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India's Challenges in Accessing Critical Minerals

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In June 2019, 10 countries formed a forum called the Energy Resource Governance Initiative or ERGI, to share their mining experiences and advice producer countries to discover and develop minerals like lithium, copper, and cobalt, with minimum impact on the environment. An American-driven venture, the ERGI includes countries that have some of the world's largest mineral reserves. Given the world's focus on de-carbonisation and technological innovation across all sectors, a race for access to critical minerals like rare earths, lithium, and cobalt is heating up. According to the World Bank, the demand for minerals for advanced batteries and magnets used in wind and solar panels as well as defence and telecom equipment could grow by up to 1000 percent in 20 to 30 years. Therefore, when China, which has succeeded in gaining control over the supply chain of these critical minerals suggested using them as a geopolitical weapon by threatening to deny access to these minerals, an alarming world, led by Washington, began to take steps to counter China. It is in this light that the timing of ERGI's establishment is being perceived as a strategic initiative.

As India takes its place as a frontrunner in adopting clean energy, its demand for renewable energy equipment will increase exponentially. However, India is deficient in many of the minerals that are required for the manufacture of renewable energy hardware. Moreover, with the recent hardening of relations between New Delhi and Beijing, India's dependence on China for equipment like solar panels and batteries render it vulnerable to any disruption in supplies. This article looks at China's strategy in acquiring strategic minerals, and the response of other nations, including India, in ensuring the security of their critical minerals supply chain.

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One of the main objectives of economic warfare is the conquest of markets and scarce resources. Nothing illustrates this better than the numerous conflicts over the control of hydrocarbons, mainly oil, not least because they are non-renewable resources, but are critical for the economic growth of nations. However, as the digital age encompasses almost every aspect of human life, and technological prowess is increasingly perceived as necessary for global leadership, the battle for other natural resources is heating up. As global warming and climate change concerns take up more space in international negotiations, the demand for renewable energy (RE) has surged, with many countries making huge strides in increasing the share of RE in their overall energy basket(s). In fact, the generation from renewable energy is expected to expand by 50 percent in the next five years. The EU has set a target of 20 percent from RE for 2020, and 32 percent by 2030, and Europe is currently leading in EV sales with 57 percent growth for the first half of 2020. Latin America has pledged 70 percent of their energy from RE by 2030, while West African states are aiming for 38 percent by 2030. China is aiming to get 28.2 percent of their overall energy basket from renewables by the end of 2020, and by 2025, it expects EV sales to represent 25 percent of all car sales in the country[1].

India too is emerging as one of the largest green energy producers in the world. Growing at 2.5 times, the fastest rate of RE capacity addition among the large economies over the last six years the end of October 2020, India's total RE installed capacity has reached over 89.63 GW, according to the Ministry of New and Renewable Energy. RE now constitutes over 24 percent of the country's installed power capacity and around 11.62 percent of the electrical energy generation. An additional 49.59 GW of RE capacity is under installation, and another 27.41 GW capacity has been tendered, making the total capacity already commissioned/in the pipeline at around 166.63 GW[2].

However, while RE is seen as a more sustainable alternative to hydrocarbons, the minerals and metals that are required to make RE equipment - like solar panels and wind turbines as well as storage batteries–are not renewable and are, in fact, as finite as hydrocarbons. Moreover, these minerals are geographically confined to a few countries, thereby triggering a race among nations to gain access to them–quite akin to the race for controlling oil sources that began in the 1930s. According to a World Bank report titled, 'Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition', published in May 2020, the production of minerals like graphite, lithium and cobalt will need to be significantly ramped up by more than 450 percent by 2050 from 2018 levels to meet the demand from energy storage technologies. Any shortage of supply could impact the speed and scale at which certain technologies can be deployed globally[3].

The minerals and metals that are, and will be, most in demand include high impact minerals like graphite, lithium (also known as "white gold"), cobalt, and vanadium as well as conventional metals such as copper, molybdenum, and aluminium, all of which are intrinsic to energy storage equipment in the form of electric vehicle (EV) batteries and power grid stabilisation for the generation of wind and solar energy[4]. With regard to minerals, rare earth elements (REE), which are a set of 17 chemical elements in the periodic table–comprising 15 lanthanides plus scandium and yttrium–are necessary components of more than 200 products across a wide range of applications, especially high-tech consumer products such as cellular telephones, computer hard drives, electric and hybrid vehicles as well as flatscreen monitors and televisions. They are also used for defence applications, such as electronic displays, guidance systems, lasers and radar and sonar systems. Although the REE used in a product may not be of a significant amount, they are necessary for the device to function[5].

Hence, if States have to transition to clean energy, or stay ahead of the fast-paced technological changes that are taking place across sectors–from telecom, information technology as well as defence–they have to ensure that their access to these minerals are assured. But, as history has shown us, the behaviour of States when securing their supplies of critical resources is competitive, even conflictual, with producer States often using their resources as strategic weapons to be used to gain political and strategic leverage. This is particularly true of minerals like REE as well as lithium and cobalt, where one country, namely China, has gained control of global supply lines and, on more than occasion, has indicated that it may use its control over the REE supply chain for politico-strategic reasons.

The Supply Challenge

Although China was one of the first countries to locate its REE resources in 1927, it was the USA that dominated the sector since it was first discovered (by accident in 1949) at Mountain Pass, California. By 1953, Molycorp (Molybdenum Corporation of America), which bought the mine, begun extracting a number of REEs, as scientists began to discover new uses for these materials. Till the mid-1990s, Molycorp dominated REE production as well as exports, and supplies were adequate. However, due to a sudden spurt in Chinese production, combined with environmental legislation in the USA, prices fell, which in turn caused production in the USA to drop, leading to supply shortages[6].

China started production of REE in the 1960s. Several mines containing some of the highest value REEs were discovered in the 1980s, and Beijing began investing heavily in the research and development of REE technologies. By 1989, it had averaged an increase in production by 40 percent; and by the 1990s, exports had increased rapidly, causing prices to plummet–although many believe that this was a deliberate strategy to put China's competitors out of business[7].

As China's mining capacity expanded, REE producers in other countries began to shift their production lines to China to benefit from the country's low labour costs and lax environmental regulations. But soon thereafter, Beijing placed its rare earth sector under the protected and strategic minerals category, prohibiting foreign firms from mining in China and restricting foreign participation in REE processing projects to joint ventures with Chinese firms. These partnerships not only allowed Chinese companies to gain access to the technology but also enabled them to cut out foreign competition from the supply chain[8]. As a result, by 2008, China accounted for more than 90 percent of world REE production, and 97 percent by 2011[9].

China's intention to dominate, indeed to control, the global REE (as well as other critical minerals) trade can be surmised from Deng Xiaoping's famous words, which is believed to have been said as far back as 1987. He said that, "The Middle East has its oil, China has rare earth"[10]. Deng also encouraged some departments in Chinese universities to devote themselves to REE processing technology, thereby providing China the technological advantage that continues till today. More recently, President Xi Jinping also decreed that, by 2025, China would be independent of the rest of the world in 10 key high technologies, many of which are critically dependent upon REE, especially rare earth permanent magnets[11].

Apart from mining and processing, China also sought to capture the super-magnet market. These magnets, which use REE like samarium and neodymium, are used to manufacture commercial and military equipment. Two companies - General Motors (GM) and Hitachi–acquired the patents for the manufacture of magnets. In 1995, two Chinese groups joined forces with a US investment firm and tried to acquire Magnequench, which is owned by GM, to produce the magnets. Although the US government allowed the deal to go through on the condition that the Chinese kept the company in the USA for at least five years, the day after the deal expired, the company shut down its US operations and relocated to China, taking the technology with them. An equally aggressive *modus operandi* was employed *vis-a-vis* Japanese companies. As a result, while in 1998, 90 percent of the world's magnet production was in the USA, Europe, and Japan, within a decade most of the magnet industry had moved to China, where it remains till today[12].

Moreover, China does not want any of its companies to assist foreign entities to develop any aspect of a complete REE supply chain. To add to that challenge, even as the demand for REE-infused components is set to grow, China has sharply restricted domestic REE mining, ostensibly to meet global standards of health and environmental safety. In fact, it is set to import nearly 40 percent of its requirement for REE ores[13]. The concern is that China will try and gain even greater access, indeed control, of REE resources worldwide, given its past behaviour. In 2005, it tried to make a deal with UNOCAL, which had bought Molycorp and the Mountain Pass mine. However, the US government did not allow the deal to go through. A similar Chinese attempt in 2009 to acquire a majority share in Lynas Corp. – the owner of the Mount Weld mine in Western Australia, the richest source of rare earths outside China–was also unsuccessful, although a Chinese company managed to acquire a 25 percent stake in another northern Australian mine. However, despite the USA's best attempts, it had to yield its position as the leading researcher in the field of REEs to China which, under the latter's Five Year Plans succeeded in establishing dominance over not only raw materials but also in REE processing as well as downstream industries[14].

Today, with reserves of 44 million tons (m.t.), China is the leading producer of REE, producing around 120,000 m.t. a year. However, several other countries also have substantial reserves of REE. Brazil has 22 m.t. of reserves, the second highest after China–although its production is much lower, at 1,000 m.t. Vietnam also has around 22 m.t. but produces 400 m.t. only. Conversely, Russia–which produces a comparatively larger amount at 2,600 m.t.–has only 12 m.t. of reserves. Fifth is India, with 6.9 m.t. of reserves. But, although it produced 1,800 m.t. in 2018, the country's rare earths industry is believed to have strong potential, with nearly 35 percent of the world's beach and sand mineral deposits containing monazite–which is a significant source of REE. In 2018, Australia produced the second highest amount of REE at 20,000 m.t., despite the fact that it has only the sixth largest reserves, at 3.4 m.t. Finally, USA with reserves of only 1.4 m.t., produced 15,000 m.t. of rare earths in 2018–up from zero production in 2017. All of this came from the Molycorp's Mountain Pass mine after it went back into production in the first quarter of 2018–although it continues to send REE oxides to China to be processed[15]. Some recent studies have also suggested that North Korea may hold the world's largest REE reserves, with initial assessments indicating a mineralisation potential of 6 billion tons, with over 216.2 m.t. of rare-earth-oxides. This suggests its potential to becoming a key player in the rare earth industry. This fact has not been lost on China, which has already secured many mineral resources in North Korea. Russia, too, has shown an interest in these minerals[16].

Given that REE reserves account for around 120 m.t. globally[17], and therefore cannot be deemed 'rare', they are found only as constituent parts of larger minerals, thereby making their extraction an expensive endeavour. Moreover, apart from Japan and China, no other country has developed the expertise for the entire process involving REEs–viz., mining, processing and separating the minerals, converting them to alloys, and then converting them to magnets, catalysts, or other intermediate products. The entire process is highly capital–intensive as well as environmentally damaging due to the chemicals required for the extraction of REEs from other ores. Few companies want to risk millions invested in a venture where they would have to absorb the costs of mining, processing, and separating low-value minerals that may not find buyers.[18] As one Canadian company official said, 'It's a very high risk for a company to begin committing hundreds of millions of dollars when you don't control your destiny–if the price goes up, China can still bring it down'[19].

Apart from REE, other minerals that are critical for the next phase of the technological revolution include lithium and cobalt and, more recently, valadium and graphite. While 90 percent of the world's cobalt (used to make cathodes which provide a source of power in batteries) reserves are found in the Democratic Republic of Congo (DRC); lithium, which is the lightest of all metals and provides the greatest electrochemical potential in combination with cost advantages for storage batteries, both for renewables as well as electric vehicles, is found mainly in a handful of South American countries: Argentina, with 17 m.t.; Bolivia, with 21 m.t.; and Chile with 9 m.t. Lithium is also found in Australia, which is estimated to have 6.8 m.t., followed by China with 4.5 m.t.

Unsurprisingly, Chinese companies have pursued investments in both South America's and Australia's mining sectors to ensure that they continue to dominate the minerals supply chain. A Chinese company became the second largest shareholder in a Chilean mining company, and also holds 51 percent stake in the world's biggest lithium mine in Australia[20]. Beijing is also trying to expand its presence and control minerals like vanadium and graphite. While vanadium is used in flow batteries, super-conducting magnets, and high-strength alloys for jet engines and high-speed aircraft, graphite is a crystalline form of carbon whose high conductivity makes it a major component in electrodes, batteries, and solar panels, as well as industrial products like steel. China has been securing additional supplies and building an integrated supply chains of vanadium from South Africa, which is the third largest producer after China and Russia, and has signed agreements with three firms in Mozambique for supplies of graphite, despite being the largest producer of graphite itself[21].

In fact, today, China has become the dominant producer of five out of the six critical minerals used for making hi-tech equipment, including REE, graphite, indium, gallium, tantalum, and cadmium. It controls more than 75 percent of the world's supply of at least three, and has consolidated its hold over them. Although it still lacks the technological expertise to produce many of these items (including magnets and semi-conductors) that are at par with the industry's leading companies and remains highly dependent on imports, it is spending huge sums of money to acquire the technological know-how, not only to become self-sufficient in these items but also to control the market for them[22]. If China decides to restrict its exports, it could set off a global shortage of REEs, which in turn could have serious consequences not only for the world's transition to renewable energy, but would also increase the reliance on China-sourced technologies for critical equipment.

Threat of Chinese Dominance

Despite many indications, it was not until the 2010 incident that the international community woke up to the consequences of dependence on one supplier for REE. In 2010, after Japan's detention of the captain of a Chinese fishing trawler following a collision with two Japanese patrol boats, China blocked the export of REE to Japan–the main buyer of Chinese rare earths. Given that China and Japan were the only two sources of semi-processed blocks of rare earth magnetic material, the materials export ban had repercussions for all countries as they would now have to rely on China for the same[23]. More concerns were voiced in 2019 when China indicated that it might 'weaponise' its control over rare earths in its trade dispute with the USA.

This occurred after Beijing made threats to curb global supplies in retaliation for the trade war imposed by the USA on China. In fact, despite several WTO rulings against Chinese export quotas, Beijing has continued its policy of both restricting the export of raw materials and REE-containing finished products, instead of just raw materials. In August 2020, China cut REE exports by 62.3 percent from the previous year[24]. Moreover, with China's own demand growing for supplies for their Belt and Road Initiative as well as its focus on end-products, Beijing embarked on an extensive acquisition strategy**,** building links with countries that have significant reserves of both REE as well as other critical minerals. It has worked to provide alternative sources of financing *sans* the funding conditions many developed countries impose. Taking advantage of the drop in metal prices between 2011-2015– partly due to China's subsequent relaxation of export quotas, but which left several mining companies starved of funds–Chinese firms acquired mines, bought equity in natural-resource firms, and invested in new projects, thereby gaining control or influence over global production of these resources. Today, Chinese companies own or control over half of the DRC's cobalt production and hold a massive stake in its mining industry. It has also expanded its presence in other mineral-rich countries, including South Africa, Latin America (Chile, Argentina and Brazil), and Australia[25].

It should, therefore, come as no surprise that, in its report, the World Bank warned of significant supply risks for REE and other minerals. According to a 2020 report, the production of lithium and cobalt may increase by 500 percent by 2050 to meet the clean energy demand alone. Similarly, the research and advisory services firm, Adamas Intelligence, has said that the demand for certain rare earth minerals (like neodymium, praseodymium, dysprosium and terbium, used for making magnets) will be 'astronomical', and will grow at a compound annual growth rate of 9.7 percent percent till the 1930s[26].

As demand grows, supply shortages will lead to higher prices. While higher prices could lead to substitution with alternate minerals and metals, and the recycling of metals can also generate more supply, this varies across the metallic spectrum. For example, the recycling of lithium is currently non-existent due to both technical difficulties in recycling lithium batteries as well as the fact that there is not sufficient accumulation of stocks to recycle. Moreover, many clean-air technologies require a purity of metallic input that cannot be achieved by the current recycling capacity. This means that the need for primary mined metals and minerals will only increase, which will make countries which do not have adequate supplies, increasingly dependent on China[27]. And, with China's exports of rare earths decreasing in recent years, with the total export of REE down by 23.5 percent year-on-year in 2020[28] (the lowest since 2015), there could be a further shortage in the coming years.

Call for Action

The 2010 Japan-China dispute over REE trade acted like a wake-up call for many nations. Prices of REE and magnets soared as supply concerns grew, setting off a scramble for alternatives. However, till 2018, Japan was the only country to have achieved some success at reducing its dependence on China – from 91.3 percent in 2008 to 58 percent in 2018[29].

Global concerns increased further when, in May 2019, amid an escalating trade war, Chinese state media warned that the country might halt rare-earths exports to the USA. The Chinese Communist Party's mouthpiece, *The People's Daily*, even asked 'could rare earths become China's counter-weapon against the unprovoked suppression of the US?'[30].

As the largest importers of Chinese REE, the USA and Japan have made it a priority to diversify their sources of rare earth metals. After adding REE to its list of critical minerals, the former US President, Donald Trump, issued an executive order in 2019 that local production should be encouraged. Japan too is determined to cut down its REE imports from China's to less than 50 percent by 2025. However, according to some reports, the US Department of Energy has told government scientists not to collaborate with MP Materials– the owner of America's only REE producing facility, the Mountain Pass Mine – as a Chinese investor owns almost 10 percent of the company, and relies heavily on Chinese sales and technical know-how. American government scientists are currently studying ways to recycle rare earth magnets to find substitutes and to locate new sources of the strategic minerals, none of which is shared with MP Materials[31]. Other countries with REE reserves were also encouraged to increase mining and, by 2019, succeeded in reducing China's global share of mining from 97.7 percent in 2010 to 62.9 percent.

Nonetheless, 80 percent of rare earth refining continues to be under Chinese control, with most REE, mined outside China being sent there for processing[32]. However, new facilities in the USA, as well as, Canada and Australia are being set up to address this problem. The US Department of Commerce has vowed to take 'unprecedented action' to secure 'critical mineral' supplies, including REE, which includes accelerating the process for mining permits to increase the production, increasing R&D, and expanding trade with allies. The Department of Defence was also tasked to increase production of rare-earth magnets, while Australia announced that it would boost production to secure supplies for itself and its allies[33]. Despite these initiatives, managing the environmental impacts of processing rare earths remains a challenge for these countries.

Meanwhile, in June 2019, the US State Department announced the formation of an Energy Resource Governance Initiative (ERGI), which is intended to find new sources for critical minerals, including rare earths. Ten countries, some with the largest reserves of critical minerals, have joined the initiative with the intention of sharing their mining experiences and advising producer countries on how to discover and develop minerals, including REE, lithium, copper and cobalt, with minimum impact on the environment.

Nonetheless, although new sources of REE are emerging, and a concerted effort is on to cut the overwhelming dependence on China, the latter still controls 98 percent of REE production, including dysprosium which is needed for making permanent magnets, and which are used in a variety of renewable equipment, including EV batteries and wind turbines. Furthermore, the various stages of producing REE and converting them to magnets are not only very capital-intensive but also environmentally damaging, which in turn draws criticism from environmental groups and lobbies[34]. Therefore, other countries need to find alternative sources for the entire REE supply chain–from raw materials to finished products–with least damage to the environment. Till then, the world will remain reliant on China.

The Challenge for India

India produces 95 minerals, including atomic, metallic, and non-metallic minerals. The metals and minerals that are deemed 'strategic' are: tin, cobalt, lithium, germanium, gallium, indium, niobium, beryllium, tantalum, tungsten, bismuth, and selenium. The rationale behind deeming them being 'strategic' is that they have few substitutes, and are available only in a few countries. They are also technologically difficult to extract, have limited supply potential yet whose demand is expected to escalate, are subject to abstract mining regulations and legislative regimes, and entail environmental risks. However, they are important across sectors–from energy to health, communications, and national security, and defence[35].

Unlike most other countries, India's REE are derived mainly from monazite (found in beach sands) as against ionic clay. In fact, India was one of the first countries to realise the importance of rare earths way back in the 1950s, and had even set up Indian Rare Earth Ltd. (IREL) to extract the minerals. However, it did not exploit its early advantage in becoming a major source of REE; instead, around 2007, mining and development of REE were frozen due to a lack of competition in the domestic market. This not only prevented investments in the mineral and manufacturing processes but also pushed large industrial consumers to source their mineral needs from the global market, particularly China. Now, with relations between the two countries becoming increasingly tense (especially after the recent skirmishes in the Galwan Valley), the government is cognizant of the growing risk of being dependent on China for the supply of critical materials and equipment, given Beijing's penchant for using its market control for strategic ends.

However, over the years, India has progressed from only mining activities to setting up facilities for separating REEs, albeit not on a commercial basis; but it has yet to gain the know-how for further valorisation, including REE processing and producing magnets, which places it in the category of only a low-cost raw materials provider[36]. Moreover, despite owning around 6 percent of the world's REE reserves India's share of rare earth oxide production is less than 2 percent of the total world production, making it dependent on China for both raw materials as well as end-products.

Nonetheless, after the 2010 Japan-China episode, Tokyo turned to India for the supply of REE, and both countries, in fact, signed a deal in 2011 to set up a plant in Vishakhapatnam to produce rare-earth oxides[37]. In 2016, a report by the Council for Energy, Environment and Water (CEEW), titled 'Critical Non-Fuel Mineral Resources for India's Manufacturing Sector: A Vision for 2030', recommended that India should increase domestic exploration and mining as well as acquire the know-how in mineral processing technologies. It also recommended that India make the strategic acquisition of mines as well as diplomatic and trade agreements with other countries a priority[38].

Realising the vast potential of its REE reserves, and in accordance with its policy of *Aatma Nirbhar*, IREL recently announced plans of setting up a Rare Earth and Titanium Theme Park in Madhya Pradesh. This envisages setting up a pilot plant based on laboratory scale technologies developed by BARC and other research institutes to encourage the production and consumption of REE within the country, and to facilitate the setting up of a value chain in the sector. It is also in the process of setting up a plant producing permanent magnets at Visakhapatnam, based on indigenous technology[39].

However, while India does have the means to develop its REE potential, the same cannot be said about other critical minerals, like lithium, cobalt, and nickel. This is presenting a challenge to achieving the goal of its renewable energy target of 450 GW by 2030, as also to the goal of electrification of transport, without remaining–indeed increasing–its dependence on the imports of the requisite minerals and materials.

Recently, some lithium reserves were discovered in Mandya, Karnataka. However, these are not sufficient to meet India's huge and growing demand for lithium, given its ambition to become a major supplier of li-ion batteries. To address the problem, the government plans to buy lithium stocks to ensure supplies that could potentially last decades, and make India self-reliant. It has also formed a joint venture to form Khanij Bidesh India Ltd. (KABIL), comprising three public sector companies–the National Aluminium Company (Nalco), the Hindustan Copper Ltd (HCL), and the Mineral Exploration Corporation Ltd (MECL) – to scout for strategic mineral assets, like lithium and cobalt (particularly in Australia and South America), acquire mines abroad, and participate in the exploration and processing of strategic minerals overseas to meet domestic requirement[40]. Moreover, reforms have been introduced in the country's mining sector which will provide more incentives for mining activities.

Apart from domestic initiatives, India is also looking at partnerships with like-minded countries to ensure diverse sources of supply. According to media reports, the four Indo-Pacific Quad members–comprising of India, Japan, Australia, and the USA–are working together, and pooling resources to rapidly build collective self-reliance in the critical minerals sector. In September 2020, the trade ministers of Japan, India, and Australia agreed to hammer out details of a new supply chain network– which is likely to include REE–by the end of the year. Further, while Japan and Australia have formed a partnership following the China-Japan conflict in 2010, in June 2020, Australia and India reportedly inked a preliminary agreement for supplying critical minerals. A deal has also been signed between Australia and the USA, whereby Lynas would process mined minerals in Texas in partnership with the Pentagon, while another Australian company, Syrah has earmarked a production line in the USA for manufacturing REE downstream equipment[41].

However, India should aim at gaining knowledge and expertise in the processing and valorisation of REE. Although India has the capability of separating and extracting dysprosium from monazite, it has not commercialised the process. By commercialising the separation process and supplying dysprosium of high purity (which is used for making neodymium magnets) to Japan, and eventually manufacturing neodymium magnets possible with Japanese cooperation, India can valorise its REE, and gain both economically and strategically. Currently, India's R&D efforts are believed to have progressed to samarium-cobalt magnets, which are used for space activities, and are a predecessor of neodymium magnets.

Overcoming Chinese Monopoly over REE

From REE to lithium, to cobalt, several countries are racing to explore and develop their own sources of these materials[42]. However, despite the slew of activity by numerous countries, and several government initiatives aimed at establishing alternate rare earth supply chains that would alleviate their growing reliance on China, these have been piecemeal at best. The main reason is that while access to rare earth ores is not a challenge as they are available in and from many countries (including Vietnam, Brazil, India, Australia, Canada, and Greenland), few countries, apart from China and Japan, have acquired the knowledge and expertise in the complete value chain–from raw materials to permanent magnets. While Japan makes superior magnets, they are more expensive; moreover, Japan is dependent on REE ore imports.

However, given the importance and growing demand for critical minerals, no country can afford the risk of having its supply being curtailed or stopped. Hence, governments need to do the following. First, both governments and the private sector will have to commit to large sums of capital to build the requisite facilities that can compete with the Chinese. But, given Beijing's control over production and exports and hence pricing, most companies are wary of losing money to price manipulations. As a result, non-Chinese producers are presented with a Catch-22 situation in which, in a reflection of OPEC's tactics, China could flood the market with REE, which would cause prices to drop, and force companies to go bankrupt. Hence, there is a need for developing processing technology that selectively separates high market value minerals economically.

Second, supportive legislation for the sector is required to encourage investment. In order to allay local opposition to mining activities, legislation allowing local communities to share the company profits could be imposed. This would also ensure the accountability of the mining companies in various fields. Third, environmental issues will have to be dealt with sensitively. REE extraction produces hazardous by-products, like toxic gases and radioactive waste water. More R&D will have to be developed to lessen, even eradicate, these environmental hurdles. The good news is that new technologies which cause less harmful environmental damage are being discovered, although China is, once again, at the forefront of such technologies.

Finally, a feasible, albeit difficult, means by which the above issues can be resolved amicably is through recycling rare earth metals. No doubt it is a lengthy and challenging process, involving de-magnetisation (by heating), crushing and roasting, followed by a leaching process, and separating materials that are embedded in devices before a rare earth oxide can be produced. However, this would reduce the need for mining and other environmentally harmful processes if these minerals can be derived from discarded cell phones as well as IT and energy equipment. Moreover, over time, it could be cost-effective while maximising the use of these minerals. Also, a lot of research is going into finding extraction methods that use less-harmful chemicals, while EV manufacturers are looking to reduce, even eliminate, the use of REE by replacing magnets with copper windings or using motors that do not require magnets.

Be that as may be, it is time for other nations to put their REE mining industry on a level playing field with China's, given the criticality of these minerals for grave issues like energy transition, defence, communications and, indeed, overall national security. It is, therefore, imperative that the world's focus should be on maximising ongoing efforts to consolidate critical raw materials, and gain access to the entire processing and end-use technology. There is an urgent requirement to understand strategic industries, and the long-term investments needed to expand and diversify the supply chain of these critical minerals and metals. There is also a need to impose international regulatory mechanisms to ensure affordability and open access for the same. The good news is that several countries have woken up to the danger of economic and strategic dependence on one source country.

Thus, it is time to consider innovative policies in place.

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