Rare Earth Elements:
An Arena of Opportunity

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Introduction

Rare Earth (RE) elements include 17 elements, namely Scandium (atomic number 21), Yttrium (atomic number 39) and Lanthanides (atomic numbers 57 to 71 in the periodic table). These are further divided into light RE elements and heavy RE elements. Despite their name, RE, with the exception of the highly unstable Promethium, are fairly abundant in the Earth's crust. Since they occur together, they are also generally produced together and, in economic terms, qualify as an industry.

This article and its contents summarise the aspects and issues highlighted in the recently published reports by the International Strategic & Security Studies Programme (ISSP), at the National Institute of Advanced Studies (NIAS), Bangalore, titled **"Dominating the World: China and the Rare Earth Industry"** and **"Does India Need a National Strategy for Rare Earths?"**. Both these reports are complementary, as they talk about the importance of RE, their application in the military and civil industry, and, more importantly, they go on to provide a holistic assessment of the important issues as indicated by the titles of these reports. The reports trace the evolution of the RE industry in China and shed a great amount of light on the strategy implemented by China as it upstaged the USA to become the dominant force in the RE industry by attaining virtual monopoly. And, they further go on to highlight how the virtual absence of any strategy put in place by India in this field has eroded whatever little presence India had in the raw material part of the RE industry.

RE Elements in Industry

China has upstaged USA to become the dominant force in the RE industry.

RE elements form critical components in a number of important industries. They are critical components of many high technology goods such as hybrid vehicles, mobile telephones, computers, televisions and energy efficient lights. RE elements are increasingly perceived to be of strategic importance not only because of their use in critical defence equipment but also because of their use in major high growth electronic consumer products as well as products for creating a greener planet. RE materials are also used in the phosphor and glass industries as also for making microwave components used in radar and satellite communication systems. RE cathodes are used in vacuum tube devices. These cathodes are used for both radar and space communications systems as well as in ion thrusters for satellites. YAG lasers, which have both military and civilian applications, use RE components. Acoustic devices use RE for variety of applications in the defence sector to include sonar and for noise suppression applications. In hybrid cars, they are used in motors, batteries, catalytic converters and glasses. Yttrium Stabilised Zirconia (YSZ) is also used to make the oxygen sensors for controlling combustion in auto engines. Many emerging technologies like windmills, fuel cells, lower energy consuming Compact Fluorescent Lamps (CFLs) and Light Emitting Diodes (LEDs) also need RE coatings.

RE Global Demand and Supply

RE materials are small contributors to the Gross Domestic Product (GDP), however, they are vital to the well-being of any advanced economy since they form critical components of any advanced product, be it in the military or civilian domain. Without getting into the details of specifics, as highlighted by the reports, suffice it to say that after the discovery of RE in 1787, the first commercial use took place in 1884 to make incandescent mantles for the gas lighting industry, followed by the second commercial use in 1903 and then in 1911 when RE were added in glass to provide colour. The RE industry evolved in the 20th century as a number of applications and commercial uses took place. Particularly in the 1970s, a large number of new applications were developed. One such example was the catalytic convertor, which used RE coatings for controlling pollutants in the exhaust gases of cars, and became a major commercial product with the advent of tighter pollution laws in the US and this subsequently went on to become a global requirement. Another example comprises the commonly used

CFL and LED, which too employ RE elements and which entered the commercial domain in 2005.

The first report on the subject works on a method of nodes to identify the complex linkages between critical input materials and their use in the final products. The outcome of adoption of this methodology points to the fact that RE materials are closely linked to many high-tech sectors of an advanced economy and these are further vulnerable to supply chain disruptions. Another deduction is that whoever controls the supply side, therefore, has the power to disrupt the economies of the advanced countries.

China's Evolution in the RE Industry

China started work on RE in the early 1950s, when the first RE concentrates were produced from mining iron ore from the Bautou mines in Inner Mongolia. China went on to establish its first dedicated Research and Development (R&D) facility for RE, the Bautou Research Institute, in 1963. This was followed by a systematic exploration programme for all commercially and strategically important minerals, including RE elements. China's current domination of the RE industrial ecosystem is the result of a well thought out and carefully crafted dynamic, long-term strategy. China has been using the dynamics of transition of the RE industry from growth into the maturity phase of the lifecycle to build a dominant presence in most RE value chains. In contrast, the USA, which actually pioneered many of the breakthrough discoveries in RE materials, has allowed its once dominant position to be eroded. The closing down of R&D centres as well as reduction in funding has severely curtailed the capability of the US. The first report highlights that today, the US has no industrial capacity in RE having allowed global market dynamics to move them all to China.

The Chinese have followed a long-term national interest in the evolution of the specifics of a medium-term strategy through the five-year plans. These have been made adaptable to the changing global conditions, keeping, the national agenda on top priority, albeit shielded behind other names and companies in the global market. The report mentions that there had been close links between Xu Guangxian, the father of the RE industry in China, and Deng Xiaoping, the Chairman of the Communist Party of China (CPC) and the head of the Politburo. Deng, in 1986, approved Programme 863, a programme with the following objectives:

- Enable China to a gain foothold in the world arena.

- Strive to achieve breakthroughs in key technical fields that concern the national and economic lifeline and national security.
- The areas identified as thrust areas included bio-technology, space technology, information technology, laser technology, automation, energy and new materials.

China has been using the dynamics of transition to build a dominant presence in most RE value chains.

Interestingly, the report points out that the Chinese do not always operate necessarily in a top-down approach as in the case of formulating and executing the highly successful RE strategy. The grand top-down view, in the case of China, has been interlinked and meshed with the lower level ideas on how to further Chinese global and national interests. China took advantage of its trained manpower, both engineers and scientists, as many of them hold powerful positions within the Party and are well connected to the higher echelons of decision-making. This enabled China to craft and execute RE specific strategies in consonance with its Grand Strategy. These included three broad-based inter-related sets of activities:

- Mining and processing.
- Manufacturing and applications including mergers and acquisitions on a global scale.
- R&D.

It was during the last two decades, the report points out, that China initiated a set of actions that were aimed at achieving not just catch-up but also dominant leadership of the global RE industry. As an example, in 1995, China tried to acquire Magnaquench, a General Motors subsidiary, that was making permanent magnets. The US allowed the acquisition post a lot of debate, but with certain conditions which expired in 2002. And since then, the assets of Magnaquench have been moved to China.

Another example of Chinese efforts to acquire dominance in the RE global chain is the attempt to acquire the Mountain Pass Mine in the US. It was at this mine that large quantities of europium, an RE element were found in 1965. Europium is used in the phosphors for the screens of the cathode ray colour television sets and forms part of various consumer electronic products, including CFLs and LEDs. In 1998, the US had closed this mine for environmental reasons. In 2005, a Chinese consortium tried to acquire the US oil giant UNOCAL. This deal did not go through but depicted the importance of the dominance of the global supply chain of RE elements and the Chinese efforts to achieve the same.

China's Current Domination of RE Industry

China today has effective controls on virtually the entire global supply chain of RE. According to a US Government Accountability Office Report of April 2010, China controls 97 percent of the RE ore, 97 percent of RE oxides, 89 percent of RE alloys, 75 percent of the Neodynium Iron Boron Magnets industry and 60 percent of the Samarium Cobalt Magnets. This control extends all the way from mining to the production of key intermediary products like magnets. Many of these intermediary products are key critical inputs for high growth industries such as hybrid cars, windmills and lighting. Two examples are important to explain the way China can use this power. The first is that RE elements are extensively used in Apple's i phones, namely, in its colour screen, glass polishing, phone circuitry, speakers and vibration units. The RE elements used are Y, La, Ce, Pr, Nd, Eu, Gd, Tb and Dy. The second example of how China decided to wield the stick to display to the world its dominance in the RE industry was when post a minor spat with Japan, it imposed a ban on RE exports to Japan, following it up with other actions that further restrict exports.

China also flexed its muscle vis-a-vis the US. In 2007, China cut supplies to W R Grace, a large US producer of catalysts for the petroleum refining industry. In the same year, it also set in place a rationing policy for RE that favoured domestic products. Thus, a message was sent to the various global companies that if they wanted access to RE material, they needed to set up shop in China to get preferred treatment. W R Grace has since then set up shop in China.

Global Impact of Control Over RE

RE shortages and price increase will affect many sectors of an advanced economy. These include not only large economic value adding industries but also many defence products and industries. Post the mature phase that RE industries are in, at present, a slowdown is indicated. However, the use of RE in critical green products like hybrid cars, windmills, lighting and fuel cells and other advanced products suggests that this industry is set to grow again and with China controlling the RE global supply chain. The expected slowdown, as mentioned, may just be the beginning of the next S curve.

The last decade of the 20th century and the first decade of the 21st century have not seen any major breakthroughs in improved technologies in the field of RE; however, efforts are on to explore new alloys to improve performance/ develop new product. The report also raises a possibility that this dominance of China will continue as long as there is a demand for RE intermediates in

key industries. But should current and future research throw up new discoveries and approaches that could well be a substitute for RE in key applications like motors and batteries, the status might alter. However, as the RE elements belong to special positions in the periodic table, they have special properties that may not be easy to replicate/ substitute. The timing of such breakthroughs, should they take place, will, thus, be critical, particularly in the key application segments. The report indicates that in the short and medium terms, China is well poised to take advantage of its dominant position. However, this is not the same as creating a new industry of the future via radical breakthroughs within the Chinese ecosystem. The report argues that this is where the US, Europe and other advanced countries and possibly India have a role to play, by exploiting their capabilities to create new industries through radical innovations, thus, offsetting the Chinese domination.

India has no major presence except in the raw material segment.

India's Status in the RE Industry

Talking of India specifically in the report titled, "Does India need a National Strategy for Rare Earths?", the authors lament the absence of any such strategy. India has no major presence except perhaps in the raw material segment of the global industry. In a few areas like permanent magnets, Indian organisations in the military/strategic sectors have established limited capabilities; however, these have not been transformed into an industrial capability that caters to both domestic and global markets.

Indigenous developments have been successful within the strategic establishments of the country as a consequence of embargos on import of permanent magnets. The major RE elements that are used in magnets are Neodymium, Praseodymium, Dysprosium and Samarium. Samarium Cobalt (Sm Co) magnets have been developed for use in the space programme by joint teams from the Defence Metallurgical Research Laboratory (DMRL) and Vikram Sarabhai Space Centre (VSSC), Starting from the PSLV- D3 flight of 1996, over 5,000 of these magnets have flown on Indian satellites and rockets. The report further goes on to clarify that the researchers were not sure whether these magnets used indigenous or imported RE material. It further states that these capabilities in Sm Co should be easily extendible to the later generations of Nd Fe B magnets.

In the domain of radar and communication products, should India embark on a programme of component and sub-system level capability, the RE availability will become critical. The report points out that though there is a strong case for a major initiative that cuts across the boundaries of various mission organisations within the national security complex, there appears to be no effort currently underway to take an integrated look at both the needs as well as capabilities required. A plan so devised will determine whether RE shortage would disrupt production supply chains or have an impact on the prices of the imported products.

Further, the report explores the use of RE in YAG lasers which are important not only in the defence sector but also in commercially important products in surgery and in the manufacturing sectors. As YAG lasers are presently being imported, any global shortage of the same will impact the prices. Should there be a programme to develop such lasers in the country, an integrated approach on how the developments in the defence sector can be used by the civilian industry and the specific roles of RE materials in such a programme need to be identified and evaluated. The report further suggests that if there are no capabilities to manufacture such lasers in the country at present, the question of whether India needs to invest resources to create these capabilities needs to be evaluated.

As the RE elements form a critical role in any Green Plan that a nation may embark upon, an important question is posed by the report, when it asks," Does India have an overall Green Plan? Do RE have a role in such a plan?"

India and the Western World

At the industry as well as national levels, the current competitive dynamics favour cooperation between the advanced economies and India. These could cover all areas from trade to specific technologies and products catering to the various needs in the commercial and military sectors. The report points out that any further breakthrough discoveries in RE are likely to take place by the Chinese. And should this take place, it would further consolidate and strengthen their global domination in the RE industry. However, any breakthrough, by a joint effort of the Western countries and India, to develop substitutes for RE would erode China's current position. The report also states that though India has a reasonable base in R&D, especially within the public sector mission organisations, its record in converting technology into viable products and services has not been very good. Active interventions would, therefore, be required at the governmental level to change this current state of affairs. The RE industry life cycle concept needs

to be co-opted with the micro level understanding of the dynamics of each RE product to overcome these deficiencies and lacunae. Further, the report suggests prioritising the value chains in the RE plan before proceeding on a path of mutual developments to offset the Chinese domination in the sector.

Conclusion

What stands out from the two reports is that China identified the importance of RE elements much before India, and embarked on a global plan to take control of the majority of the global supply chain. In the process, it also removed the erstwhile dominance of the US and Europe in the sector. India, on the other hand, does not have an integrated policy on RE vis-a-vis its industrial and military sectors, and needs to evolve the same as also consider devising strategies to carry out research in the field of substitutes of RE, that would reduce and subsequently end the need of RE and, thus, the dominance of China in the sector.

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