HOUSES OF PARLIAMENT
PARLIAMENTARY OFFICE OF SCIENCE & TECHNOLOGY

POSTNOTE

Number 368 January 2011

# Rare Earth Metals

Rapid global industrialisation and population growth are placing increasing pressure on availability of raw materials. A group of elements known as the Rare Earth Metals have become a highly sought-after resource for high-technology and low carbon industries. Currently, global demand is increasing, and there are concerns over future availability. This POSTnote examines the debate on future supplies, and discusses the UK and international response.

## Overview

- Rare Earth Metals (rare earths) are a group of elements widely used in high-tech goods and low carbon technologies.
- China produces 95-97% of world supply, but is reducing exports, and increasing prices to foreign consumers.
- The global impact of these restrictions is greatest in countries with large high-tech manufacturing sectors such as Japan, the USA and Germany.
- The direct impact of these restrictions to the UK economy is currently limited as it has only a small rare earth processing industry.
- However, a consistent supply is of future strategic as well as economic importance to the UK.
- Alternative sources are expected to become available from the USA and Australia by 2014, predicted to meet the anticipated global non Chinese demand.

## Background

**Rare Earth Metals** are a group of elements employed extensively in high-technology applications. They are found in items such as monitors and mobile phones, as well as low carbon energy technologies. They are also used in chemical processes such as petroleum refinement as an industrial catalyst. Some are relatively abundant in the Earth's crust, but are not often in concentrations high enough to make mining currently economically viable. Global supply relies on a small number of sources, dominated by China.[1] In the past decade, China has tightened control of rare earth exports by introducing export quotas that have been reduced each year (Fig 1).

### Rare Earth Supply

China has emerged as the dominant supplier of rare earths for various reasons. It has 35% of known world reserves, and has invested in the development of rare earth processing techniques since the 1960s. Also, it gave extensive state support to mining in the 1990s. Moreover until recently, regulatory controls in China were relatively weak, which meant that Chinese producers were able to offer rare earths at low prices compared to competitors in other countries. This suppressed large scale development in other countries with known reserves (Commonwealth of Independent States, USA, Australia, India and Malaysia).[2] China currently supplies between 95-97% of global demand. The rest is met by small amounts from Russia, Brazil and Vietnam.

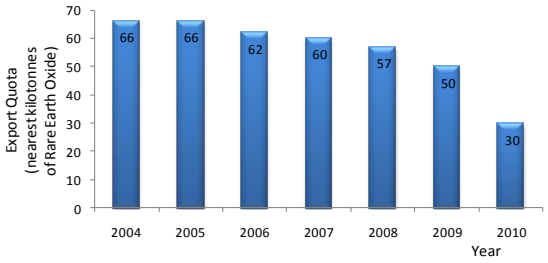


**Figure 1. Yearly Chinese Export Quotas of Rare Earth Oxide**[2]

The rare earths may be supplied in elemental form or compounds such as rare earth oxides, chlorides and carbonates. These are collectively known as **rare earth products** (within the industry the term rare earth oxide or

REO is used to refer to all of these). It is these which are subject to export quotas. Rare earth products can then be further processed for use in chemical industries or manufactured into **downstream goods** containing rare earth metals, for example mobile phones and magnets. No Chinese export quotas currently exist on downstream goods,[3] of which China is also a large and growing exporter.

### Rare Earth Demand

Although widely used, many applications of rare earths require relatively small quantities of material. Hence, global production of rare earth products is only around 124 thousand tonnes of REO annually, compared with ~11.1 million tonnes annually for a metal such as zinc.[4] The rare earths anticipated to have the greatest increase in demand in the coming years are neodymium, dysprosium and praseodymium. These are a component of high power magnets, used in some electric vehicles and wind turbines. Currently, 4% of new offshore wind turbines use a magnetic drive system containing rare earths, which improves reliability and mechanical efficiency. This figure is anticipated to rise to 15-25% by 2015. Demand for electric vehicles is also forecast to increase. Global rare earth demand is forecast to grow at between 8-11% a year from 2011 to 2014, driven largely by the rate of growth of these two low carbon technology markets.[1] Global non Chinese demand is predicted to rise to ~62.5 thousand tonnes of REO annually by 2014. Box 1 describes the rare earths and some of their applications in more detail.

**Box 1. The Rare Earth Metals and their Applications**

A widely accepted definition of the rare earth metals is the group of elements containing the lanthanides, scandium and yttrium, as they all exhibit similar chemical properties.

| Element | Example Applications |
|---|---|
| Scandium | metal alloys for the aerospace industry |
| Yttrium | phosphors, ceramics, metal alloys |
| Lanthanum | batteries, catalysts for petroleum refining |
| Cerium | catalysts, polishing, metal alloys |
| Praseodymium | improved magnet corrosion resistance, pigment |
| Neodymium | high power magnets for laptops, lasers |
| Promethium | beta radiation source |
| Samarium | high temperature magnets, reactor control rods |
| Europium | liquid crystal displays, fluorescent lighting |
| Gadolinium | magnetic resonance imaging contrast agent |
| Terbium | phosphors for lighting and display |
| Dysprosium | high power magnets, lasers |
| Holmium | the highest power magnets known |
| Erbium | lasers, glass colorant |
| Thulium | ceramic magnetic materials under development |
| Ytterbium | fibre optic technology, solar panels |
| Lutetium | X-ray phosphors |

Lanthanum to samarium are often referred to as the light rare earth elements, and europium to lutetium as the heavy rare earth elements, which are less common and consequently more expensive.

## Recent Developments

As indicated in Figure 1, in recent years China has been reducing its supply of rare earth products to the global market. In 2004 it introduced maximum yearly export quotas of rare earth products. 2010 saw a 40% cut in export quotas. Shipments have also recently been delayed at ports by Chinese customs officials. The secretary general of the Chinese Society of Rare Earths has said a further reduction in quotas is under consideration. There are early signs that impacts might be seen on downstream goods – for example delays in magnet exports from China. China may have a range of motivations for the export controls:[5]

- **Environmental considerations -** cited as a key reason for reducing export quotas (see Box 3).
- **Industry regulation -** the Chinese government are aiming to limit mining rights to fewer, state owned enterprises.
- **Clamp down on smuggling -** with recent delays in shipments possibly due to a crackdown on this practice.
- **Increasing domestic demand -** with Chinese demand forecast to exceed the average global rate of growth.
- **Conservation of resources** – with the aim of slowing the rate of exhaustion of Chinese reserves.
- **Encouragement of higher value manufacturing investment -** with export taxes and quota restrictions resulting in rare earth products costing up to three times more for firms outside China than domestic ones. This may be intended as an incentive to foreign manufacturers to relocate to China and invest in the Chinese higher value manufacturing industry.

### Market Response

The average price of the rare earths for a non-Chinese purchaser has risen from 2009 to 2010, with some showing up to a ten-fold increase.[6] The Chinese internal price has also increased, although less dramatically. Rapid changes in price are not unusual, as the low number of suppliers has historically caused large fluctuations. There have been some suggestions of a possible price bubble. This is because prices could continue to rise over the next few years if exports are further restricted, but could then fall as a result of various global responses to the situation, or through a change in Chinese policy.

### Which countries are affected?

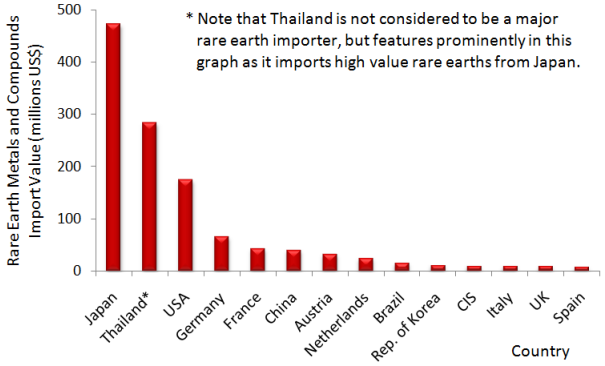


**Figure 2. 2009 Import Values, Top 14 Rare Earth Importers[7]**

The sectors most affected are those that process rare earth products into downstream goods or use rare earths in industrial applications such as catalysts. Thus, countries whose high-tech manufacturing industry is heavily reliant on rare earth imports are most impacted. These are shown in Figure 2.

### Price and Availability of Downstream Goods

Sectors which rely on downstream goods using small amounts of rare earths (for example mobile phones) are not currently significantly affected by increases in price, as it is only a small proportion of the total product cost. Price increases may be more of an issue when the rare earth content is higher (for example in high power magnets). Some say these will still be cheaply available from China (as producers there have access to cheaper raw materials), others point out that market conditions may push up these prices too.

## UK Impact and Response

As shown in Figure 2, the UK is a relatively minor importer of rare earth products and there has been limited commentary on the issue from wider UK industry. However, some industry stakeholders have raised concerns over damage to UK alloying and catalyst production industries. Impacts on some companies are detailed in Box 2.

**Box 2. UK Rare Earth Importing Industry**

This sector is relatively small in the UK. There are few companies in the UK that make direct use of materials covered by the current export restrictions. Two that do are:

***Less Common Metals***: Based in Birkenhead, a subsidiary of the Canadian Great Western Minerals Group, specialising in the production of rare earth alloys. It is currently seeking to secure an alternative supply chain by re-opening a former mine in South Africa, planned for 2013.

***Magnesium Elektron***: A Manchester-based magnesium alloy manufacturer, using rare earth metals in alloys for the aerospace industry. It has experienced increased costs as well as delays as a result of the Chinese export restrictions. It is also interested in potential alternate supply chains.

### UK Low Carbon Technology Industry

Manufacture of low carbon technologies is seen as a key area of future growth for the UK. It is generally accepted that a consistent supply of raw materials is important for this growth, and concerted effort to develop a strategy to secure resources is needed. Two key areas which are likely to contribute to increased UK demand for rare earths are wind turbine and electric vehicle manufacture. However, Renewable UK, a leading renewable energy trade association, reports that no wind turbine manufacturers have expressed concerns about rare earth availability to them. Similarly no manufacturers operating in the UK have approached the Office for Low Emission Vehicles expressing concern. This reflects the fact that downstream goods are not covered at present by export restrictions.

### UK Government Policy

In the recent past, the UK government has pursued a policy of leaving all non oil and gas commodities to the open market, and has not striven to stockpile or otherwise influence market conditions. However, the present government is aware that other countries are taking action to respond to significant market failures, and is monitoring the situation. The Department for Environment, Food and Rural Affairs (Defra) is involved in analysis of the risks to UK business and resource security as part of the development of policies on resource efficiency. Policy focuses on raising industry awareness of the need to design products with recovery, re-use and recycling in mind (page 4). The Department for Business, Innovation and Skills (BIS) also has a keen interest because of the potential future impacts on various industry sectors including low carbon and high-tech manufacturing. Beyond this, the UK government currently has no specific policies regarding rare earth materials, but is undertaking a policy review. Some industry stakeholders suggest that guaranteed loans to allow industry to secure resources could also be useful.

A number of military systems contain rare earth components. The Ministry Of Defence has commissioned the Defence Science and Technology Laboratory to investigate a number of military systems to quantify any significant resource risks (including rare earths) strategic to the military. The findings will be presented in mid 2011.

## Global Response

Countries such as Japan, the USA and Germany have far larger rare earth processing industries than the UK and concerns about rare earth supply issues have been expressed by a wider range of stakeholders. There has been a range of responses to availability issues.

### Rare Earth Mine Exploration

The last few years have seen a surge in rare earth exploration activities around the world. Each deposit is made up of a unique range of minerals, containing a suite of rare earth metals, and often contain strongly radioactive isotopes, further complicating the mining process. Each new deposit therefore requires the development of a bespoke separation process, so development time is long, costly and high risk. Much of the relevant expertise is currently held in China. It is estimated that only 5% of exploration ventures yield a producing mine.[8] Rare earth mining and production is also beset with environmental concerns (Box 3) and so obtaining planning consent is also complicated.

**Box 3. Environmental Impacts**

While many applications of the rare earths contribute to emissions reductions through their use in low carbon technologies, there are many environmental issues surrounding their production. A major concern is the radioactivity of materials which are nearly always found with rare earths. Refinement processes also often involve chemicals such as sulphuric and hydrofluoric acid. Lax regulation and illegal mining operations have resulted in these aspects posing significant hazards to the local environment, causing illness and occupational poisoning of workers and residents, and polluting land and water. Like most other mining operations, rare earth mining uses a considerable amount of energy, often generated by coal fired power stations. Also when products containing rare earths are scrapped, the rare earths may be released into the environment, and the effects of this release are not well understood.[9]

The three largest mines outside of China could be supplying most of the global non Chinese demand by 2014 (Box 4).

However these new producers exploit reserves containing mainly light rare earths. Global supply of heavy rare earths will still be reliant on China beyond 2015.

**Box 4. Major Mining Initiatives Outside China**

***Mountain Pass, California USA:*** Owned by Molycorp Minerals. Mining restarted in December 2010. Output should start at 3000-5000 tonnes of REO a year, rising to at least 20000 tonnes by 2014, with 40000 tonnes under consideration.

***Mount Weld, Australia:*** Owned by Lynas Corporation. Progress is well advanced, with production to begin in early 2012, producing an initial 11000 tonnes of REO annually, rising to 22000 tonnes by 2014.

***Nolans, Australia***: Owned by Arafura Resources Limited. Company forecasts production of 20000 tonnes of REO annually, by 2013.

Some companies which use rare earth products are investing in exploration to secure their supply chains. Toyota is developing a mine in Vietnam, and Sumitomo, Mitsubishi and others are exploring developments in Kazakhstan and Brazil. There are few known reserves within the UK, although little research into this has been completed. However, even if significant reserves were found, planning and environmental regulations would be likely to make domestic mining uneconomical.[9]

### Trade Negotiations and WTO Rules

World Trade Organisation (WTO) rules permit temporary export restrictions on environmental grounds. However, the development of a two-tier market system in China (see Recent Developments on page 2) appears to contravene WTO rules, and is currently under investigation by the EU and Mexico. Japan has raised the issue bilaterally with China, and the Office of the United States Trade Representative recently announced that "the United States will continue to pursue vigorous engagement with China on this issue and will not hesitate to take further action, including WTO dispute settlement, if appropriate".

### Stockpiling and State Support of Industry

The USA has a stockpile of unprocessed rare earth ore mined domestically in the 1990s. The US government has developed legislative proposals to establish a programme securing supply,[10] Concerns about rare earths used in military equipment have been downplayed by a Pentagon study, which concluded that China's monopoly on rare earth materials poses no threat to US national security.[11] Japan has accumulated the largest stockpile outside of China and has established the Japan Oil, Gas and Metals National Corporation, created to secure raw materials for Japanese industries.[12] The German government-owned KFW bank is operating a loan guarantee scheme to aid German companies in securing strategic raw materials.

### Recycling and Re-use

Many applications of rare earths result in very low concentrations in scrap, making recycling difficult and expensive. The recycling potential is greater in devices that use more material (e.g. those containing magnets). Despite the potential that recycling offers, many products are not designed to allow recovery of high value components easily at end-of-life. Some suggest that manufacturers have limited incentives to work towards this with existing design and assembly processes. However, government policy is based upon raising awareness of the need for this. Japan leads the way in research into rare earth recycling, with Hitachi aiming to recycle electric motor magnets by 2013. There is relatively little activity elsewhere. Defra say that re-use (for example reusing magnets from speakers) is also important.

### Substitution and Innovation

Finding other materials to substitute or reduce quantities of rare earths, or redesigning products so they are less dependent on them, is also being considered. However, many applications of rare earths are highly specific, with substitute materials either not available, or resulting in reduced performance. For example, no material has yet been developed which would yield a magnet of strength comparable with neodymium-based magnets. However, there is ongoing research into designing electric motors which do not use rare earths. Japan has recently announced development of a motor using non rare earth based magnets, and Tesla Motors have opted for induction motors in their commercially available electric vehicles, that also do not require rare earths. As discussed on page 2, the offshore wind industry currently mainly uses designs that are not reliant on rare earth magnets.[1]

## Wider Global Resource Issues

Rare earth metals are an example of a mineral resource experiencing availability issues. Many of the concepts outlined here are also common to other materials. As world resources come under increasing pressure, nations may use varying strategies to meet their needs. One consequence could be greater "resource nationalism", where governments exert control over their natural resources. Schemes such as the EU Raw Materials Initiative are designed to identify critical materials and to develop policies to prevent or mitigate supply issues. Whether or not a material is considered "critical" depends upon variables such as economic importance and supply risk. Economic importance takes into account factors such as the existence of substitutes. Supply risk incorporates factors such as the number and political stability of the supplying countries, and the impact of natural disasters or climate change on mining operations and transport routes.

**Endnotes**


1 *Lanthanide Resources and Alternatives*, May 2010, Oakdene Hollins
2 *Rare Earths*, November 2010, ABSCO Materials Presentation
3 *The Economics of Rare Earths and Yttrium*, November 2007, Roskill
4 US Geological Survey, Mineral Commodity Summaries, January 2010
5 *China's Rare Earth Elements Industry: What Can the West Learn?* March 2010, Institute for the Analysis of Global Security
6 Lynas Corporation Limited, http://lynascorp.com/
7 UN Commodity Trade Statistics Database, http://comtrade.un.org/db/
8 *Rare Metals in the Age of Technology*, January 2010, The Jack Lifton Report
9 *Rare Earth Elements*, June 2010, British Geological Survey
10 *Rare Earth Elements: The Global Supply Chain*, September 2010, Congressional Research Service, US Congress
11 Pentagon Office for Industrial Policy, www.acq.osd.mil/ip, not yet published
12 http://www.jogmec.go.jp/english/index.html


POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of policy issues that have a basis in science and technology. POST is grateful to David Phillips for researching this briefing, to the Engineering and Physical Sciences Research Council for funding his parliamentary fellowship, and to all contributors and reviewers. For further information on this subject, please contact the co-author, Dr Chandrika Nath on nathc@parliament.uk. 