of lithium-ion batteries and as the main application in car batteries; lithium-ion demand is growing fast. Rare earth hydrogen storage materials are major raw materials for the production of nickel-hydrogen battery. As nickel-hydrogen battery shows positive development prospects in the electric tool and electric vehicle sectors, it is forecast that China's hybrid electric vehicle market will acquire explosive growth after 2010 and the annual growth rate will reach 12% (China Research and Intelligence, 2010).

According to Reuters, global sales of hybrid electric cars are forecast to reach 3 million units in 2015 with a total REM requirement of 33,000 tonnes. One of the largest growth areas is expected to be the production of hybrid vehicles, such as the Toyota Prius. Each hybrid car contains 16 kg of rare earths, predominantly in its batteries and electric motors. It is estimated that the motor in the average Prius hybrid uses about 193 grams, or about 7 ounces, of neodymium and 24 grams of dysprosium, while the fully electric Nissan Leaf uses about 421 grams of neodymium and 56 grams of dysprosium.

The Chinese government, determined to become a world leader in green technology, and plans to invest billions of dollars over the next few years to develop electric and hybrid vehicles. A group of 16 big state-owned companies had already agreed to form an alliance to do research and development, and creates standards for electric and hybrid vehicles. The plan aims to put more than a million electric and hybrid vehicles on the road over the next few years in what is already the world's biggest and fastest growing auto market. The announcement, analysts say, is another example of how China seeks to marshal resources and tackle industries and new markets. The plan also underlines what China describes as its growing commitment to combating pollution and reducing carbon emissions.

The Chinese government announced it will spend $14.7 billion through 2020 on alternative drive train vehicles, with the bulk of the money going towards all-electric vehicles. Pike Research, projects that between 2010 and 2015, China will have 1.85 million hybrids and EVs sold, with 1 million EVs on the road. In the U.S. more than 2.3 million hybrids will be sold during that time, and 840,000

Table 10: Annual sales of Toyota prius worldwide and by region (in thousands)

Year	World	Japan	North America	U.S.	Europe	Other
1997	0.3	0.3				
1998	17.7	17.7				
1999	15.2	15.2				
2000	19.0	12.5	5.8	5.6	0.7	0.01
2001	29.5	11.0	16.0	15.6	2.3	0.2
2002	28.1	6.7	20.3	20.1	0.8	0.2
2003	43.2	17.0	24.9	24.6	0.9	0.4
2004	125.7	59.8	55.9	54.0	8.1	1.9
2005	175.2	43.7	109.9	107.9	18.8	2.9
2006	185.6	48.6	109.0	107.0	22.8	5.3
2007	281.3	58.3	183.8	181.2	32.2	7.0
2008	285.7	73.1	163.3	158.6	41.5	7.7
2009	404.2	208.9	144.3	139.7	42.6	8.4
Jan-Sept2010	401.3	254.2	105.9	103.3	35.5	5.8
Total	2,011	826.9	939.1	917.5	206.1	39.7

Source: Toyota Corporation

plug-in and all-electric vehicles. At the 2010 Beijing Motor Show, more than 20 electric vehicles were on display, most of which came from native automakers. As of May 2010, at least 10 all-electric models have been reported to be on track for volume-production. The first mass produced plug-in hybrid car (BYD F3DM), all-electric minivan (Luxgen 7 MPV EV) and all-electric long-range bus (500 km range Zonda Bus) are Chinese (Gartner John , 2010).

Many of the rare earth metals are also used in sectors such as semi-conductors. The semiconductor industry is dominated by Chinese Taipei, South Korea, United States, and Japan. The role of the semi-conductor industry is one of a technology enabler: the semiconductor industry is widely recognized as a key driver for economic growth throughout the electronics value chain. The semiconductor market represented USD213 billion in 2004 and the industry was one enabling factor in the generation of USD1200 billion in electronic systems business and USD 5000 billion in services, representing close to 10% of world GDP that year. The semi-conductor industry is also a high-growth industry, experiencing 13% growth on average per annum over the last 20 years (Korinek, J. and J. Kim, 2010).

There are numerous examples that point to China's anticipated increase in rare earth consumption. For example, at the end of July 2008, China had 600 million cell phone users. Less than one year later, by the end of March 2009, China had 670 million cell phone users (Xinhuanet, 2009). China's mobile phone industry has high growth rate, raising its share on the global mobile phone market. During 2007, 600 million mobile phones were made in China which accounted for over 50% of the global production. The domestic sales of cell phone made a breakthrough of 100 million in China in 2006. In 2007, the domestic sales of cell phone in china were 190 million, increased by 74%. For year of 2007, sales volume had reached about 23 billion USD, increased by 17% as compared with 2006. The export volume of China's cell phones added up to a record high of 385 million in 2006, increased by 69.3% as compared with 2005. In 2007, this figure reached 483 million, increased by 125.45% as compared with 2006. As far as 2006, the export volume had reached 31.214 billion USD, increased by 52.47% as compared with 2005. The export volume of 2007 was 35.6 billion dollars, increased by 114.01% as compared with 2006 (Pr-inside, 2008).

The rare earth metals are critical for the production of smart bombs, laser targeting systems in tanks, and silent technology used in helicopter blades. The rare earth metals of most concern to the military and the Defense Department are neodymium, samarium, and yttrium. Neodymium is an essential metal in a magnetic alloy which was developed separately by General Motors in Detroit and Sumitomo Special Metals Co. in Japan in the 1980s. Now it is used in speaker magnets, disk drives, motors, and, more importantly, in missile weapons systems like the Joint Direct Attack Munition (JDAM). Neodymium is also used in magnets for hybrid-electric motors being developed to cut fuel use in U.S. Navy destroyers. Samarium is needed for magnets being used by Lockheed Martin Corp.'s SPY-1 radar systems on Aegis destroyers. China is the only supplier in the world for yttrium which is needed for the laser gun sights in the General Dynamics Abrams tank (RC Zar, 2010).

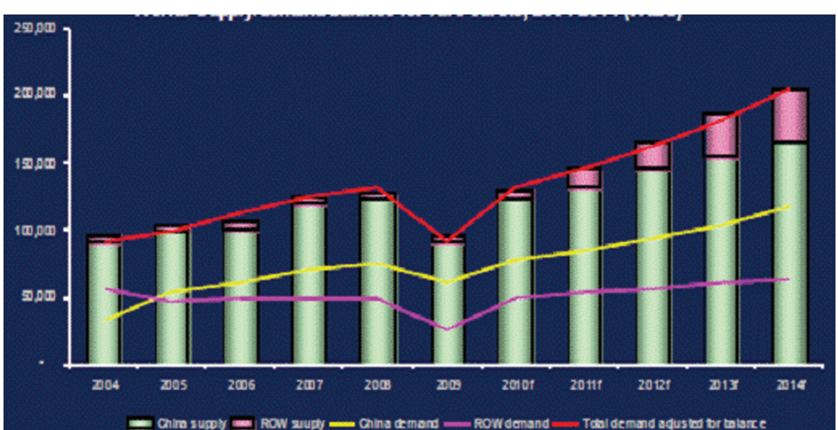
The DDG-51 Hybrid Electric Drive Ship Program uses neodymium iron boron magnets which help power the guided destroyers. Night vision goggles and rangefinder equipment use rubidium to increase accuracy and visibility. The Aegis Spy-1 Radar uses the samarium cobalt magnet to withstand stresses as it has the highest temperature rating of any rare earth magnet. Even with a threefold increase in REE demand over the past ten years, demand is expected to increase even further, by anywhere from 8 to 790 percent over the next five years (Kientz R, 2010).

Rare earth elements are needed for China's expansion of its own military needs (aircraft carriers, nuclear-powered submarines, and ballistic missiles). Home-grown production needs will further cut exports already reduced to crippling levels. Not surprisingly, these measures have raised real concerns outside of China regarding the future availability of the refined products created from REMs. The rare earth supply chain for the sleep paralyzed Western defense industries is now being held hostage by the Chinese who want to keep the rare earth metals for their own rapidly expanding markets.

4. Global Demand-Supply Interface by 2014

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. 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. While new or reopened mines outside of china are expected to increase global production, resulting in an over all surplus, shortfalls are expected in certain elements, particularly in Neodymium and Europium, and the heavy rare earths Terbium, Dysprosium, and Yttrium. Demand for rare-earth metals is likely to increase between 10 percent and 20 percent each year, analysts say, thanks to growing demand for elements like neodymium, which is used in making hybrid electric vehicles and generators for wind turbines.

Figure 7: World supply/demand balance for rare earths, 2004-2014 (t REO)



Source: Roskill, IMCOA, CREIC, Neo Materials Technology

World demand for rare earth elements are estimated at 134,000 tonnes per year, with global production around 124,000 tonnes annually. The difference is covered by above-ground stocks or inventories. World demand is projected to rise to 180,000 tonnes annually by 2012, while it is unlikely that new mine output will close the gap in the short term. By 2014, global demand for rare earth elements may exceed 200,000 tonnes per year. China's output may reach 160,000 tonnes per year (up from 130,000 tonnes in 2008) in 2014 (Marc Humphries, 2010). An additional capacity shortfall of 40,000 tonnes per year may occur. New production from ROW could meet increased demand to 2014-but will the "balance" be right? This brings spotlight on the absolute necessity for other countries get to full-scale rare earth production sufficient to meet global demand and to deploy a complete mining-to-magnets manufacturing supply chain as soon as possible outside China.

The above table shows that the global demand REO in 2014 will be around 180-190,000t a little less than the global supply of 190-210,000t. However some individual oxides will be in short of supply particularly the heavy rare earths like Terbium, Dysprosium and Yttrium, their proportion to the total demand is comparatively less, although their importance to some the applications are very important. Since supply of these elements is going to be so tight, the prices for Tb, Dy and Y will remain strong. Neodymium iron boron permanent magnet is the leading product among rare earth magnetic materials. With the development of new application areas, it is forecast that the global neodymium iron boron industry will maintain the growth rate of 15% in the coming five years, whereas Chinese neodymium iron

Table 11: Forecast supply and demand for selected rare earths in 2014

Rare Earth Oxide	Demand @ tpa REO	%	Supply @ tpa REO	%
Lanthanum	50-55000t	28.4%	52-57000t	26.9%
Cerium	60-65000t	36.5%	80-85000t	40.2%
Neodymium	34900t	19.4%	33000t	16.3%
Terbium	400-500t	0.3%	400-500t	0.2%
Dysprosium	1900-2300t	1.1%	1800-2000t	0.9%
Yttrium	10-14000t	6.7%	9-13000t	5.7%
Total	180-190,000t	100%	190-210,000t	100%

IMCOA, 2009

boron industry will maintain the growth rate of 20% and the global demand for Neodymium will outstrip the global supply with a thousand tonnes marginal difference in 2014.

The rare earth content of NdFeB magnets varies by manufacturer and application. An electric drive vehicle may use up to a kilogram (kg) of Nd, while each wind turbine may contain several hundred kilograms. Rare earth PMs may also incorporate praseodymium (Pr), which can be substituted for or combined with Nd. Dysprosium (Dy) or terbium (Tb) may also be added to the inter metallic alloy to increase the temperature at which the magnet can operate before losing its magnetic. The cumulative demand for Nd and other REEs in these clean energy technologies is a function of both the material content per individual product and the total number of products sold. Therefore, aggressive technology penetration rates envisioned under many worldwide clean energy strategies could significantly increase global demand for Nd, Pr, Dy and Tb (London I.M. 2010).

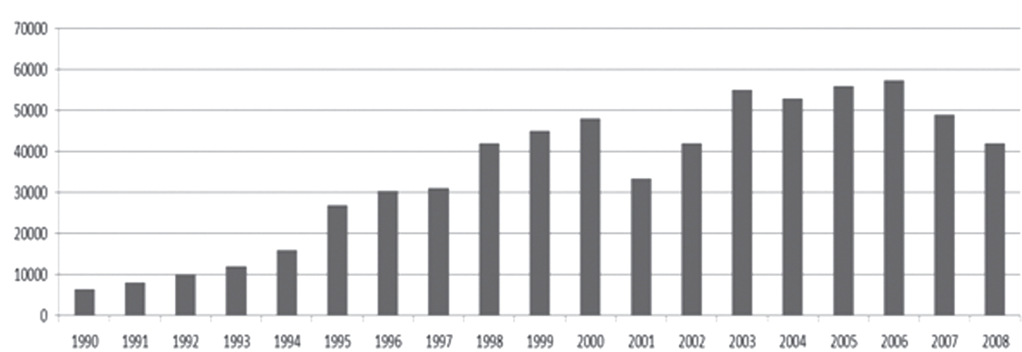
Chinese economy will continue to grow or near double digit rates for the foreseeable future and disposable income for automobiles, personal electronics, etc driving significant internal RE demand. China is already the largest auto market and will produce 500,000 electric vehicles in 2011 and, leads in wind power generation. So to meet this increasing demand for REEs, China has employed a number of controls to date such as, production limits, export quotas, export tariffs, stockpiling, closing of separation plants and even literally blowing up illegal mines (REITA, 2011).

5. International Trade in Rare Earth Elements

The section examines the trade in rare earths and importance and Chinese export restrictions. Rare earths were traded freely and at a discounted price on the global market before the mid-2000s. Since 2005, however, China-the world's leading RE producer- gradually tightened export restrictions on rare earth oxide (REO).China has become the largest country of rare-earth deposits, producer, consumer and exporter and, there is a growing demand-supply gap because of a dearth of any other major supplying nation. China's imposition of export quotas on several rare earth metals, on the grounds that it needs the higher quantities for its clean energy and high-tech sectors, is squeezing an already starved market. China wants rare-earths companies to add value by making more technologically advanced products rather than exporting the raw material. While it has cut foreign sale quotas of the minerals, there are no restrictions on exports of finished products.

Figure 8, shows the gross volume in tonnes of exports of REEs which grew from 6500 tonnes in 1990 to 57,400 tonnes in 2006 and declined to 49,000 tones in 2007, and 42,000 tonnes in 2008, respectively. It indicates that the

Figure 8: Gross volume of exports from 1979 to 2008



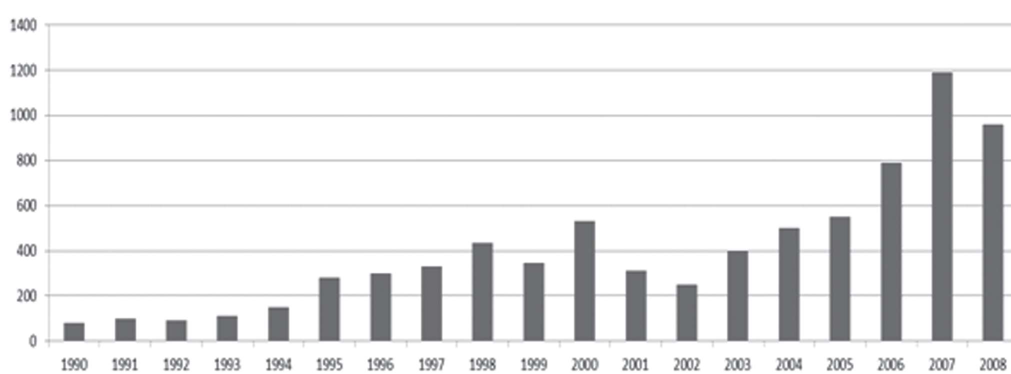
Source: Reitausa.org, 2010

gross volume of exports had been in a growth trend until 2006, and then declined in 2007 and 2008 mainly because of the global financial crisis which had very badly affected the major rare earth consuming countries such as U.S, Japan and Europe. Although, China began to control exports of rare earth products with quota administration since 1999, the total exports did not decrease generally, until 2007 except a decline in 2001.

Figure 9, explains the gross value of exports in million U.S dollar from 1990 to 2008. The total exports in value terms also grew outstandingly, reaching to peak level at about, USD 1.2 billion, in 2007, while the export value was just 80 million in 1990. From 1998 to 2005, the annual average of gross value for exports was about USD 420 million, and the annual average of gross volume for exports was about 46,946.63 tonnes, namely 8.98 USD/Kg. In 2007, the price was about 24 USD/Kg, which exuberantly increased in the last months of 2010 to USD 60/kg, and above.

Rare earth prices remained static for decades due to plentiful supplies, lulling the high-tech industry into a false sense of security. After Beijing cut export quotas by 70 percent for the second half of 2010, prices of some rare earths has gone up, as much as 850 percent. Due to the extensive management of rare earth resource exploitation and scattered distribution of the rare earth industry, many foreign importers used the opportunity to force down the price. When the global demand for rare earth materials increases year by year, China exported 6,100 tonnes of medium-end and low-end rare earth products in 1990; the average price was 13,600 USD/ton. In 2009, China exported 36,100 tonnes of rare earth smelting and separation products,

Figure 9: Gross value of exports from 1979 to 2008



Source: Reitausa.org, 2010

rising by 16.67% YOY. The export value amounted to USD 310 million and the average price was only 8,959 USD/ton (China Research and Intelligence, 2010). Low prices for rare earth elements from China, contributed to cuts at the Mountain Pass mine in the United States, one of the main source of supply for many years, before it closed in 2002. They also discouraged most entrants to the industry until the last two years, when prices began to climb because of strong demand.

The data from UNComtrade data base shows that in 2009, a total of 43 countries reported exports of rare earths. The entire exports were valued at 427.75 million US$ and 61232.32 tonnes of rare earths were exported by the 43 countries. The details of the top ten exporting countries by volume in tonnes and value in million US$ in 2009 have shown in table 13. China including Hong Kong and Macao exported about 39 thousand tonnes with a share of more than 64 percent in 2009 followed by Japan exported 5904 tonnes with a share of 9.64 percent and Russia exported around 4619 tonnes in 2009. Estonia and U.S were in the fourth and fifth position respectively in terms export volumes. Analysis of exports in value terms shows that China including Hong Kong and Macao accounted for slightly more than 50% of the share of rare earths exports by value. China was followed by Japan with a share of around 23% and Germany with a share of around 5%. China therefore continued to be the dominant exporter of rare earths both in terms of volume and by value and China for all purposes continues to be an

Table 12: Top ten exporters of rare earths by volume and value in 2009 (Million US$)

Reporter	Exp Qty (Tonnes)	% Share by Qty Tonnes	Country	Export Value	% Exports by Value
China+HK+Macao	39201.67	64.02	China+HK+Macao	240.97	50.97
Japan	5904.61	9.64	Japan	107.35	22.71
Russia Federation	4619.61	7.54	Germany	22.44	4.75
Estonia	2678.85	4.37	USA	15.36	3.25
USA	1332.50	2.18	France	14.02	2.96
France	1246.13	2.04	Norway	13.64	2.89
Austria	2578.62	4.21	Italy	11.80	2.50
Kazakhstan	1053.32	1.72	Estonia	10.38	2.20
Germany	657.55	1.07	Russia Federation	9.92	2.10
United Kingdom	555.85	0.91	United Kingdom	6.62	1.40

Source: UN Comtrade data base

effective monopolistic supplier of rare earths.

The details of the top ten importing countries by quantity and value in million US$ in 2009 are placed at table 13. In 2009 a total quantity of 69638.07 tonnes of rare earths were imported by a total of 91 countries. United Sates was the top importers of rare earths in terms of quantity with Japan and Germany occupying second and third positions. United Sates accounted for 23.57% of the world's share of rare earth imports by quantity which was equal to 16416 tonnes. Japan imported 13490 tonnes and accounted 19.37 percent of the total imports. Germany imported 8000 tonnes followed by France importing 6985 tonnes. The entire imports were valued at 608.48 million US$ 69638.07 tonnes of rare earths were imported by the 91 countries. Japan was the largest importer of rare earths in 2009 by value terms, followed by USA, Thailand and Germany respectively. Japan accounted for 25% of the world's rare earth imports.

The difference in quantity between total rare earths exported and imported amounts to 8405 tonnes. This difference is very large and cannot be explained away as statistical error. One possible reason could be the belief that rare earths are smuggled from China. Illicit exports are typically in the form of REE mixed with steel and exported as steel composites. The process is reversed in the country recovering the REE's (British Geological Survey, 2010). In case the smuggled REE's are accounted for at the receiving country either deliberately or inadvertently, then some portion of this discrepancy of around 8000 tonnes could be partially explained.

Table 13: Top ten importers of rare earths by quantity and by value in 2009

Reporter	Trade Qty Tonnes	% Imports Qty	Reporter	Value US $ Million	% Imports by Value
USA	16416.371	23.57	Japan	152.12	25.00
Japan	13490.908	19.37	USA	115.03	18.90
Germany	8218.155	11.80	Thailand	67.51	11.09
France	6985.406	10.03	Germany	51.76	8.51
Austria	4456.6	6.40	France	40.57	6.67
Estonia	4124.822	5.92	China+HK	38.19	6.28
China+HK	4039.644	5.80	S. Korea	24.90	4.09
S. Korea	2632.811	3.78	Austria	21.62	3.55
Brazil	1314.483	1.89	Malaysia	11.29	1.86
Russia	1195.176	1.72	Italy	10.00	1.64

Source: UN Comtrade data base

5.1 China's Exports and Imports

In 2009, China exported a total of 38573.02 tonnes but the total of all the rare earths exported to 46 countries added up to 40982.13 tonnes. The quantity and the percentage share of the top 10 customers of China is indicated in the below table. United States was the largest importer of Chinese rare earths by quantity and imported around 14700 tonnes of rare earths, these accounted for 38% of the Chinese exports. Japan imported around 10500 tonnes and its share amounted to 27%. North America (mainly the United States) and Asia each account for around 36% of the Chinese rare earth exports by quantity. Around 24% is exported to Europe.

China's exports were valued at 239.37 million US$ in 2009. The details of the top ten customers of China in million US$ in 2009 are depicted in table 15. The largest importer of rare earths from China was Japan with around 76 million US $, followed by the United Sates with around 67 million US$. Japan and the United Sates accounted for nearly 61% of the exports of rare earths from China. About 30% of the exports are accounted by Hong Kong, France, Germany, South Korea and Netherlands.

5.2 Rare Earth Export Control by China

Several objectives motivate implementing export restrictions on strategic raw materials. In some cases, these can be understood as a response to market imperfections. The question remains, however, whether export

Table 14: China's top 10 customers by quantity and value in 2009

Partner	Qty in Tonnes	% Share	Partner	Trade Value million US$	% Share
USA	14764.6	38.28	Japan	76.66	32.29
Japan	10519.71	27.27	USA	67.48	28.43
France	4391.593	11.39	Hong Kong	21.75	9.16
Hong Kong	2658.938	6.89	France	20.45	8.61
Italy	1509.58	3.91	Germany	15.58	6.56
Austria	1465.062	3.80	Rep. of Korea	8.40	3.54
Germany	1034.877	2.68	Netherlands	7.60	3.20
Australia	979.646	2.54	Italy	5.51	2.32
U.K	594.76	1.54	U.Kingdom	2.67	1.12
Netherlands	494.23	1.28	Other Asia	2.65	1.12

Source: UN Comtrade data base

restrictions are the most effective tool to achieve the desired outcomes. As many of these raw materials are produced in a limited number of countries, export restrictions that are imposed in one country may motivate other countries to follow if importers massively move to buy their raw materials. The restrictions imposed by the first country then lose their effectiveness. This can in principle lead to a situation of competitive policy practices – and of higher and higher export taxes.

Many export restrictions are put into place for environmental reasons or to preserve natural resources. In other cases, export restrictions are imposed in order to encourage supply of raw materials to domestic producers of downstream semi-processed goods. On 23rd September 2010, exports of rare earth elements (REEs) from China to Japan apparently stopped due to a dispute over maritime boundaries. This use of economic leverage to influence policy raised concerns about the impact of China's strategic hold on these precious metals. REEs have long been considered the "enhancers" of global products and are used to manufacture defense and commercial high-technology items. Their availability today, however, could be jeopardized since China controls over 97 percent of their production and refinement (CSIS, 2010).

Until recently, the global dependency on China for rare earths was a well-kept secret. But word started to spread fast after Beijing cut export quotas by 70 per cent for the second half of 2010, sending prices of some oxides - the purified form of rare earth elements - up as much as 850 per cent. The need for alternative supplies from outside China suddenly became obvious. The Chinese dominance has raised concerns within industry regarding prices and lead times for critical defense hardware. With demand increasing, the problem of purchasing and shipping REEs for products is concurrently growing.

In the first week of July 2010, China announced a number of changes affecting the rare earths sector. These changes included a reduction in the total amount of rare earths that may be exported from China besides other measures (Gareth P Hatch, 2010). China has passed the "2009-2015 Rare Earth Industry Development Plan". According to the document, in the next six years, no new rare earth mining permit will be approved. The separation of newly formed rare earth smelting companies will be strictly reviewed. China has officially cited environmental issues as one of the key factors for its recent regulation on the industry, but non-environmental motives have also been imputed to China's rare earth policy. According to The Economist, "Slashing their exports of rare-earth metals...is all about moving Chinese manufacturers up the supply chain, so they can sell valuable finished goods to the world rather than lowly raw materials" (The Economist, 2010). Foreign companies also taking part in this business of value additions. One possible example is the division of General Motors which deals with miniaturized magnet research, which shut down its US office and moved its entire staff to China in 2006. A news release in December 2010 announced that one Japanese company had moved its magnet-producing industry to China to take advantage of cheaper prices and more certain supplies. This is what the Chinese are trying to do; it's just good business.

5.3 Chinese Rare Earth Export Quotas

China practices the quota license administration on the export of rare earth products since 1998 citing the need for environmental management and resource conservation. In recent years, Chinese government cuts down the volume of export enterprises, export quotas and annual exploitation volume of rare earth ores. The Beijing government argues that its curbs are for environmental reasons and to guarantee supplies to Chinese clean-energy firms it is trying to promote internationally. But it has also said its dominance as a producer should give it more control over global prices. China's Commerce Ministry allotted 14,446 tonnes of quotas to 31 companies, which was 11.4 percent less than the 16,304 tonnes it allocated to 22 companies in the first half of 2010 quotas a year ago. While industrial users of the minerals in industrialized countries face tighter supplies and higher prices, China's export curbs have created opportunities to open mines or revive dormant production in Canada, Australia and the United States. China cut its export quotas for rare earths by 35 percent in the first round of permits for 2011, threatening to extend a global shortage of the minerals needed for smart phones, hybrid cars and guided missiles.

Export quotas have been falling continuously since 2005. The plan to restrict rare earth exports were reportedly commenced in 2005-06.The aim was to restrict rare earth production in China to around 80000 tonnes (People's Daily, 2009). But the decline between 2008 and 2009 was quite drastic. There is wide-scale concern that China may soon restrict or even ban the export of particular rare earths. There has been much speculation about China's future policy on rare earths. However it is quite clear that China has been systematically and methodically

Table 15: Chinese export quota and demand from rest of the world (ROW): 2005–2010. (tonnes REO)

Year	Domestic Companies	Foreign Companies	Total	Change	ROW Demand
2005	48,048t	17,657t	65,609t	-	46,000t
2006	45,752t	16,069t	61,821t	-6%	50,000t
2007	43574t	16,069t	59,643t	-4%	50,000t
2008	40,987t	15,834t	56,939t	-5.5%	50,000t
2009	33,300t	16845t	50,145t	-12%	25,000t
2010	16304t for 1st half	5978t for 1st half 2010	30,258t	-40%	48,000t

Sources: Kingsnorth, 2010, Hatch 2010

reducing quotas (Kara Hudai et all, 2010).

In 2010, it cuts down the export quota to 30,258 tonnes, including 22,512 tonnes for domestic enterprises and 7,746 tonnes for foreign enterprises. The data shows that the export quotas for 2010 have been reduced by 40% compared with 2009. This is a far greater reduction than forecast that the reductions would be of the order of 6-7% in the coming years. The impact of the change will have far reaching consequences, particularly outside of China. Chinese rare earth export quotas for 2010 are now significantly less than rest of the world (ROW) consumption having a gap of 18,000 tonnes. The quota for 2010 was 30,258t REO compared with ROW demand of 50000t. Total ROW production capacity is currently 10-12,000t at best, which indicates a shortfall of 10-15,000 t at least in 2010. China announced in December 2010 that it will cut its export quotas for rare-earth minerals by more than 11 percent in the first half of 2011, further shrinking supplies of metals needed to make a range of high-tech products. The move comes on the heels of a 40 percent slash in the export quota on such minerals in 2010. The export restraints have inflamed trade ties with the United States, European Union and Japan in particular (Tom Miles, 2011).

But a further reduction in quotas for 2011 issued late 2010 would be consistent with recent Chinese policy. The Chinese government typically makes a main allocation of quotas near the end of the year, followed by a smaller, supplemental allocation in the summer. But the supplemental allocation issued last July was down 72 percent from a year earlier, as Chinese officials called for making sure that their own industries had ample supplies and that heavily polluting illegal mines should be closed. According to the revised "2009 to 2015 Development Plan of the Rare Earth Industry" prepared by the MIIT, the annual REO export level from China will be restricted below 35 kt between 2009 and 2015. If the aforementioned targets can be strictly enforced, the existing stockpiles outside China are expected to be exhausted over time, which will further strengthen China's competitiveness. With the current quota system, China does not distinguish between the individual rare earth oxides but limits the total tonnage of exports across the board. That has led to Chinese companies exporting as much as possible of the high-value heavy rare earths like dysprosium, instead of low-value light rare earths like cerium.

5.4 Other Export Restrictions

Export restrictions are applied to many of the rare earth metals originating from China. Export restrictions come in a variety of forms. They include quantitative restrictions (quotas), export taxes, duties and charges and mandatory minimum export prices. In so far as they can affect export volumes, the reduction of VAT rebates as well as stringent export licensing requirements may also be considered forms of export restrictions. As discussed before China has announced several cuts in export quotas of rare earth metals and raised export taxes to as high as 25 percent, from zero to 15 percent previously (IER , 2011).

Export Taxes on Rare Earth Exports from China

In late 2006, the Chinese government introduced a tax on rare earth exports of 10%, which was increased to 15% on selected rare earths in 2007. Effective from 1 January 2008, export taxes were raised to the following levels

China has added a 15- to 25-percent export duty on rare earth exports and 41 rare earth products have been listed in the category of prohibited processing trade. Rare earth exporters, including

Table 16: Chinese export taxes on rare earths

Materials	Tax (%)
Europium, terbium, dysprosium, yttrium as oxides, carbonates or chlorides	25%
All other rare earth oxides, carbonates and chlorides	15%
Neodymium metal	15%
All other rare earth metals	25%
Ferro rare earth alloys	20%

10 foreign companies, are facing stricter supervision on their qualification. The move is an increase from the 15 percent temporary export tax on neodymium, used in batteries for hybrid cars including Toyota Motor Corp.'s Prius. Lanthanum, also used in hybrids, and cerium, used for polishing semiconductors, were not taxed in 2010, and will be taxed at 25 percent in 2011, the Chinese ministry reported in December 2010. China's export tax for dysprosium will be kept at 25 percent next year, and the same with terbium, according to the statement of China's finance ministry.

In 2007, China withdrew the refund of VAT (16%) on exports of unimproved rare earths, while the refund on higher value-added exports such as magnets and phosphors remains in place. The effect of this decision, combined with the export tax regime above, is that non-Chinese rare earth processors such as cerium polishing powder producers and rare earth magnet producers pay 31% more for rare earth raw materials (plus transport and storage costs) than their Chinese counterparts.

In other cases, export restrictions are imposed in order to encourage supply of raw materials to domestic producers of downstream semi-processed goods. In the years prior to the 2008 downturn Chinese exports of rare earth compounds were declining while exports of metals and alloys were increasing slightly.

In 2008 and 2009, China began implementing regulations to place greater controls on the rare earth industry. For example, the Ministry of Land and Resources implemented a regulation in 2009 that would "protect and make rational use of China's superior natural resources," in particular, tungsten, antimony, and rare earth ores. According to the regulation, the Ministry of Land and Resources is suspending any applications nationwide for survey or mining licenses for rare earth ores. The goal for controlling the rare earth industry in China is "to prevent over-exploitation and blind competition, and to advance the effective protection and scientific, rational use of these superior mineral resources." The Chinese argue that the REM industry is unsustainable and is rife with environmental externalities that ultimately take a toll on the public. They maintain that export restrictions are in place to reflect the true price of REMs and their ecological costs, while protecting the environment from overexploitation and illegal mining operations (ICTSD, 2010). Most of the analysts argue that, if China causes a shortage of rare earths, it will be a temporary shortage, since the rising prices for rare earth elements will serve as an incentive for others to enter the market, leading to greater supply. The United States, for example, has 13 percent of known rare earth reserves and could get back into the production and refining business. Still, there will be a lag before new production becomes available, and it could easily come from an equally troubling source. After China, Russia has the next largest reserves (19 percent), and it is at least as likely (if not more so) to play games with export restrictions, and have more lax safety and environmental standards as well (New York Times, 2010). Countries that rely on Rare Earth Metals (REMs) for manufacturing are lashing out at China after Beijing officially announced a further 35 percent reduction in export quotas. The cut, which will affect exports for the first half of 2011, follows a 72 percent reduction in REM exports in the second half of 2010.

6. REE Pricing and Price Movements

Despite the rising demand and the historical high prices reached by many commodities, mine capacity expansions and new mine production capacity have not kept pace. Overall, the price of minerals is driven by multiple physical, financial and political factors. When deciphering price data and trends, it is helpful to know whether there is a market surplus or deficit and the extent of the imbalance. Physical parameters (e.g., stock changes, closures of old mines and the start-up of new ones) are in turn influenced by general economic conditions and financial forecasts (e.g., inflation and exchange rates) that inform investor sentiments. Unanticipated shocks- such as monopolistic or oligopolistic pricing (e.g., export quotas); geopolitics and natural disasters- also play a role in affecting physical and financial parameters.

6.1 Negotiated Pricing and Metal Exchanges

Most rare, precious, minor and specialty metals and their alloys are traded through bilateral contracts based on negotiated pricing between parties. The fragmented nature of some of these markets and the remoteness of some producers has resulted in traders playing a dominant role. Regionally, traders account for a large part of the specialty metal supply coming out of regions such as China, the former Soviet Union and Africa. The nature of the process limits price disclosure in these markets and the prices of specialty metals quoted by traders and consultants vary widely in their reliability (U.S Department of Energy, 2010). To understand the price behavior and volatility of key materials, it is also important to examine the ways in which these commodities are bought and sold, in conjunction with whether they are produced as a co- or byproduct of other specialty metals (e.g., REEs) or a by-product of a major metal. Both aspects influence the price behavior and volatility of a mineral. The influences of these factors can be gleaned from a comparison between the historical price trends of commodities produced as a byproduct of metals traded on major exchanges and

Table 17: Purchase option and source of price information for REEs

Minerals	Purchase option	Source of price info
Rare Earth Elements	Negotiated purchase, not traded on metal exchanges and therefore no spot market; however, illegally traded REEs are sold through less formal channels and may possibly be sold on the spot markets	Trade journals, based on information from producers, consumers and traders

commodities mainly transacted through bi-lateral contracts.

For now, the demand/supply equation has been wildly swayed, and prices have rocketed. It has been widely reported that the Chinese authorities plan to implement a 'fully unified pricing mechanism' in order to control the price of rare earths throughout the country. On closer inspection, the proposed mechanism seems to apply only to the Fujian, Guangdong, Hunan and Jiangxi provinces, and the Guangxi autonomous region, at this time. These five jurisdictions are adjacent to one another in the southeast of China, an area whose elution deposited/ ion-absorbed clays are rich in the heavy rare earth elements. Inner Mongolia and other northern jurisdictions, which predominantly produce light rare earths, do not appear to be covered by the announcement. It would thus appear that the change is an attempt by the authorities to specifically control the prices of the more valuable heavy rare earths (Gareth P Hatch, 2010). Some would argue that China is already well in control of rare earth pricing with more than 90 percent market share, Chinese firms already control prices.

Are the Chinese looking to actively manipulate the price of rare earths? To assume that 'the Chinese', in some unified conspiracy, are working to throttle back rare earth supply and raise prices would be incorrect and there are certainly some Chinese rare earth companies that recognize they will get the best pricing for material outside China, and would love to use their expertise to help establish operations outside China. This would allow these Chinese companies to more directly reap the benefit of worldwide demand. Problems associated with future pricing of rare earths will affect different parts of the supply chain differently. Supply risks, at least in the short-to-medium term, are less associated with the prospect of increasing prices because in most cases the cost of these elements is a small part of the final product manufacturing cost. However, in the last 6-12 months the price of many rare earth elements has increased by approximately

300-700%, which in some cases has had a more significant impact on the price of the final product.

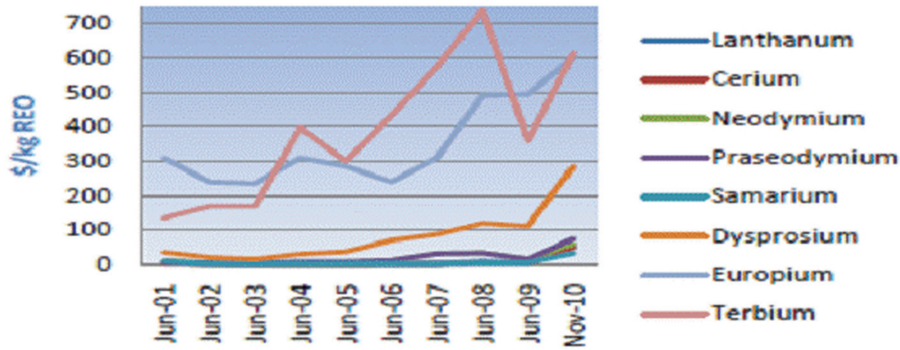
6.2 Rare Earths Price Movements

Rare earth prices remained static for decades due to plentiful supplies, lulling the high-tech industry into a false sense of security. After Beijing cut export quotas by 70 percent for the second half of 2010, prices of some rare earths gone up as much as 850 percent. When the global demand for rare earth materials increases year by year, China exported 6,100 tonnes of medium-end and low-end rare earth products in 1990; the average price was 13,600 USD/ton. In 2009, China exported 36,100 tonnes of rare earth smelting and separation products, rising by 16.67% YOY. The export value amounted to USD 310 million and the average price was only 8,959 USD/ton (China Research and Intelligence, 2010:3). Low prices for rare earth elements from China contributed to cuts at the Mountain Pass mine in U.S one of the main source of supply for many years before it closed in 2002. They also discouraged most entrants to the industry until the last two years, when prices began to climb because of strong demand.

2008 marked the peak in China's rare earth industry. However, in 2009, due to the economic downturn, demand fell sharply. Prices fell due to oversupply on the international market and price wars among Chinese suppliers, in particular smaller players. Since 2005, the Chinese government has been imposing export quotas on many of the rare earth metals, resulting in reduced global supply. Higher prices are a natural result of such supply restrictions. The latest data reveals that, China's exports of rare earth metals burst through the $100,000-per-tonne mark for the first time in February 2011, up almost nine fold from a year before, while the volume of trade stayed far below historical averages and each tonne fetched a mere $14,405 on average. The apparent price rises have averaged $10,000 per tonne per month but accelerated in February 2011, galloping ahead by $34,000 per tonne, according to Reuters calculations based on data from China's Customs office (Tom Miles, 2011). The explosion in export values has coincided with a collapse in volumes coming out of China, the source of almost the entire world's rare earth supplies, which has cut export quotas of the 17 rare earth metals and raised tariffs on exports.

Figure 10 illustrates the historical average prices of individual rare earth oxides between 2001 and 2010. REE prices have raised threefold overall since 2001. This period covers the 2001 recession, which had lingering effects until 2003, and the 2008– 2009 recession. Two things to note are that the heavier rare

Figure 10: REO prices from 2001–2010



Source: Lynas Corp 2010

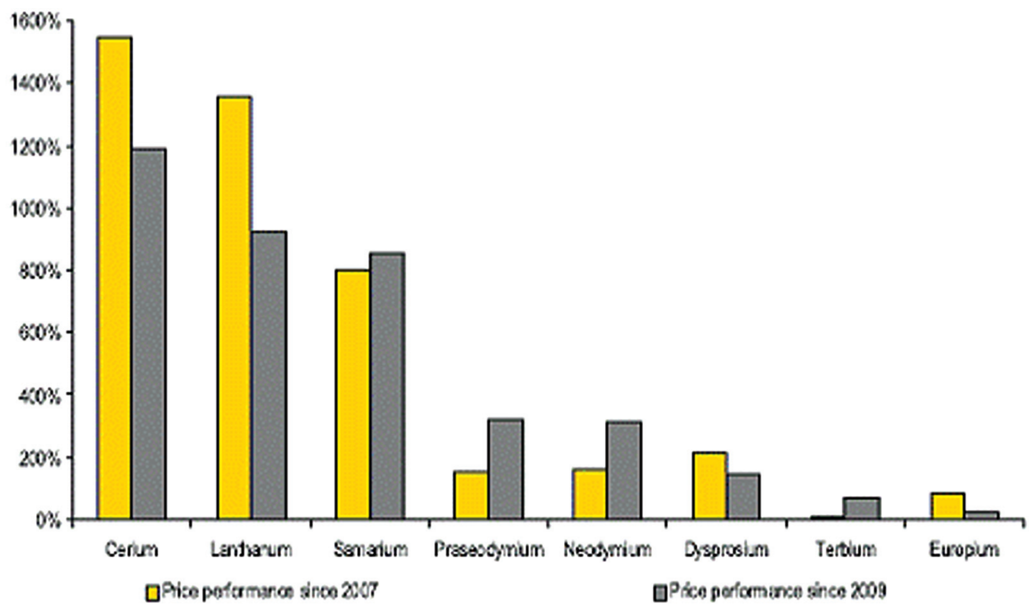
earths (e.g., dysprosium, terbium and europium) are relatively more expensive, and that prices have risen fairly steadily since 2003 due to China's rising domestic demand and escalating export controls. The price jumps from 2009–2010 can perhaps be attributed to a reduction in China's rare earth export quota. The export quota which is for total rare earth exports, resulted in higher prices for REO exports. This led to an unexpected fall in China's export of LREEs which are generally lower priced. As a result of the greater scarcity of light rare earths, the price of LREEs rose much more than the HREEs. Rare earth oxide and rare earth metal prices track closely, with the prices for metals always higher (though relatively more so for some rare earth elements than others) (British Geological Survey, 2010).

After soaring in recent years, rare earth prices have virtually skyrocketed in 2010. Cerium, for example, jumped from on average USD 3.88 per kg in 2009 to USD 50 per kg at beginning of November 2010, while the average price of lanthanum increased tenfold between 2009 and 2010. Terbium and Europium, on the other hand, recorded relatively modest increases of only 7% and 23%. Unlike the conventional metals, rare earths are not traded at the exchange. As a result, pricing is highly obscure, and there is no way for either producers or consumers to hedge prices. Neodymium prices quintupled at the same time to $23 a pound and slumped before almost fully recovering last quarter of 2010. The price of neodymium oxide, also used in magnets in BlackBerrys, has surged more than four- fold to $88.5 a kilogram from $19.12 in 2009 because of rising demand and reduced supply from China, according to Sydney-based Lynas Corp., which is building a A$550 million ($542 million) rare earths mine in Western Australia.

As discussed before the two heavy rare earths, dysprosium and terbium are in short supply, mainly because they have emerged as the miracle ingredients of green energy products. Tiny quantities of dysprosium can make magnets in electric motors lighter by 90 percent, while terbium can help cut the electricity usage of lights by 80 percent. According to a new United States Energy Department report, the most important of these for clean energy is dysprosium. Its price is now $132 a pound compared with $6.50 a pound in 2003. Terbium prices quadrupled from 2003 to 2008, peaking at $407 a pound, before slumping in the global economic crisis to $205 a pound.

While the long-term price of the light rare earths remains open for debate, the quotas will continue to tighten the supply of heavy rare earths like terbium and dysprosium, sending prices soaring. Dysprosium oxide, used in hybrid vehicles, lasers and nuclear reactors, is already selling for $284 a kg and that is projected to rise to over $400 in the next couple of years, according to Asian Metals. The rising prices have been a cause for concern in importing nations, which have become reliant on affordable REMs from China. The recent controversy over

Figure 11: Rare earth prices have multiplied over a short period of time.



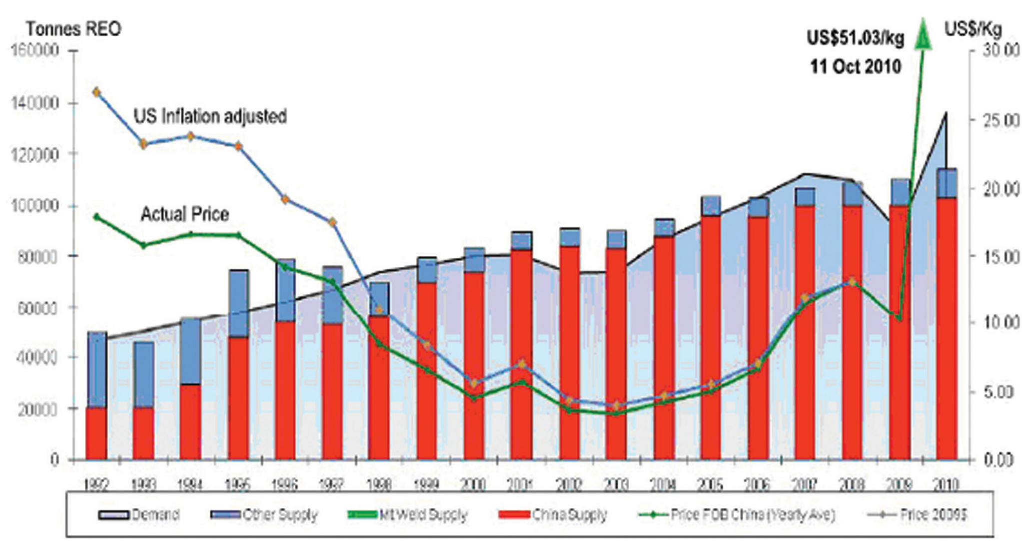
Source: Lynas Corp, Commerzbank Corporates and markets

China's clampdown has prompted prices such as cerium oxide to climb by 700 percent in less than a year. In light of China's virtual monopoly of the REM market, critics have argued that the country is simply flexing its economic muscle.

The figure 12 shows that the prices dropped continuously as supply from China increased substantially up to 2000. The 1992 was the year when Deng Xiaoping famously stated, "the Middle East has oil, and China has rare earths", since then, China has not only remained the world's largest REO producer, but has also successfully moved its manufacturers up the supply chain. During this period rare earth investment at state, provincial and local levels also increased as china dominated the market. When the prices were fallen too short at the international market, the mountain pass mine in California the main supplier of REEs till early 1990s was unable to cope with the escalating cost and finally shut down its operation in 2002 also during this decade the major buyers of rare earths such as U.S, Japan and Europe switched the purchase to China.

During 2000 to 2006 prices again went down; however from 2003, the price started to increase slightly and it is unlikely to be seen the prices again at this level. The major drivers that had an impact on setting the prices on this period were the high level of competition within China and handful of

Figure 12: Historic supply, demand and pricing



Source: Lynas Corp, 2010

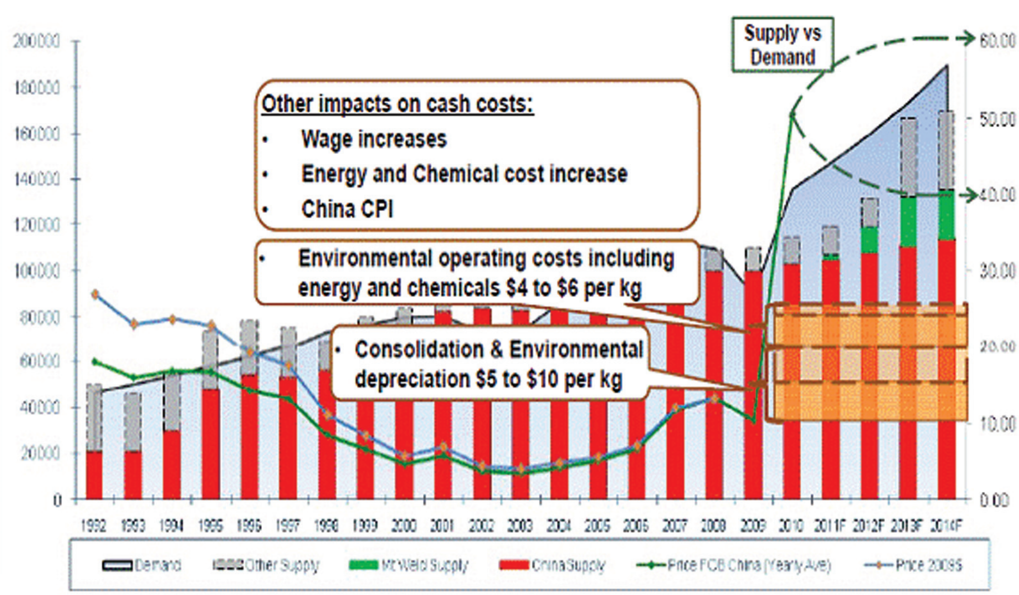
powerful buyers in Japan, USA and Europe. During this period the number of producers in China reduced from 600 to 150 companies by mergers and acquisition and there were little regulation from government side and there were no investment in environmental compliance within the Chinese rare earth Industry. This period also witnessed reducing supply from other countries along with over all demand growing from 2003 onwards after sluggishness in demand from 2000 to 2003.

The figure also shows that from 2003 onwards the prices started to increase again and there was a steep rise in prices in 2007-2008 due to changing market conditions in China. The major drivers of the price during this time were the temporary crack down on environmental standards which resulted in the temporary closure of multiple producers. Cost increasing in China due to the start of environmental compliance, as well labour, energy and chemical costs increasing and tightening between demand and supply also contributed in increasing prices.

In 2009 the price moved down mainly because of the demand sharply dropped due to global financial crisis while global supply almost remained at the same level. However as the economies started to

Figure13: Future outlook and price drivers

Structural change in industry has commenced



Source: Lynas Corp, 2010

recover and by the end of 2009 the prices started to increase again not only because of the global recovery but a number internal policies that China adopted related to rare earth industry. China started the consolidation of production and marketing channels that restricted Chinese supply and demand recovering strongly after GFC induced the prices to increase inside China and consequently increasing the international prices.

The figure 13 shows the future trend in demand, supply and prices up to 2014. There would be a number of factors that affects the price movements both in Chinese domestic market and international level. Assuming current trends continue, new projects are developed and there is a 'balance' in supply and demand for individual rare earths through extra supply. The Challenges for 2014 will be the tight supply and 'balance' between demand supply will still be an issue; so prices for Tb, Dy and Y will remain strong. And other issues include, can the rare earths industry in China be successfully controlled? And will the first of the new non-Chinese projects be successfully built and commissioned?

The impact of Chinese interventions in the domestic industry such as implicit assistance to domestic downstream processors of the targeted products and thus providing them a competitive advantage will have an impact on the prices. China is seeking sustainability and prices will respond to market demand and supply from a sustainable base. Estimates from Chinese government reports shows that the "Chinese price" for rare earths is about ¼ of the price that would result from an environmentally sound, worker friendly, profitable operation. This means that the "real" price of rare earths is about four times higher than the current China price. An entire set of "green" industries have grown up over the past ten years in reliance on that China price. The danger is that as the China price is phased out, many of these green industries will prove to be unprofitable. A primary example of this risk is the electric car. Since the China price for rare earths is virtually certain to be phased out very quickly, this risk is quite real (Steve Dickinson, 2010). However, technological change often brings sharp changes in demand, which, in turn, may lead to strong price volatility. An example is the tantalum capacitor industry. Two-thirds of world tantalum production is used in electronic components. When the tantalum price increased sharply in the late 1990s, the electronics industry encouraged capacitor designers to improve their niobium capacitors and multiple ceramics capacitors in order to replace the tantalum components. The demand for tantalum, and its price, fell sharply as a result.

7. Conclusions

For China rare earth is the wild card now. The Chinese government has stated that its reserves of rare earths are finite and, therefore, they will be developed for the prime benefit of China's manufacturing industry. To help generate manufacturing jobs and move up the value chain, a series of measures has been implemented to "conserve resources and to maximize the benefits" of its rare earths endowment. 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.

China has officially cited environmental issues as one of the key factors for its recent regulation on the industry, but non-environmental motives have also been imputed to China's rare earth policy. According to The Economist, "Slashing their exports of rare-earth metals…is all about moving Chinese manufacturers up the supply chain, so they can sell valuable finished goods to the world rather than lowly raw materials (The Economist, 2010). Although often needed only in small quantities, these metals are increasingly essential to the development of technologically sophisticated products. They play a critical role in the development of innovative "environmental technologies" to boost energy efficiency and reduce greenhouse gas emissions. Hydrogen-fuel based cars, for example, require platinum-based catalysts; electric-hybrid cars need lithium batteries; and rhenium super alloys are an indispensable input for modern aircraft production. In addition, there are few substitutes available in the short-term for these raw materials.

The study finds that, a major ongoing issue for the rare earths industry is the balance. Due to the absurdity between the supply and demand of individual rare earths, there always exists a situation in which there is a shortfall of some rare earths while others are in surplus. On the basis of known analyses of major resources it is considered that some of the 'heavy' rare earths are more likely to be in short supply in the future.

Although production of some strategic minerals is very concentrated, this does not necessarily suggest that future production will be similarly geographically restrained. The future production situation is mixed. For some strategic minerals, the reserve base is more geographically concentrated than the present production. For others, the raw materials are more widely dispersed. In the case of some of the most concentrated raw materials, particularly those largely found in China, such as rare earths, the future reserves are less concentrated than present production would suggest.

Since early 90s, Chinese rare earth producers have had an unregulated approach to the supply in the international market. This has been exploited by a concentrated number of buyers who have collaborated to force prices down. As China gradually increased its bargaining power by restricting supply with tightening market, rare earth prices have improved significantly over the years. Whilst the next 5 to 10 years, global demand will surpass supply, China Rare Earth export quotas will play a critical element in the supply chain of rare earths out side China.

There are few basic features of Chinese supply that we can derive from the above analysis. The main aspects include, China still hold more than 36 million tonnes of rare earth oxide reserves, excessive secondary processing capacity and easy availability of cheap processing chemicals, and heavy investment in research and technology. However the supply of Chinese heavy rare earth is finite with 15- 20 years of mine life and Chinese are rigorously regulating the mines on environmental grounds.

To control the supply China has introduced a number of measures such as imposing 15 percent of taxes on light rare earths oxides and neodymium metal and, 25 percent tax on heavy rare earths and other metals. Government has recommended that the management of rare earth mines should be consolidated under three four main enterprises and has stepped up efforts to restructure the rare earth industry and has introduced favorable policies, and is encouraging acquisitions and mergers to restructure the sector. According to plans, the Chinese government will bring down the number of rare earth companies from 90 to 20 within 2015. These measures will have short – medium term repercussions in the international market and industrial applications.

There is no rare earth source that can match the Baotou tailings dump, these deposits can be found all over the world. China's actions have put this issue firmly on the radar screen and countries are getting serious about developing new sources. Several new overseas mine projects are in the pipeline but few are likely to be able to compete with China on prices. Besides, it would require at least a decade before new mines can make an impact on the global market and the study shows that China will continue to control the global market for some time to come.

China's control over rare earth elements has the potential to increase foreign dependence on China for finished goods. China has adopted various policies to further develop the rare earth industry at its roots. China's vision is to increase industrial utilization of rare earth elements and control the market of rare earth applications.

China recognized the strategic value of its RE resources long before the days of Deng Xiaoping. With skill, patience and investment China has transformed the Rare Earth industry into what it is today. Government support of advanced curricula in RE sciences has produced thousands of technical professionals employed in RE industry today.

China's moves are creating panic in the rare earth sector and its efforts to monopolize the sector will backfire since the nation's policy makers seem to have failed to realize that such high-handed measures are uniting the rest of the world against China. Business partners and prospective investors will insist on tougher terms of contract or develop other ways to protect their business interests.

Most of the analysts argue that, if China causes a shortage of rare earths, it will be a temporary shortage, since the rising prices for rare earth elements will serve as an incentive for others to enter the market, leading to greater supply. The United States, for example, has 13 percent of known rare earth reserves and could get back into the production and refining business. Still, there will be a lag before new production becomes available, and it could easily come from an equally troubling source. After China, Russia has the next largest reserves (19 percent), and it is at least as likely (if not more so) to play games with export restrictions, and have more lax safety and environmental standards as well.

According to Financial Times, China wants to forge a new phase of globalization where many of the roads – financial, commercial and perhaps eventually political- converge on Beijing. China is not seeking a rupture with the international economic system (although some foreign companies are fearful of a technology grab). But it is looking to mould more of the rules, institutions and economic relationships that are at the core of the global economy. It is trying to forge post-American globalization.

While China says its deposits of rare-earth minerals account for only about a third of the global total, the country mines most of the world's marketed supply, which has raised concerns that China could deplete the supply too quickly. The move to build reserves comes as China's supply of rare-earth metals to the rest of the world already is shrinking despite growing demand for the elements. In response to Chinese restrictions on supply the high-tech-focused nations of U.S, The European Union, Japan and South Korea, all of which are dependent on China for rare-earth supplies, have highlighted stockpiling strategies.

High-technology and environmental applications of the rare earth elements have grown dramatically in diversity and importance over the past four decades. Many of these applications are highly specific and substitutes for REE's are inferior or unknown. REE's have acquired a level of technological significance much greater than expected from their relative anonymity.

If new supplies of rare earths do not come online within the next 10 years, a global shortage would likely to affect new energy industry such as wind turbine, solar panels, electric vehicle production and electronics. According to the U.S government report, the issue even carries national security implications because of the rare earth content in many advanced military weapons, the economic threat of depending on a single country and getting new sources of supply into production is not that easy. Rare earth elements are needed for China's expansion of its own military needs (aircraft carriers, nuclear-powered submarines, and ballistic missiles). Home-grown production needs will further cut exports already reduced to crippling levels. Not surprisingly, these measures have raised real concerns outside of China regarding the future availability of the refined products created from REMs.

China has been strategically motivated in the development of many new high tech applications which have helped quadruple the size of the RE market since 1990. Chinese economy will continue to grow near double digit rates for the foreseeable future and disposable income for automobiles, personal electronics, etc will drive the internal demand for REs significantly. China is already overtaken U.S as the largest auto market and expected to produce 500,000 electric vehicles in 2011and also leads in wind power generation. So to meet this increasing demand for REEs, China will gradually reduce the exports.

So to summarize

- China's RE reserves are finite.
- Chinese internal demand for RE

materials and technologies is forecasted to continue growing at double digit rates for the foreseeable future.

- These conditions will continue to drive Chinese policies to limit RE production and exports to better manage its precious natural resource.
- China already produces 80% of global requirement for fully dense RE permanent magnets and 100% of the global RE metal requirement for all RE permanent magnets (fully dense and bonded) produced.
- Prospects of the Chinese expanding RE raw material output beyond its own internal demand only appears to make sense if China can leverage this increased production to bring more downstream manufacturing into the country (more magnets, motors and motor assemblies for example)

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