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THE "RARE EARTH" MARKET: A STRATEGIC MARKET

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Abstract:

The "rare earth" market, formed by 17 metals –most of them belonging to the lanthanide group– which for many years did not have any use of interest, has grown very strongly in the last twenty years, even at the current moment of economic crisis. The demand of these metals grows at an annual rate of 10%. They have numerous uses in some vital sectors for economic development, like information technologies and renewable energies, and they are also of great interest in the defense sector. However, the world production of rare earth is dominated by China in an alarming percentage of 97 %, as well as some related industries such as refining, obtaining of alloys and, to a lesser extent, manufacturing of new-generation magnets. Currently, China has slowed down its production and very serious questions arise for the coming years.

Keywords:

Rare earth, refining, alloys and magnets manufacturing, computer industry, renewable energy, next-generation magnets, weapon systems, reduction of exports, rising prices, shortages, dependence.

INTRODUCTION

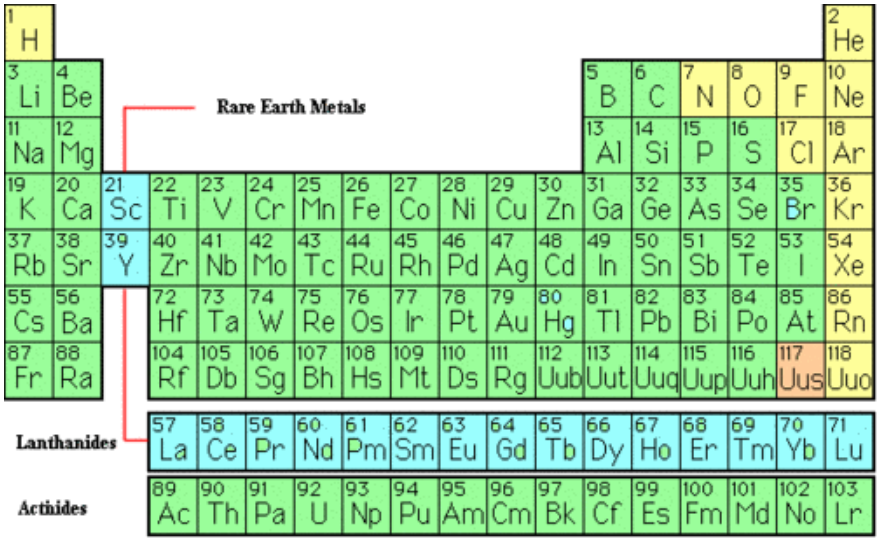
A report published by the IEEE last March[1] drew attention to the existence of certain chemical which are *critical* for the energy sector, specifically the so-called *rare earth*, whose global production is dominated by China. The consumption of these elements rocketed in the last years due to an intensive use of new technologies. This report focuses on how necessary these products are in order to get efficient processes of renewable energy generation, as well as on the concerns in Europe and the United States about the guarantee of its supply.

Now we will elaborate on the above information and we will relate the importance of these materials to the Defence sector, bearing in mind some new aspects for the analysis of the problem of current concentration of global production, refining and manufacturing industry of the components associated to these materials.

WHAT IS RARE EARTH?

Rare earth elements, also known as *special metals,* are a group of 17 metallic chemical elements: scandium (atomic number 21), yttrium (atomic number 39) and the lanthanides group –lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium– whose atomic numbers range from 57 to 71. Even though scandium and yttrium are not part of the lanthanides group in the periodic table, they behave in a very similar way to them. Rare earths are usually presented as dust and metallic oxides. They are obtained from 25 minerals that can be found in nature in a bigger proportion than their name suggests. However, this name is justified by the low concentrations found and the difficulty of locating concentrations of an adequate size for commercial exploitation, which is complex, expensive and aggressive with the environment. The figure below shows the position of *rare earth*, coloured in blue, in the periodic table.

[1] HIDALGO Mª del Mar. *Los elementos críticos del sector energético: una cuestión de geopolítica*. Instituto Español de Estudios Estratégicos. March 7th, 2012.



Source: www.espirareearth.com

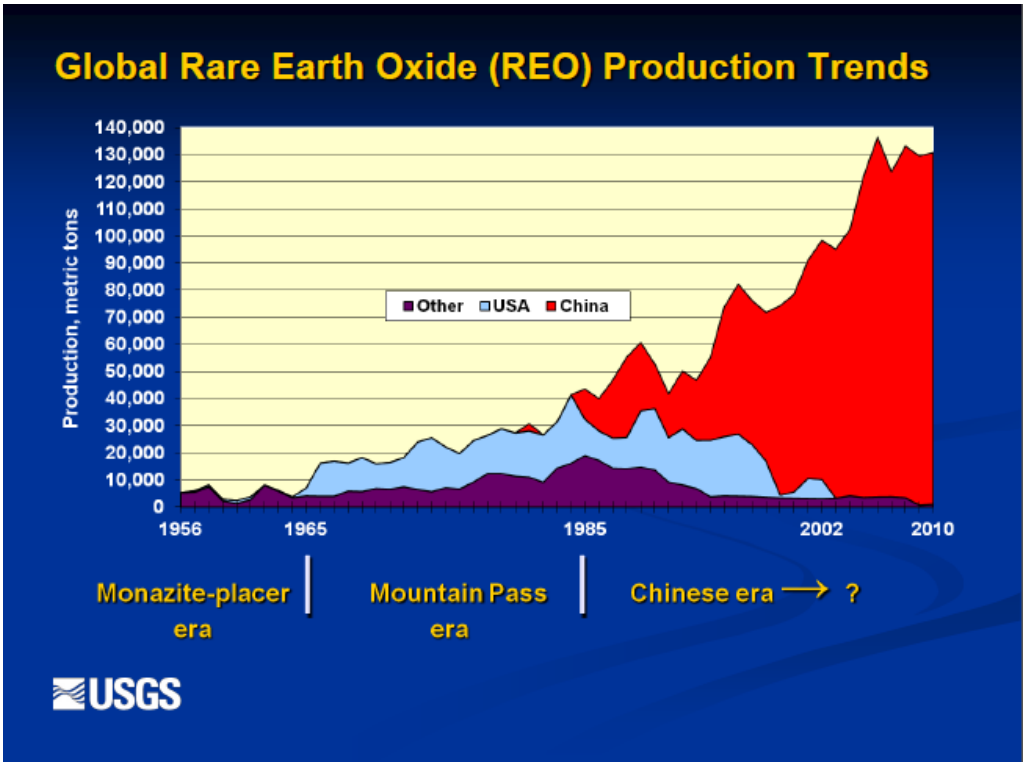
Fig.1

STRATEGIC IMPORTANCE

For many years, rare earths were little known elements; they were thought to be useless. However, in the last decades, it has been found out that they have many uses in the new technologies that have been developed. Their strategic importance not only lies in the essential role they play in civilian and military IT industry, but also in the various systems of renewable energy generation, as well as in weapon and military equipment manufacturing. In addition, their increasing use and the high concentration of their production, dominated by China, make rare earths a group of vitally important materials for the economic and politic sovereignty of any self-respecting country or group of countries, such as the USA, Japan, Canada and the European Union. These countries have already expressed their concerns on this issue.

Nowadays, *rare earth elements* are used for the production of computer hard disks, smartphones, TV screens, touch screens, hybrid vehicles, wind turbines, solar panels or energy-efficient fluorescent light bulbs, among many other objects. In a few years, China has taken over the rare earth market through an investment policy in exploitation of the existing deposits in the country, mainly Baotou mine, in the autonomous region of Inner Mongolia. China also controls the acquisition of the companies that exploit deposits in other countries, as well as the creation of specialized facilities for processing minerals and derivatives. Combined with low costs of exploitation, both from an environmental and wage point of view, this has caused the abandonment of investment in exploitation of these resources in western countries during the last fifteen years. The consequences of that are very serious currently, as China controls 97% of this market.

The following chart shows what countries have dominated the world production of rare earth at some point. It can be observed, on the one hand, a period of US prevalence, which started in the mid-sixties and lasted more than twenty years, during which this country was an undoubted leader. On the other hand, it can also be observed how China started to increase its production powerfully in the late eighties, at the same time that USA progressively lost its prevailing position and disappeared from the market when the Mountain Pass mine in California was closed in 2002, due to its high relative cost of exploitation.



Fuente: Servicio Geológico de EE.UU.
Fig. 2

As it can be seen, China has an absolute control of the *rare earth* extraction currently.

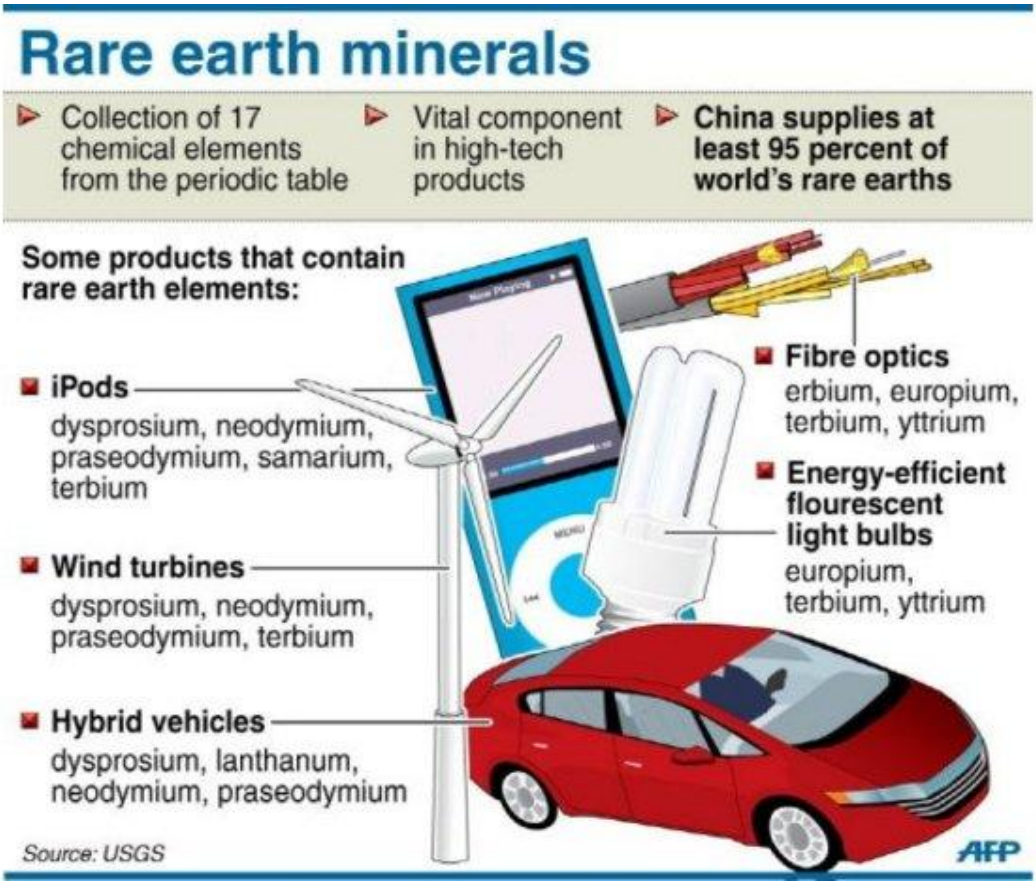
In order get a better idea of the importance of these materials, we will list below their main industrial uses, both civilian and military, and we will analyze their market and its worrying evolution in the last three years.

USE IN NEW TECHNOLOGIES

Civilian industry

The following picture, published on the internet by the United States Geological Service, shows to what extent these materials are part of our daily lives.

It shows the use of five of these metals (dysprosium, neodymium, praseodymium, samarium and terbium) in an iPod, though the same metals are used in smartphones and tablets. In addition, some of these materials are also used for the production of computer hard disks (neodymium) and new TV screens (yttrium and europium). All these uses constitute an important first field of application.



Source: United States Geological Service

Fig.3

In the left part of the image, it can be seen that four rare earth elements are also used for the production of wind turbines. Many of them are used for producing powerful permanent magnets which are part of the generators mentioned.

Magnets made of rare earth elements are also used in engines and high performance electric generators for the new hybrid vehicles, which entails an important consumption of these materials. Although it is not represented in the picture, lanthanum and cerium are also used in their batteries, yttrium, cerium and europium in their glasses, control panels and other components. In addition, lanthanum and cerium are used in catalytic converters for vehicles, in order to reduce gas emissions.

Finally, rare earth elements are used in energy-efficient fluorescent light bulbs (erbium, europium, terbium and yttrium) and in fiber optics (erbium, europium, terbium and yttrium), two important fields of application.

To sum up, the five fields mentioned are very important: they are all experiencing a strong growth, they create employment and they are highly dependent on rare earth elements.

Moreover, there are other important uses in civilian industry that are not included in the picture above. However, it is worth it to list them. Some of these uses are also interesting for military weapon industry, as it happens with fiber optics and some other uses mentioned above. These are the following:

- Medicine (healing of some specific types of cancer, MRIs, CT scans, X-rays, lasers and surgical instruments)… yttrium, neodymium, terbium, gadolinium, thulium and holmium.
- New petroleum refining processes… lutetium.
- Diesel engines… cerium.
- High-intensity lights… scandium.
- Fuel cells… terbium.
- Superconductors at low temperatures… yttrium.
- Superconductors at high temperatures… thulium, lanthanum.
- Alloys in aircraft engines… praseodymium.
- Nuclear reactors… samarium, europium, gadolinium, dysprosium and holmium.

Military industry

As it has already been said, many of the uses mentioned, almost all of them, can be interesting for military industry. That is something obvious and there is no need to comment further on it, we can just check again the list above. However, it is worth mentioning the use of these metals in certain military applications and systems in order to get an idea of their importance for the Defense sector:

- Alloys for air force and space flight… scandium.

- Lasers used for military purposes… neodymium, samarium, dysprosium and ytterbium.
- Smart bombs… samarium.
- Sonar… terbium.
- Night vision lenses… lanthanum.
- Fluorescent screens… europium.
- Weapon systems… yttrium, europium and terbium.
- Signal amplification… neodymium, yttrium, lanthanum, dysprosium and terbium.

Next generation magnets market stands out for its importance. There are two types of magnets: a) samarium-cobalt and b) neodymium-iron. The former keep their excellent characteristics even at high temperatures, which makes them adequate for missile guidance and control systems, smart bombs and aircraft. The latter are the most powerful magnets that currently exist and they are used in weapon systems.

As an example, the figure below, published by the Congressional Research Service[2], shows the use of rare earth elements in missile guidance and control systems, smart bombs and unmanned aircraft.

Fuente: Congressional Research Service (www.crs.gov)
Fig.4

[2] BAILEY Valery. *Rare Earth Elements in National Defense. Background, Oversight, Issues and Options*. Congressional Research Service. April 25th, 2012.

Last year, the United States Congress raised the question of the vulnerability of the Defense industry in the U.S. The U.S. Defense Secretary was requested an assessment about which rare earth materials "are critical to the production, sustainment, or operation of significant United States military equipment" or which can be "subject to interruption of supply, based on actions or events outside the control of the Government of the United States".[3] In March 2012, the U.S. Department of Defense presented an assessment that identifies seven rare earth materials that meet the criteria above: *dysprosium, erbium, europium, gadolinium, neodymium, praseodymium* and *yttrium*. This can be read in a document that the Congressional Research Service published on the internet[4]. Finally, it is important to point out that U.S. military industry rare earth materials consumption represents only 5% of the total consumption of the country. However, that does not mean that some of these materials with other civilian applications are not critical for the Defense sector, especially because its supply is highly dependent on another country. Currently there is a debate going on in the U.S. concerning that issue. At the moment, only *yttrium* is formally considered as critical by the Defense Department. That implies storage plans in order to ensure its availability for three years. However, the debate is still open.

RARE EARTH MARKET

Rare earth materials production process is complex and is divided in three phases. In all of them, China has an almost monopolistic control (the world market percentage China controls is indicated in brackets):

- Mineral extraction (97%).
- Metal oxide separation and refining (97%).
- Metal separation and creation of alloys (89%).

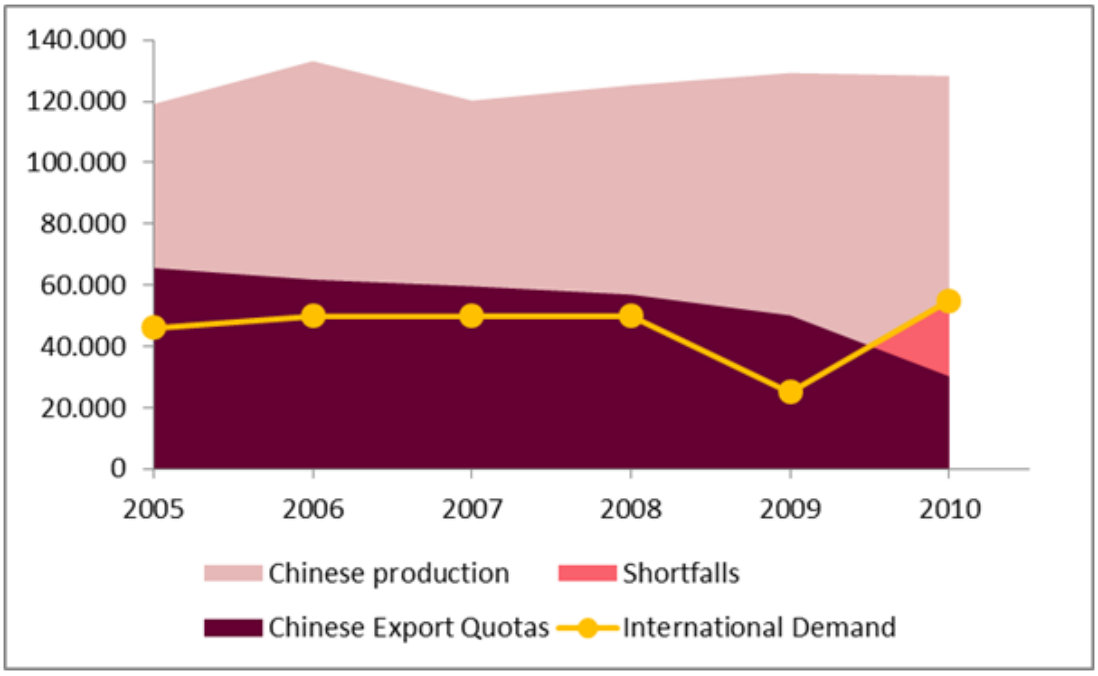
After that, different items and components, such as next-generation magnets, are manufactured. China controls around 70% of the world market in this phase. Even though it might seem that the rest of the countries have some more autonomy in this phase, they are completely dependent on China, because they need the raw materials in order to manufacture any product. Regarding the magnets market, which is highly interesting for the Defense sector and the energy sector, China controls 75% of the world production of neodymium magnets and 60% of the production of samarium-cobalt magnets? Great quantities of gadolinium are also used in the production of samarium-cobalt magnets,.

[3] Skelton National Autorization Act for FY 2011 (Section 843)
[4] BAILEY Valery, Op. cit., 3-4.

Although there are companies in the U.S. that produce them, the U.S. does not extract any samarium or gadolinium.

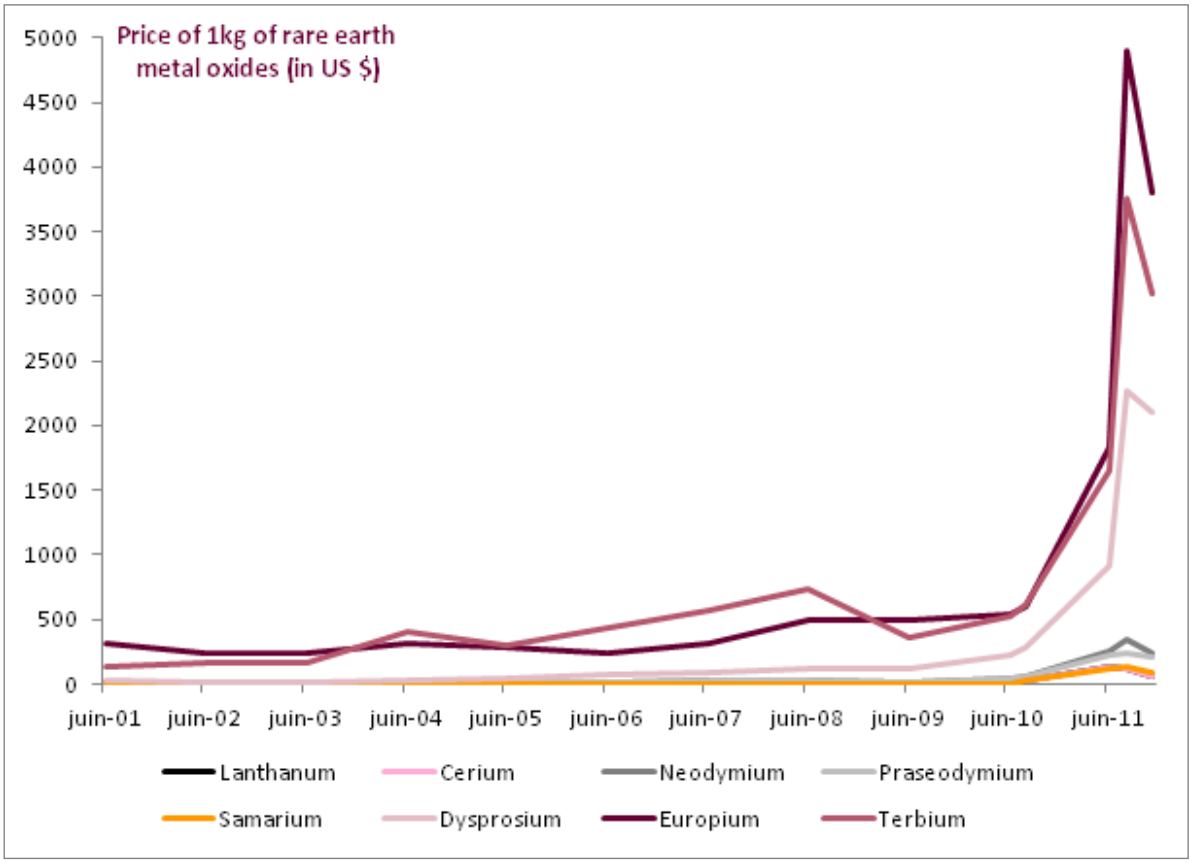
Nowadays, rare earth world demand is 136,000 tons (data from 2010). It is expected that it rises up to 200,000 tons in 2015, as rare earth market grows annually at a rate of 10%, even in the situation of economic crisis we are going through. China will be able to produce approximately 140,000 tons, but it will devote at least 70% to internal consumption. Thus, it is evident that we need to start exploiting mines in other countries and recover the companies and refining technologies that were abandoned in the past due to market laws and a lack of strategic vision. Fortunately, the U.S. has decided to recover Mountain Pass mine in California, which was abandoned back in 2002 because its high operating cost made it impossible to compete with Chinese labor and environmental costs and with this country's state subsidy policy. Mountain Pass mine will produce 20,000 tons this year and it will double its production in 2013.

Now we will explain how important it is that the offer of these materials meets an increasing demand that develops swiftly, in line with new technologies. As the graph below shows (fig. 5), this equilibrium was broken in 2010 when China decided to reduce its exports by 40%.



Source: http://energy.sia-partners.com
Fig.5

As a result, rare earth prices, which had been almost stagnant since 2001, rose dramatically in the second semester of 2010 and the first six months of 2011, as shown in the graph below:



Source: http://energy.sia-partners.com
Fig.6

Fortunately, prices are going down noticeably throughout 2012. Nevertheless, there has been a clear warning: between 2009 and 2011, the price of certain rare earth materials has been multiplied by ten in some cases, by twenty (lanthanum oxide) or even by thirty (cerium oxide). At this moment, despite the relative fall of prices in 2012, they are 500% higher than the prices in 2009. One of the most expensive rare earth materials is europium, whose price has reached at some point 5,000 dollars per kilo, while in 2009 it cost 500 dollars per kilo.

Some countries, such as the United States, Canada or Australia, among others, have reacted by reopening abandoned mines and supporting the companies of this sector. Brazil, India, Malaysia, Vietnam, South Africa and some other African countries (Mozambique, Zaire and Tanzania) also have some reserves. Nevertheless, the equilibrium will not be recovered until

some years have passed. In addition, it is very difficult that offer meets demand, as demand grows swiftly. That poses a problem, especially if China keeps on with its current restriction policy[5].

In order to complete the explanation of the current situation, we will comment on three interesting aspects:

Risk of interruptions in the supply chain

Regardless of the fact that the market may face up dramatic price rises of these metals in the following years, just like it has recently happened, there is another problem that Japan has already suffered, a problem that was a serious warning to all of us: China's decision to cut the supply to a concrete country, as a political instrument of pressure. In 2010, Japan arrested the captain of a Chinese fishing boat in the South China Sea, a sea whose waters are disputed between China and Japan. This caused a diplomatic conflict. As a result, China decided to cut its rare earth exportations to Japan, which caused serious concern in the car industry (Toyota needs 10,000 tons of rare earth annually for its hybrid vehicles) and in the new technologies industry. Both industries are highly dependent on the supply of rare earth. Consequently, the Chinese fishing boat captain was quickly released.

The possibility that China has to deny, cut or slow down the supply of rare earth as a political instrument of pressure is another reason for taking up again rare earth production in countries where there are deposits of these materials. In addition, it is important to reduce the amount of rare earth elements used in the various production processes and find substitutes for their applications. This search has already begun, but it will take long. Toyota, for example, is currently developing an electric engine which needs a considerable smaller amount of rare earth. Toyota has also bought a mine in Vietnam in order to ensure the rare earth supply it still needs.

The fact is that the risk of facing higher prices and problems in the chain supply is real and it could become widespread in the short term if the evaluation made by some analysts who assure that China will keep on reducing its production in 2013 and 2014 was confirmed.

China's investment outside its frontiers

In 2005, little time after Mountain Pass mine in California was closed, the Chinese oil company CNOOC tried to buy the Californian company Unocal, which owned that mine at the time. The United Stated did not allow that. Later, Chevron bought Unocal. However, two years later some Chinese companied tried to buy it again.

[5] This summer we have learnt that Chinese authorities are about to implement new measures that would eventually lead to a cut of 20% in production.

In Australia, another of the few countries that produce rare earth elements, Chinese state mining companies have acquired 51% of Lynas and 25% of Arafura, two companies which aimed to export rare earth outside Australia and were looking for funding.

It has been confirmed that Greenland has significant rare earth reserves, whose extraction will be easier thanks to the ongoing thaw. Europe tries to take part in its exploitation and assure new sources of supply. For such purpose, Mr. Tajani, the current European Commissioner for Industry, visited Greenland the past 16th July in order to subscribe an exploitation agreement for the companies in the EU. China is also trying to enter this market: Hu Jintao arrived in Greenland the following day, which gives an idea of how important are these investments for the Chinese government.

Chinese internal prices

Finally, another remarkable aspect is that China has caused a raise in prices, as we have already mentioned before, putting forward the need to avoid damaging the environment[6] but at the same time it has kept internal prices low, granting internal supply. Chinese businessmen obtain benefit but apart from that, for any foreign company willing to invest in the post production processes, that is, metals separation, refining, creation of alloys or producing parts in order to sell them in the immense rare earth market, it is worth settling in China. There, labor force is much cheaper, supply is granted and prices are 50% lower. The incentive for foreign companies is evident, and it damages the rest of the countries.

All the reasons mentioned above have motivated the U.S., the EU and Japan to bring a lawsuit against China in the WTO last March. They accused China of violating market rules and manipulating prices. This lawsuit has not been resolved yet.

Regarding this lawsuit, President Obama declared that it was necessary to "take over" the energy future of the country and that he wanted U.S. companies to manufacture products in the future, so he asked China to "comply with its engagements as a member of the WTO"[7]. Furthermore, he decided to create an agency aimed to watch and make observe international market rules with other countries, in order to avoid dumping (artificially low prices) and non-tariff barriers. It is also remarkable that the President of the U.S. declared that he would not allow U.S. energy industry to put down roots in another country.

[6] Rare earth materials exploitation is very harmful for the environment because acids and radioactive products are manipulated.
[7] Infobae.com 13-03-12

WORLD RESERVES

The biggest reserves of rare earth elements are located in China (55 million tons), which means between 30% and 50% of the total, depending on the source consulted. China is followed by Russia (19 million tons) and the U.S. (13 million tons). There are some other countries, such as India, Australia, Brazil and Malaysia, which also have some smaller reserves, as we can see in the graph below[8].

Source: U.S. Geological Service.Fig.7

According to other sources, there are also important unexploited reserves in Vietnam (12 million tons), Canada (3 million tons) and Greenland (5 million tons).

FUTURE

At the moment, we are waiting for the WTO to force China stop its abusive commercial practices. It is possible that the WTO eventually achieves this goal, though it is very difficult. It is highly likely that the situation improves to some extent, but the demand of rare earth

[8] The image shows the biggest reserves of rare earth elements. The data are from 2010 and the quantities are expressed in tons.

grows so fast, particularly in China, that during the following years we will probably face a situation of insufficient offer, which will lead to new rises in prices and difficulties to get rare earth in the amounts needed.

Fortunately, the countries which had stopped exploiting their deposits are reopening them. In addition, there are significant reserves that had not been exploited yet, as it has been said throughout this paper. But how long will it take to reach a world production capable of satisfying the growing demand? And what commercial policy will China implement in the future? In any case, at least for the moment, we are going to face up some difficult years.

At the same time, the evolution of the market will depend on the search for rare earth substitutes, new less-dependent technologies and recycling of waste. All these aspects are already being studied. However, these processes of change are slow and the fast development of both computer and energy technology in the world entails that there will surely be a strong demand of rare materials in the following years.

[i]

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NOTE:** the authors of the ***Opinion Documents are responsible for the ideas expressed in them. Those ideas do not necessarily reflect the opinions of the IEEE or the opinions of the Spanish Defense Department.