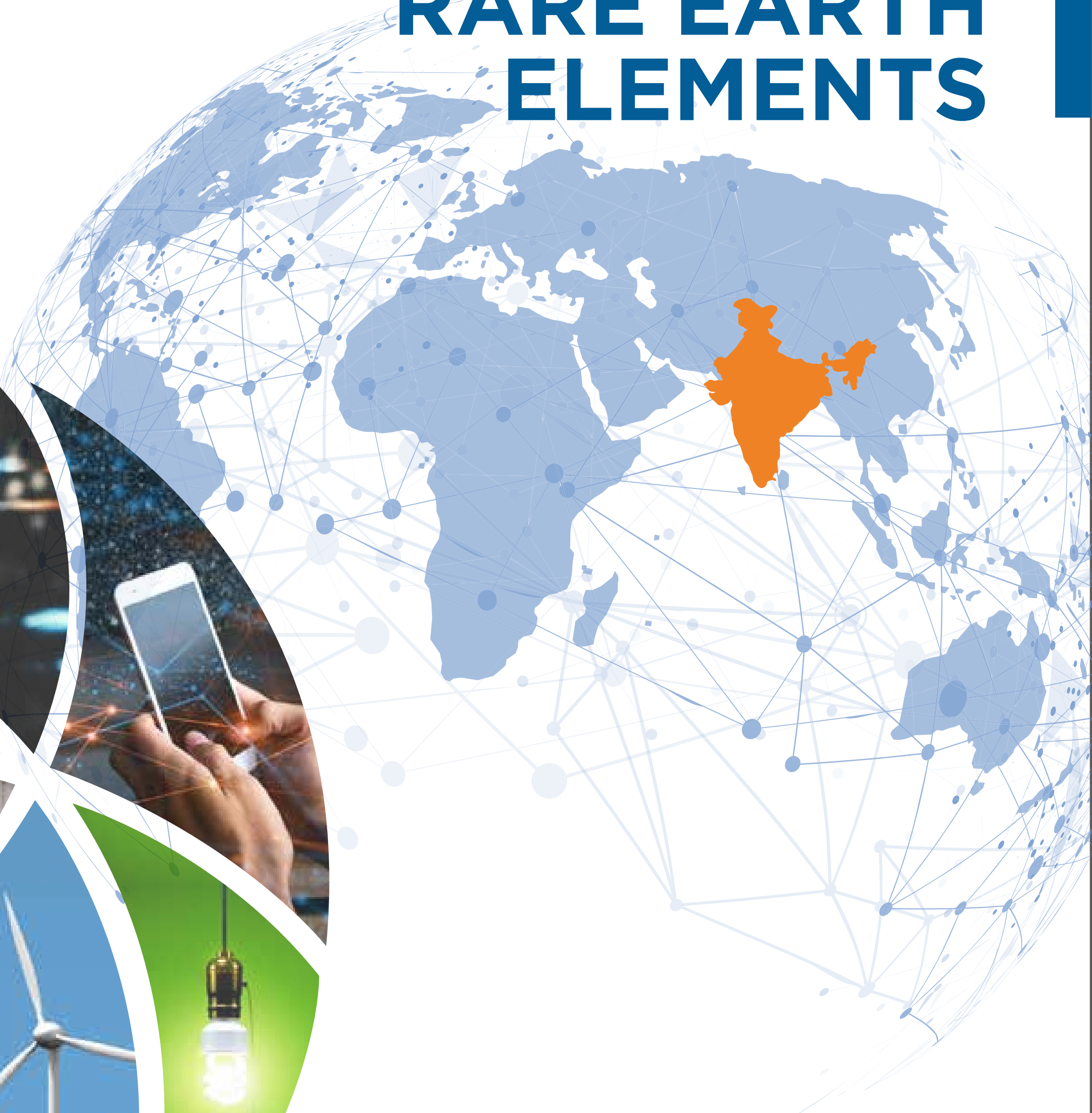
INDIA SECURING RARE EARTH ELEMENTS



Working Paper No: 97

India Exim Bank

EXPORT-IMPORT BANK OF INDIA

WORKING PAPER NO. 97

INDIA SECURING RARE EARTH ELEMENTS

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1.

Introduction

The world is evolving at a very significant pace ever since the turn of this century. Amidst these phenomenal and unexpected developments impacting countries across the globe, long-term security in supply of key resources remains a cause of significant concern than ever before.

India which has assumed an important stature in the global arena desires to remain self-sufficient and produce goods by itself within its own geography. In fact, the propensity to focus on self-reliance has assumed importance now, again, especially after witnessing the pandemic situation globally, which took the world by storm beginning 2020.

To realise the aforesaid, the Government is increasingly being proactive to facilitate and allow investors from abroad to open shops in India. This will not only help India to produce goods for itself but also facilitate exports to other geographies.

Amidst this, it is also pertinent for India to secure typical raw materials / resources which are required to manufacture, especially high technology products in the country. Manufacturing of high-tech products requires availability of rare earth minerals.

Thus, securing such rare earth minerals are of paramount importance for achieving self-reliance and long-term security of the country. It is pertinent to note that manufacturing of products across industries such as defence, aerospace, electronics, electrical equipment, including renewable energy, is highly dependent on the rare earth elements (REEs).

It will not be out of place to mention that India had taken cognizance of such a need soon after its independence, with the Government of India establishing the Indian Rare Earths Limited, a Public Sector Undertaking, as early as in the year 1950.

While the status of REE reserves is well known, the extraction of the same is highly complex. This complexity arises not just from the view point of economic viability of operations, but also the various environmental and radioactive risks associated with its mining. In fact, the US was one of the first few countries to have taken the step for the extraction of REEs from its Mountain Pass mine in California.

It is also important to note that high-tech manufactured goods including the products in the electronics industry are some of the most demanded goods in the world.

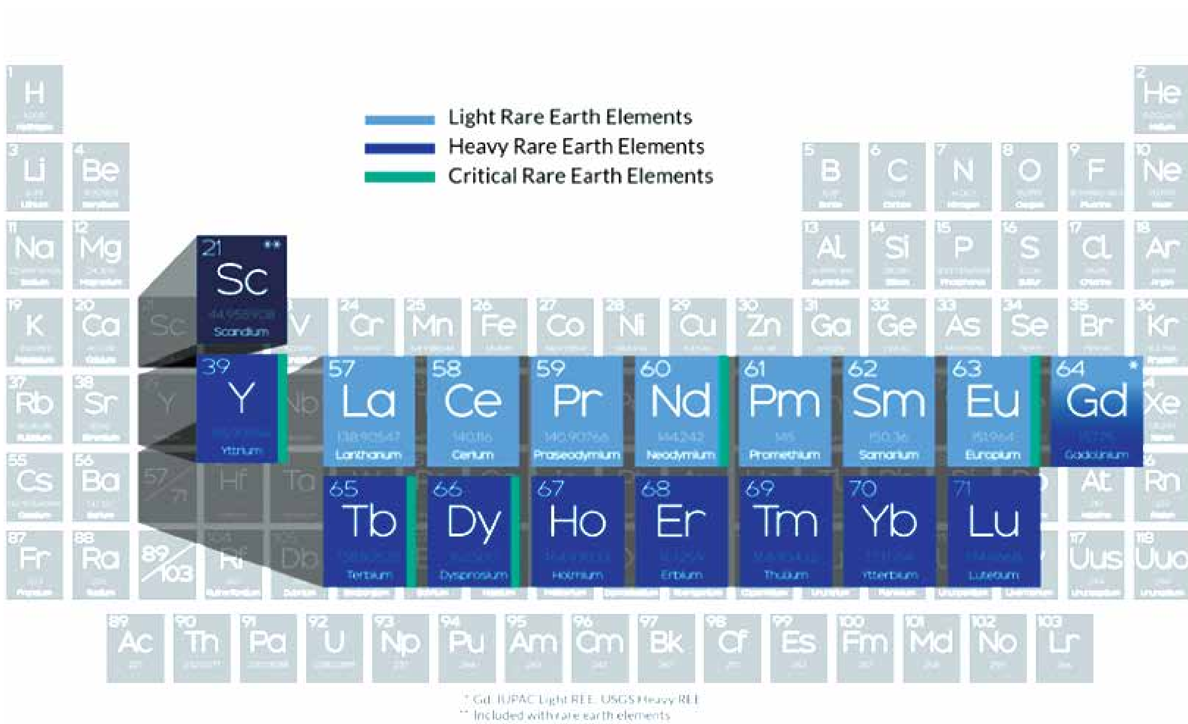
Given that China has the largest reserves and was ready to incur the risks associated with the extraction of the REEs, the world, including India, became increasingly dependent on China, especially in the last few decades.

As the Government is increasingly giving thrust to campaigns such as ‘Make in India’ and ‘AtmaNirbhar Bharat’, the need to secure critical resources like REEs becomes a paramount need.

This Study has made a concerted effort to highlight the status and availability of REEs globally, and in India. The paper also highlights the exact need for REEs in India, and the need to secure rare earth assets.

An attempt has also been made to understand the initiatives taken by other countries globally to secure such strategic resources. The paper delineates a few strategies that India may like to take keeping in mind the evolving global scenario and securing its growth prospects for industries which would need REEs to prosper and grow.

Exhibit 1: Rare Earth Elements - The Lanthanide Series Including Scandium and Yttrium



Source: Adapted from National Energy Technology Laboratory, Department of Energy, USA

2.

Overview of Global Rare Earths

Introduction

The rare earth elements (REEs) are a set of 17 metallic elements. These include the 15 lanthanides on the periodic table plus scandium and yttrium. The rare earth elements are all metals, and as a result, they are often termed as the "rare earth metals." However, these metals are very difficult to mine because it is unusual to find them in concentrations high enough for economical extraction.

The 15 lanthanides are lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium.

Thulium and lutetium are the two least abundant rare earth elements; however, they each have an average crustal abundance that is nearly 200 times greater than the crustal abundance of gold.

The most abundant of the REEs are cerium, yttrium, lanthanum and neodymium. They have average crustal abundances that are similar to commonly used industrial metals such as chromium, nickel, zinc, molybdenum, tin, tungsten, and lead.

REEs were first discovered in 1788. However, global annual REEs production and consumption was less than 5000 metric tons of rare earth oxides (REO) before the 1950s, and until the 1960s, they were even rarely used in the daily lives of the people. Since the 1960s, rare earth applications gradually expanded to everyday life, and found utilities in manufacturing of television screens, the petroleum industry, and computer systems; therefore, the global REEs production and consumption have seen a significant increase in recent decades.

Due to their unusual physical and chemical properties, such as unique magnetic and optical properties, REEs have diverse applications that touch many aspects of modern life and culture. Specific REEs are used individually or in combination to

Table 1: Consumption of Rare Earths by Industries in India (in tonnes)

Industry	2015-16	2016-17
Total	**63.8**	**1867.9**
Rare Earth Compounds Producers	31.9	1862
Paints Driers/Pigments	-	-
Cinema Arc Carbon	-	-
TV Colour picture tube	0.9	1.0
Glass/Optical polishing	0.09	1
Glassware decolouring	3.9	0.4
R&D and others	27.01	3

Source: Indian Minerals Yearbook 2018

make phosphors—substances that emit luminescence—for many types of ray tubes and flat panel displays, in screens that range in size from smart phone displays to stadium scoreboards. Some REEs are used in fluorescent and LED lighting. Yttrium, europium, and terbium phosphors are the red-green-blue phosphors used in many light bulbs, panels, and televisions[1].

According to United States Geological Survey, as of 2018, there are 120 million tons of rare earth deposits worldwide, including 44 million in China, 22 million in Brazil, 22 million in Vietnam and 18 million in Russia. Yet, almost 89% of the world's rare earth elements output was mined by China until 2011. The number still stands at over 70%.

However, it may be noted that producing rare earths creates toxic waste water, gases and tailings - left-over materials that are not sellable - which includes ammonia and thorium that are environmentally hazardous, including causing severe damage to the lungs and liver. China's relatively weak environmental regulation and low prices for chemicals and labour had given its rare earth producers a competitive edge.

GLOBAL SCENARIO

Reserves

According to the United States Geological Survey (USGS), the total world reserves of the REEs were estimated to be around 120 MT in 2018. Out of the 120 MT, China alone accounted for the 37% of the global reserves and is followed by Brazil and Vietnam at 18% each.

Further, Russia has 10% of the global REE reserves and stands fourth in the list. It is followed by India which has almost 6% reserves. It may be noted that African nations such as Tanzania and South Africa also have a decent presence of rare earth reserves.

Table 2: Global Reserves of Rare Earths in '000 tonnes (2018)

Country	**Global reserves of rare earth**	**Share in world reserves**
China	44,000	36.7%
Brazil	22,000	18.3%
Vietnam	22,000	18.3%
Russia	12,000	10.0%
India	6,900	5.8%
Australia	3,300	2.8%
Greenland	1,500	1.3%
USA	1,400	1.2%
Tanzania	890	0.7%
Canada	830	0.7%
South Africa	790	0.7%
Other countries	4,080	3.7%
World total (rounded)	**120,000**	**100%**

Source: USGS; India Exim Bank Research

[1] The Rare-Earth Elements— Vital to Modern Technologies and Lifestyles, USGS https://pubs.usgs.gov/fs/2014/3078/pdf/fs2014-078.pdf

2.1.1. Production

The total global production of rare earth was recorded at 170,000 tons in 2018, and has come a long way in the last two decades when the production stood at 64,000 tons in 1994 – exhibiting an average annual growth rate of 40.5%, during this period.

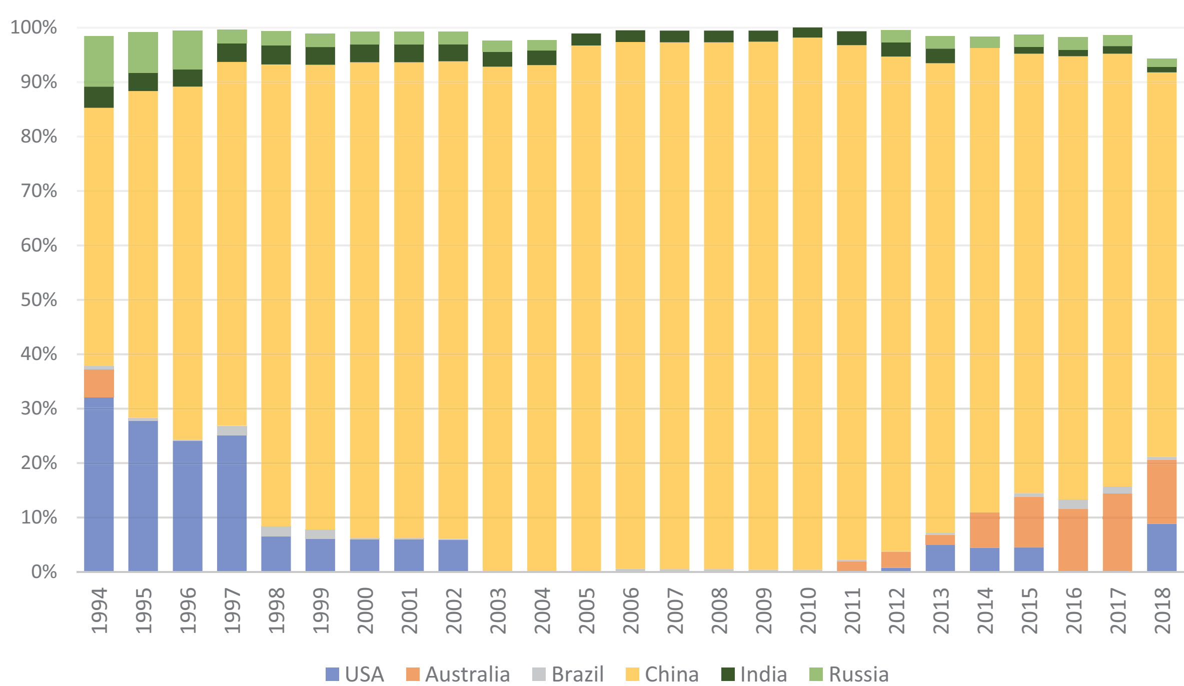
The share of China in global production of REEs increased from 47.4% in 1994 to as high as 97.7% in 2010 before falling back to 70.6% as in 2018.

With the advent of colour televisions in the world, the USA started exploiting its Mountain Pass Mine in California for REEs. Europium was the main element for the colour images in the TVs and the Mountain Pass Mine produced Europium from bastnasite, which contains 0.1% Europium. This led to the USA being the largest producer of REEs in the world in 1960s.

However, China entered the REEs market and began producing since 1980s. The other economies in the world could not really compete with China in terms of the mining cost. China further strengthened its position with a rising demand for REEs in the industries like defence, consumer electronics, amongst others. In fact, China evolved as not just the largest producer of REEs but also the largest consumer of the same.

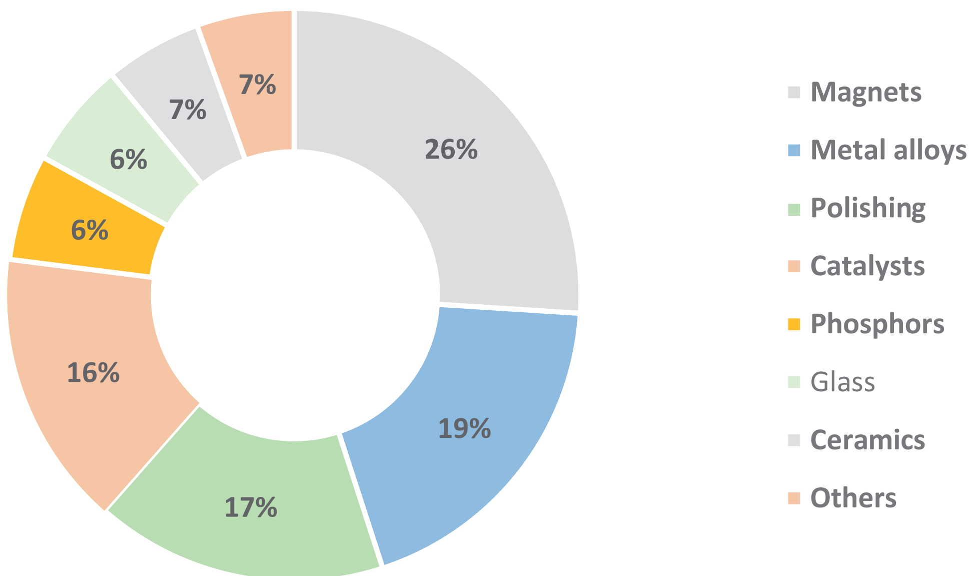
With a huge concentration of REEs production in China, the prices of the REEs increased in the world market which led to other manufacturers also exploring the market and getting back to the mining of the REEs. As a result, with others aggressively looking at exploration and mining REEs, the share of China in the REEs production has marginally declined in the recent years.

Figure 1: Share of Major Countries in the Production of REEs



Source: USGS; India Exim Bank Research

Exhibit 2: Applications of Rare Earth Elements



Source: Adapted from National Energy Technology Laboratory, Department of Energy, USA

Table 3: Features, Sources, and Application of Rare Earth Elements (17)

Metal	Properties	Sources and mining regions	Uses
Lanthanum (La)	• Lanthanum is a soft, silvery-white, ductile and malleable metal. Lanthanum is the first member of the Lanthanoid Group (Rare Earths) of the Periodic Table and is the 28th most abundant element within the Earth's crust. • The difference in properties within this group of elements is not much, as the added electrons, which make them differ are concealed in inner orbitals rather than their outermost orbital, which is the most influential, and therefore, as these elements are all chemically similar, they are often found together.	• The main ores from which it is extracted today are Monazite and Bastnäsite, where Lanthanum makes up 25% and 38% of the minerals, respectively. Allanite and Cerite also contain Lanthanum, but these ores are not mined for their lanthanum content in particular. • The main mining regions of the aforementioned ores are the USA, Brazil, India, Sri Lanka and Australia, making up the world production of lanthanum at 12,500 mt/year. The reserves of this element are estimated to be in the region of 6 million mt. • Despite being one of the 'rare earths', Lanthanum is probably one of the least rare, occurring in a tonnage similar to that of lead and tin combined	• Despite there being no commercial uses of lanthanum alone, it is often utilised once alloyed with other elements. For example, lanthanum nickel is a good absorber of hydrogen gas, and as the powder can absorb up to 400 times its own volume. This could prove useful for future use in hydrogen fuelled cars, as a way of storing the hydrogen gas. • However today, it is mainly used as an addition to glass. It is used as a core material in carbon arc electrodes for film/photographic studio lighting and floodlighting, as it produces an emission spectrum similar to that of sunlight. • Lanthanum salts included in zeolite crystals are used in petroleum refining, helping to stabilise the zeolite at high temperatures.
Cerium (Ce)	• Cerium is the most abundant of the rare earth elements. It is a reactive, grey metal and a member of the Lanthanoid Group of the Periodic Table. • It is the 25th most abundant element within the Earth's crust. • Due to its reactivity, it is stored in light mineral oil to protect it against oxidation	• Cerium is extracted from the ores Bastnäsite and Monazite, and its annual world production is in the region of 24,000 mt. • The main mining areas are the same as other rare earths: viz., the USA, Brazil, India, Sri Lanka, Australia and China. The characteristics and uses of cerium are also very similar to all lanthanides, however, cerium is one of the most reactive	• Cerium oxide is probably the most important outlet for cerium, and has many applications centred on glass and ceramics production. • It is used as an addition to glass melts and ceramic glasses, catalysts, refractory ceramics and glass polishing. Cerium metal in a highly pure form is used in casting alloys, for example, as an additive to aluminium, magnesium, iron, battery and vacuum alloys.

			• It is also used to add resistance to stainless steel, tool steel and lamps, and can refine the grain in some alloys.
Praseodymium (Pr)	• Praseodymium is a soft, malleable, silvery and ductile metal. • It is a member of the Lanthanide group of metals and is the 39th most abundant element within the Earth's crust. • Praseodymium reacts slowly with oxygen forming a flaky, green oxide layer. This oxide layer does not protect the element from further oxidation, and for this reason is often stored in a sealed plastic container or covered with oil, although it is actually less readily oxidised than other rare earth elements. Praseodymium also reacts rapidly with water.	• Praseodymium can only be found in two types of ore, namely monazite and bastnasite. • The main mining areas are China, the USA, Brazil, India, Sri Lanka and Australia. • Reserves of praseodymium are estimated to be around 2 million tonnes. World production of praseodymium is about 2500 tonnes per year.	• Praseodymium can be used in glass production to give the glass a yellow tint which filters out infrared radiation, and can be used in eye wears to protect the eyes of welders. • When alloyed with magnesium, praseodymium produces a very high strength metal used in aircraft engines. • Praseodymium can be found occurring in everyday products as well, such as colour televisions, fluorescent lamps and energy saving lamps, as well as the pyrophoric alloy used in cigarette lighter flint.
Neodymium (Nd)	• Neodymium is a bright silvery-white metal belonging to the Lanthanoid group in the Periodic Table. It is the 26th most abundant element within the Earth's crust. • Neodymium is quickly tarnished in air, meaning that it must be either sealed in a plastic container or covered in oil. It reacts slowly with cold water and rapidly with hot water.	• Neodymium can be extracted from all minerals and ores which contain lanthanides, however the most important one is monazite and certain bastnasite deposits. • China, the USA, Brazil, India, Sri Lanka and Australia are the primary sources for these ores, with China dominating production. • There are thought to be reserves of neodymium in the region of 8 million mt. • Very pure neodymium metal is produced by reacting neodymium fluoride with calcium, however, little is produced due to the high costs involved.	• Most of neodymium's applications are somewhat overshadowed by its success as a permanent magnet, first produced in 1983. • Neodymium also has various applications within the glass industry. Neodymium oxides create purple and sky-blue tints for artistic glass and ceramics, and when added to cathode-ray tube glass, picture brightness is enhanced by absorbing yellow light waves. • The most prominent application, however, is the neodymium-iron-boron (NdFeB) permanent magnet, which has given rise to many applications and dominates

			neodymium consumption at nearly 70%. Permanent magnets are used in most of the luxury electronics today, such as computer hard drives, mobile phones, and audio speakers. • These magnets are also widely used within car manufacture for ABS, anti-glare lights and mirrors, electronic windows and door locking.
Promethium (Pm)	• Promethium is a rare-earth metal that emits beta radius. It is very radoiactive and rare, so it is little studied: its chemical and physical properties are not well defined. • Promethium salts have a pink or red colour that colours the surroundings air with a pale blue-green light.	• Promethium, which is radioactive, with the most stable isotope having a half-life of 17.7 years, is not considered to be naturally occurring, although trace amounts have been found in some radioactive ores. • Promethium can be produced by irradiating neodymium and praseodymium with neutrons, deuterons and alpha particles. It can also be prepared by ion exchange of nuclear reactor fuel processing wastes.	• Most promethium is used for research purpose. It can be used as beta radiation source in luminous paint, in nuclear batteries for guided missiles, watches, pacemakers, and as a light source for signals. Promethium can also be used as a source of x-rays and radioactivity in measuring instruments.
Samarium (Sm)	• Samarium is a silvery-white metal and a member of the lanthanoid group of the Periodic Table and the 40th most abundant element within the Earth's crust. • Samarium is stable in dry air, but in moist air an oxide layer forms. • Samarium has strong magnetic properties and when mixed with cobalt makes permanent magnets, second only to neodymium magnets in strength.	• Samarium is found in the minerals monazite and bastnasite that contain all rare earth elements. • These ores are mined in China, the USA, Brazil, India, Sri Lanka and Australia. Monazite contains 3% by weight of samarium. • There are thought to be around 2 million tonnes of reserves worldwide, with only 700 tonnes per year being extracted worldwide.	• Samarium is used in permanent magnets (alloyed with cobalt), which are 10,000 times more powerful than iron, and have the highest resistance to demagnetization of any material, as they can withstand temperatures of over 700°C. Their strength makes them particularly useful for the miniaturization of devices, such as headphones and motors.

		• Commercially, samarium is extracted by electrolysis of the molten chloride with sodium chloride. It can also be produced by heating samarium oxide with barium or lanthanum, which drives off the samarium as a vapour.	• Samarium oxide is used in ceramics and making glass that absorbs infrared rays. Samarium is also used as a catalyst to aid conversion of ethanol to ethane, and as a neutron absorber for control rods, which regulate reactor cores in nuclear power plants.
Europium (Eu)	• Europium is a soft, silvery metal, rather like lead. Europium belongs to the lanthanoid group of elements within the Periodic Table. • It is one of the rarest earth metals and also the most reactive. This metal oxidizes rapidly in air and reacts with water to produce hydrogen.	• Although europium is found in high quantities in minerals such as calcium aluminium silicates, this is not used as a commercial source, and instead it is mined from the rare earth minerals, monazite and bastnasite, which are sources for all the lanthanoid elements. • Europium is not a major component, but it is found in extractable amounts, and is one of the more abundant lanthanoids. • Monazite can be found in river sand in countries such as India, Brazil and South Africa. Bastnasite deposits can be found in the Mojave Desert in California. World production of rare earth ores is mostly from China, normally as europium oxide	• Europium oxide (Eu2O3) has a vital role to play in colour televisions and computer display screens as a phosphor for emitting a pure red light. • It is this red spectrum that also causes europium to be used in low-energy light bulbs to create a more natural, warm light instead of the cold glare of traditional fluorescent tubes. • Europium is also added to mercury vapour tubes to give powerful street lighting a more natural light. • Europium is employed in the medical field, as the highly sensitive luminescence provided by europium, attached as a tag to complex biochemical, assists in live tracing of these materials during living tissue research.

Gadolinium (Gd)	• Gadolinium is a soft, shiny, silvery metal and a member of the lanthanoid group of the Periodic Table. It is the 41st most abundant element within the Earth's crust and the 6th most abundant rare earth element. • This metal reacts slowly with water and dissolves in acids.	• Similar to all the other rare earth elements, gadolinium is found in the ores monazite and bastnasite, although not in great quantities. • Despite this, the main source of gadolinium is from China's inner Mongolian mines. • World production of gadolinium is said to be about 7,500 mt per year and is separated by ion exchange techniques. • Although China is the main producing nation, gadolinium is also found in countries such as the USA, Brazil, India, Australia, Greenland and Tanzania. Global reserves of gadolinium are believed to be in excess of 1 million tonnes.	• Gadolinium has the greatest ability to capture thermal neutrons of all known elements, and therefore, has various nuclear industry applications. In nuclear energy production, Gadolinium is used as a 'burnable poison', especially in boiling water reactors, to even out the performance of the reactor over time. • Gadolinium is also the most efficient element used to detect power plant radiation leaks. • It is used in magnetic refrigeration to significantly reduce carbon dioxide emissions, due to increased energy efficiency. • In medicine, gadolinium is used in MRIs to provide better imaging of tumours. It is also used in electronic ceramics, glasses, lasers, magnetic recording and crystal scintillators. Gadolinium is used with yttrium to form garnets that have microwave applications. • Gadolinium compounds are also used to make phosphors for colour televisions.

Terbium (Tb)	• Terbium is a silvery metal, similar to gold, and is soft enough to cut with a knife, making it a malleable and ductile substance. • Terbium is one of the rarest of the rareearth elements, and is the 57th most abundant element within the Earth's crust.	• Terbium can be extracted from the ores, monazite, bastnäsite and euxenite, occurring in the proportion of 0.05% in monazite, 0.02% in bastnäsite and 1% in euxenite. • Despite its presence being so small, it is still economically viable to extract. The main areas of mining and production of terbium are in China, in the ion-absorption clays found in the southern region, as well as in the USA, Brazil, India, Sri Lanka and Australia. • There are reserves of terbium in the region of 10mt per year. The production of terbium metal requires terbium fluoride to be heated with calcium (Ca) metal in a tantalum (Ta) crucible under a vacuum.	• Terbium has few, yet rather important, applications. When alloyed with zirconium oxide (ZrO2), it is used a crystal stabiliser of fuel cells. • It also is used to make solid-state devices, energy efficient light-bulbs and, again, when alloyed with other metals can help provide metallic films for magneto-optic recording data.
Dysprosium (Dy)	• Dysprosium metal is similar to most of the other rare earth metals, it is a shiny silvery colour and is soft enough to be cut with a knife. • It is a member of the lanthanum group of the Periodic Table and is the 42nd most abundant element within the Earth's crust. Dysprosium is slowly oxidised by oxygen, is rapidly dissolved in acids and reacts with cold water.	• Dysprosium is primarily obtained through an ion exchange process from monazite sand. • Dysprosium production is dominated by China, but in 2010 the Japanese chemical group Showa Denko set up a plant in Vietnam to extract dysprosium, with the aim of securing a stable, non-Chinese supply of rare earth magnetic materials.	• There are numerous uses for dysprosium, and it is often difficult to find a substitute. Its most common use is in Nd-Fe-B magnets, where the addition of dysprosium prevents the loss of magnetism at high temperatures. • Applications include high performance motors, energy-conserving home electronics, and wind power generation. • Its high melting point and thermal neutron absorption cross-section allow dysprosium to be used in nuclear applications. • Other uses include alloying with special stainless steels, and use in laser materials.

Holmium (Ho)	• Holmium, similarly to most other rare earth elements, is a bright, soft, silvery metal that is also malleable and ductile. It is a member of the lanthanoid group of the Periodic Table and is the 56th most abundant element within the Earth's crust. • Holmium is slowly attacked by water and oxygen and in moist air will form a yellowish oxide. It will also dissolve in acids.	• The main area of production of holmium is the rare earth mines in Inner Mongolia in China, which is responsible for 97% of all the rare earth elements. • The main ores of holmium are the rare earth minerals monazite and gadolinite. In monazite, holmium can be present in as much as 0.5% • Other areas which contain deposits of rare earth ores include the USA, Brazil, India, Greenland and Tanzania. • Reserves of holmium are estimated to be in the region of 400,000 tonnes and annual production is about 10 tonnes per year.	• Holmium has few commercial applications. It can be used to colour glass yellow and is also used in ceramics, lasers and nuclear applications. • Holmium has the highest magnetic moment of any naturally occurring element, and has therefore been used to create the highest known magnetic fields. • These magnetic properties are likely to be further exploited in the future.
Erbium (Er)	• Erbium is a bright silvery metal, which is soft and malleable. It is a member of the lanthanoid group of the Periodic Table and the 44th most abundant element within the Earth's crust. • Erbium reacts slowly with air and water and dissolves in acids. Despite this, in comparison with the other rare earth metals, it is quite corrosion resistant.	• Erbium, like all other rare earth elements, is mainly obtained from the Inner Mongolian mines within China. • It is found in the rare earth ores monazite and bastnasite, although it is not a major component of either, but is present in amounts worthy of extraction. • Other minerals containing erbium include xenotime (yttrium phosphate) and euxerite (a complex ore of many metals), and these are, in fact, better sources for erbium. • World production of the metal is mainly in the form of erbium oxide.	• Erbium has two main commercial applications, as a medical laser and in fibre optic cables. Erbium lasers have medical and dental uses because they are suited to energy delivery without thermal build up in human tissue. • In cosmetic treatments, they are used to ablate the epidermis, revealing the smoother and younger-looking underlying skin. • In dentistry, erbium lasers have been proven safe and effective for the removal of tooth decay and cavity preparation. • The other main use of erbium is in transmitting data through fibre optics.

Thulium (Tm)	• It is a member of the lanthanoid group of elements and is the 61st most abundant element within the Earth's crust. • Thulium reacts with water and slowly tarnishes in air, but compared with the other rare earth metals, it is fairly corrosion resistant. • Along with lutetium, thulium is the rarest rare earth metal, but is still 200 times more abundant than gold.	• Thulium is mainly mined in the Inner Mongolian mines in China, which accounts for 97% of the world's rare earth metals. • Small quantities of thulium are found in the rare earth minerals monazite and bastnasite. Monazite contains about 0.002% thulium and bastnasite contains about 0.0008% thulium. • Reserves of thulium are estimated to be around 100,000 tonnes and world production of thulium in the form of its oxide is about 50 tonnes per year.	• Due to the difficulty in obtaining large quantities of thulium, it has few commercial applications. • It is used in magnetic refrigeration to significantly reduce carbon dioxide emissions due to increased energy efficiency, in cathode ray tubes and in medical image stabilisation. • One of its isotopes, thulium-169, could be used in sensitive X-ray phosphors for portable X-ray machines, but it is considered too expensive for commercial application.
Ytterbium (Yb)	• It is a member of the lanthanoid group of elements and is the 43rd most abundant element within the Earth's crust. • A protective layer forms on ytterbium's surface, as when the pure metal is exposed to air, it slowly oxidises until it reaches a level where this oxide layer will protect it from further oxidisation.	• Commercially, ytterbium is extracted from monazite, which comprises of 0.1% ytterbium. • Other ores include euxenite, which is found in Greenland and Brazil, and xenotime. • The main mining areas are China, the USA, Brazil, India, Sri Lanka and Australia, with global reserves estimated at around 1 mt. World production is approximately 50 tonnes per year.	• There is little commercial application for Ytterbium, although the uses include strengthening stainless steel, doping phosphors in electronic devices and acting as an industrial catalyst. • One of ytterbium's isotopes can be used as a portable radiation source as an alternative to an x-ray machine when electricity is not available. • Ytterbium salts are being introduced into the chemicals industry and catalysts in place of toxic and polluting ones.
Lutetium (Lu)	• Lutetium is a silvery white metal belonging to the lanthanoid group of the periodic table. • Lutetium has the highest atomic weight, highest density, highest melting point, and is the hardest of all the rare earth elements.	• Lutetium occurs in very small amounts alongside yttrium. • It is recovered, by ion-exchange routines, in small quantities from yttrium-concentrates. • It can also be prepared by the reduction of anhydrous $LuCl_3$ or LuF_3 by an alkali or alkaline earth metal.	• Due to the difficulty in obtaining large quantities of lutetium, it has few commercial applications. • It is used in single crystal scintillators and in detectors in positron emission tomography.

	• Also, along with thulium it is the rarest of the rare earth elements, being the 60th most abundant element within the Earth's crust. The metal is also corrosion resistant.		• It has also recently found use as a pure beta emitter: stable lutetium nuclides emit pure beta radiation after thermal neutron activation, so it is used as a catalyst in cracking, alkylation, hydrogenation, and polymerization.
Scandium (Sc)	• Scandium is a soft, silvery, yellow-white metal and a member of Group 3 of the Periodic Table, heading a list of 10 metals called the First Row Transition Elements. • Scandium is the 35th most abundant element in the Earth's crust. It tarnishes in air and burns easily once it has been ignited. • It is also a rare metal, not because it is hard to find, but because it is hard to find in a large concentration (i.e. an ore), and is thinly distributed around the world (0.0025% of the Earth's crust), so collecting and purifying the substance is expensive and time-consuming.	• While resources of scandium are relatively abundant, it is widely dispersed in minute quantities. • World primary production of scandium is thought to be in the order of only a few tonnes per year • Although scandium is not mined in much quantity, sufficient amounts to meet the demand are available in tailings. The majority of scandium metal comes from the military stockpiles (extracted from uranium tailings) in Kazakhstan and other former Soviet countries.	• Consumption is in the order of 5,000 kg/year, and typically is employed in aluminium alloys as a grain refiner. • The original use of scandium-aluminium alloys was in nose cones for Soviet submarine-launched ballistic missiles since it allowed the missile to pierce through the Arctic ice-cap (from beneath) without incurring any damage. • Today, aluminium-scandium alloys are mostly used for minor aerospace industry components and for high-quality sports equipment. • Small amounts of scandium are also used in high-intensity lights and fuel cells, as well as in firearms.
Yttrium (Y)	• Yttrium is a soft, silvery-white metal that is a member of Group 3 of the Periodic Table; it is the 28th most abundant element within the Earth's crust. • Yttrium is stable in air, as it is protected by the formation of a resistant oxide film on its surface.	• Yttrium phosphate makes up approximately 50% of the ore Xenotime. • Yttrium oxide though, is mainly found in a rare earth mineral Monazite and makes up about 2.5% of it. • Other minerals containing yttrium oxide in smaller quantities are fergusonite and samarskite. • Yttrium oxide is extracted from the aforementioned ores, of which about 600 mt are produced a year.	• Yttrium is used in alloys which improve magnesium (Mg) castings. It gives a finer grain to chromium (Cr), molybdenum (Mo) and zirconium (Zr) metals. • Also, when added to cast iron, it makes it more workable. Unusually for metals, when alloyed with chromium and aluminium it becomes heat resistant. • Yttrium oxysulfide, when doped with europium, creates the red colour in televisions.

		• There are thought to be world reserves of yttrium oxide in the region of 9,000,000mt, while comparatively there are only a few tonnes of yttrium metal produced each year, which requires yttrium fluoride to be heated with calcium metal in order to be produced.	• Yttrium oxide is used as a glass additive, rendering it heat and shock resistant, and is therefore used in camera lenses. • Yttrium oxide is also used for making superconductors, and the compound yttrium-barium-copper oxide (YB2Cu3O7-9) was the first superconductor to work at temperatures of liquid nitrogen (-183°C). • Yttrium-iron-garnet (YIG) is used as resonators in frequency meters and in magnetic recording.

Source: Minor Metals Trade Association (MMTA), United Kingdom

3.

Trade in Rare Earth Elements

The study evaluates the trade of the REEs by taking together two HS codes, namely, HS 280530 (Earth-metals, rare; scandium and yttrium, whether or not intermixed or inter-alloyed), and HS 2846 (Compounds, inorganic or organic, of rare-earth metals; of yttrium or of scandium or of mixtures of these metals).

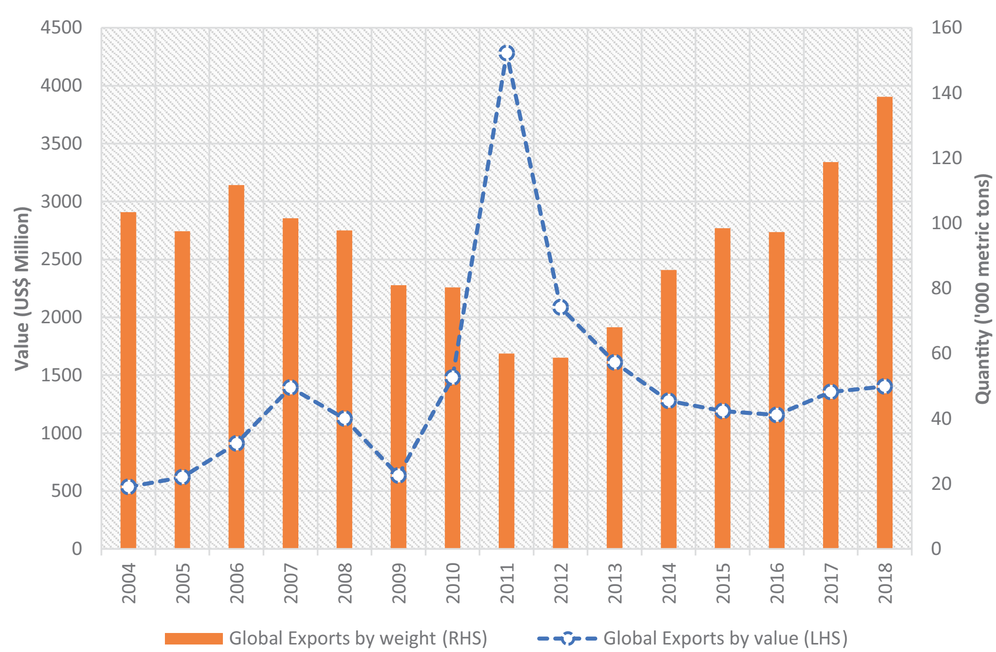
The global exports of the rare earth elements by value were registered at US$ 1402.3 million in 2018, up from US$ 534.8 million in 2004, recording an AAGR of 20.8%, during this period.

Further, by volume, the global exports were recorded at 138.8 ('000 metric tons) in 2018, up from 103.3 ('000 metric tons) in 2004, growing at an average rate of 3.2%, during this period.

It may be noted that the export value reached as high as US$ 4280.6 million in 2011, from US$ 534.8 million in 2004. During the same period, the exports by weight reached as low as 59.9 ('000 metric tons), from 103.3 ('000 metric tons). The opposite direction in the growth of exports by value and the weight is due to the fact that China slashed export quotas in 2010, the result of which can be seen in 2011. Due to this export quota slashing, the average price which was just US$ 18.4/kg in 2010 shot up to US$ 71.4/kg in 2011.

Until 2010, there was less interest in REEs, as companies outside China could not compete China on price. However, with the prices rising, because of high demand and low exports from China, a large number of new mining projects were operationalized across various countries. Post-2011, the prices gradually dropped and reached US$ 10.1/kg.

Figure 2: Global Exports of Rare Earth Elements by Value and Quantity

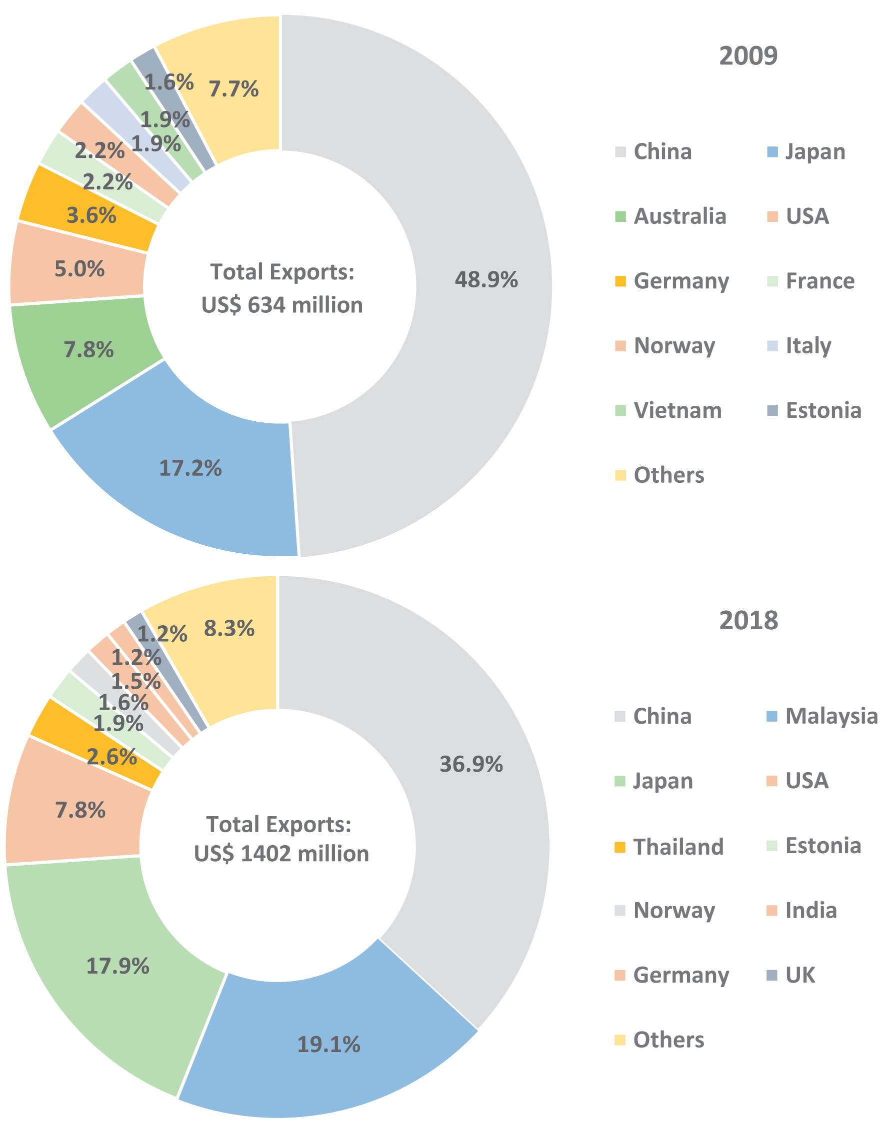


Source: USGS; India Exim Bank Research

While REEs have been produced for almost a century, the countries supplying them have changed. In the mid-twentieth century, almost all REE mining was conducted at Mountain Pass, California, and by 1990, only eight countries reported exporting these minerals either in concentrated or refined form.

Today, more than 90% of mining and refinement is done in China. There are very few companies outside China producing REEs. China, which once focused on exporting REEs in their raw forms, has used forward integration to its benefit. In the 1970s, China exported only rare earth concentrates. By the end of the 1990s, China began producing magnets, phosphors, and polishing powders. Now, China produces finished products such as electric motors, batteries, and LCDs[2].

Figure 3: Major Exporters of Rare Earth Elements by Value: 2009 and 2018



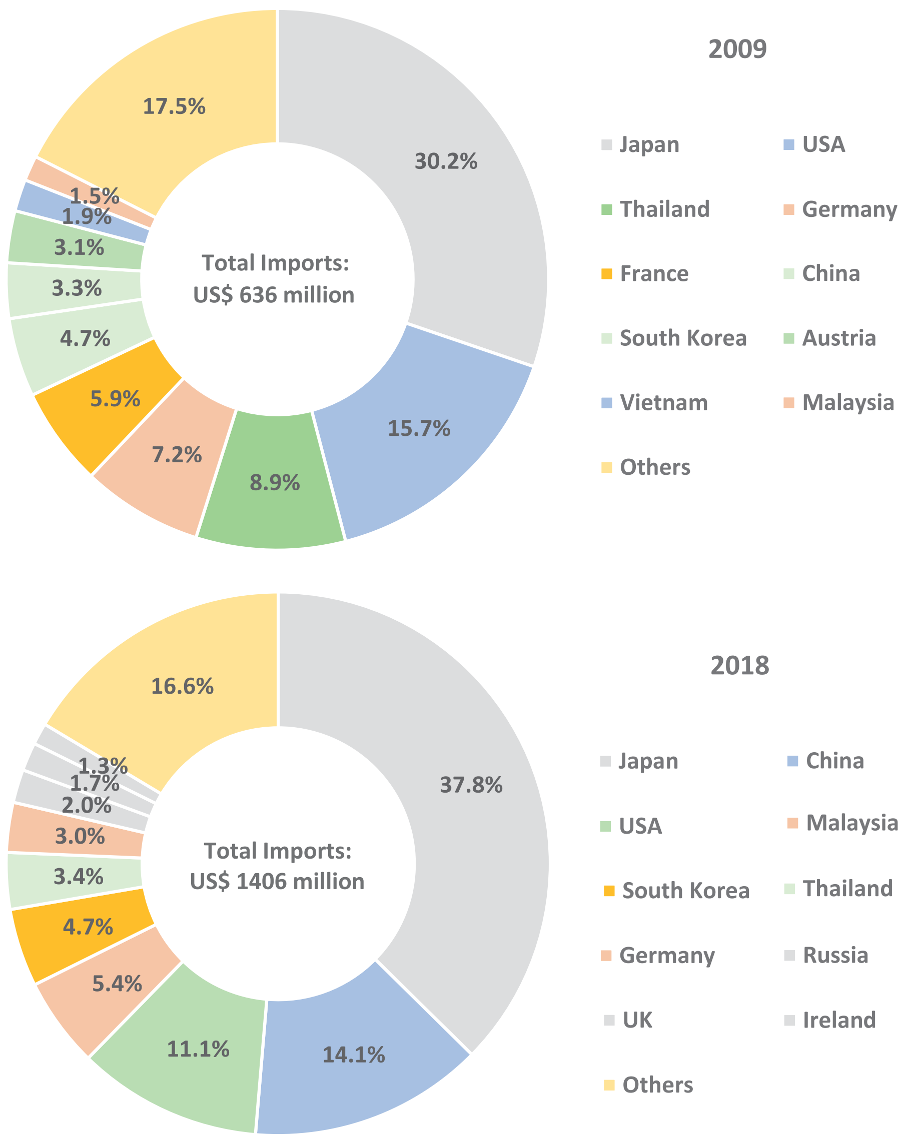
Source: UN COMTRADE; India Exim Bank Research

[2] World trade in rare earths, Chinese export restrictions, and implications, Mancheri (2015)

As a result, the share of China in the world exports which was 52.4% in 2004, declined to 48.9% in 2009 and 36.9% in 2018. On the contrary, India's share has marginally increased from 0.15% in 2004 to 1.45% in 2018.

With respect to the imports, Japan is the largest importer of REEs accounting for almost 38% of the global imports in 2018, up from 30.2% in 2009. Further, China's share in the global imports has also increased from 4.7% in 2009 to 14.1% in 2018. Some countries like Japan, Germany, France, and the US imported concentrates and oxides, conduct further purification, manufacture metals and other REE-based products and re-export[3].

Figure 4: Major Importers of Rare Earth Elements by Value: 2009 and 2018



Source: UN COMTRADE; India Exim Bank Research

[3] World trade in rare earths, Chinese export restrictions, and implications, Mancheri (2015)

India's trade scenario

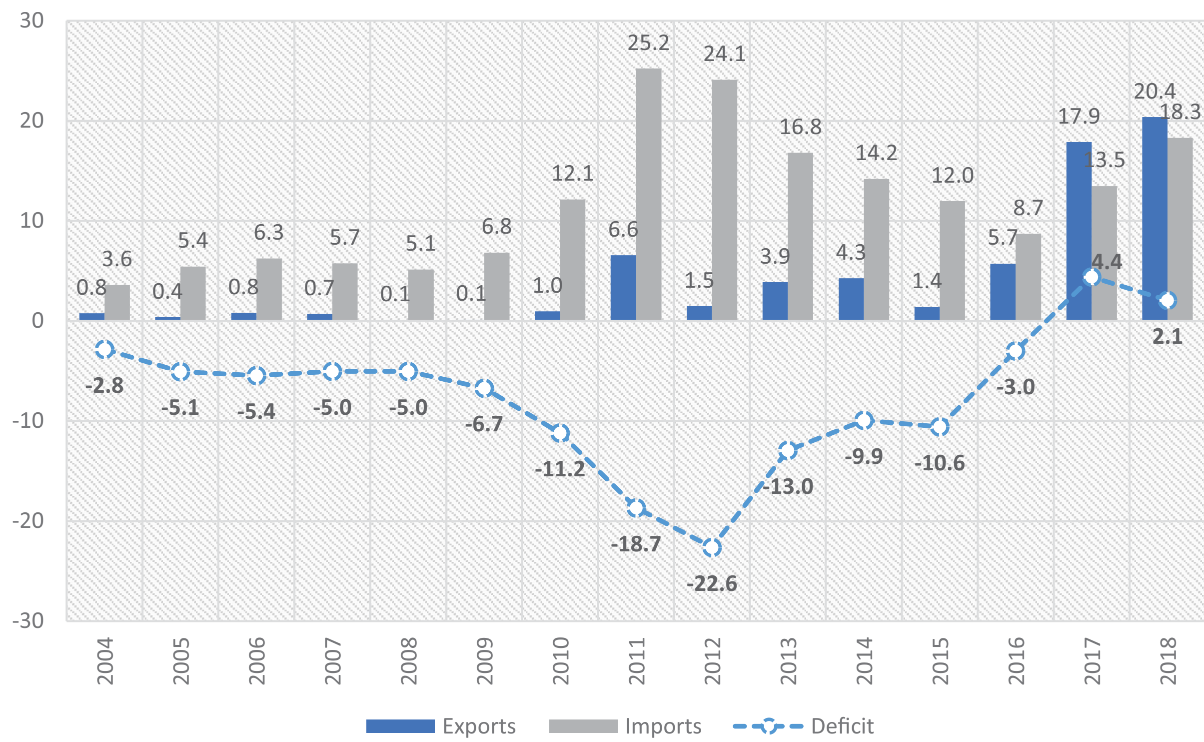
India's trade by value in rare earth elements was registered at US$ 38.6 million in 2018. This is almost nine times more than the trade witnessed in 2004. As a result, the average annual growth rate in India's trade of REEs was observed at over 25% during 2004 to 2018.

Further, while India was registering trade deficits consistently during the last fifteen years in REEs, the country registered a trade surplus during 2017 (US$ 4.4 million) and 2018 (US$ 2.1 million).

India's exports of the rare earth elements have been quite erratic, both with respect to their value as well as the export destinations. In terms of consistency, Japan has been one of the major export destinations for India. Japan's share in India's total exports of REEs in the last fifteen years has mostly been in the double digits.

In 2018, Vietnam was the largest exporting destination for India with a share of over 41%, followed by Japan at 23.3%. However, with respect to the quantity exported, Japan was way ahead with a share of 35.6%, followed by Vietnam at 10.4% in 2018.

Figure 5: India's Trade in Rare Earth Elements (US$ Million)



Source: UN COMTRADE; India Exim Bank Research

Table 4: Major Export Destinations for India's Rare Earth Elements by Value

Country	2004	Country	2009	Country	2013	Country	2018
Japan	81.8%	Japan	56.9%	Vietnam	51.2%	Vietnam	41.7%
Germany	10.4%	New Zealand	17.6%	Japan	41.6%	Japan	23.3%
Vietnam	2.1%	Nepal	10.1%	UK	3.7%	Spain	14.0%
UK	1.6%	UAE	4.1%	Germany	2.2%	Malaysia	10.5%
UAE	1.2%	Sri Lanka	3.5%	USA	0.3%	China	2.9%
Sri Lanka	1.0%	Liberia	3.0%	Belgium	0.3%	France	1.3%
Afghanistan	1.0%	Germany	2.7%	Australia	0.2%	Italy	1.3%
USA	0.5%	UK	1.3%	Uganda	0.1%	Netherlands	1.2%
Congo	0.4%	Egypt	0.4%	China	0.1%	South Korea	1.1%
Singapore	0.1%	Saudi Arabia	0.2%	Kazakhstan	0.1%	USA	1.1%

Source: UN COMTRADE; India Exim Bank Research

With respect to India's import of the rare earth elements, India majorly imported the REEs from China. China's share in India's imports of REEs grew from 31% in 2004 to 44.3% in 2008 and 47.7% in 2013, before falling down to 34.5% in 2018. It also may be noted that the USA's share in India's import of REEs has gone down from 38.3% to 7.1% in the last fifteen years.

Table 5: Major Import Sources for India's Rare Earth Elements by Value

Country	2004	Country	2009	Country	2013	Country	2018
USA	38.3%	China	44.3%	China	47.7%	China	34.4%
China	31.0%	Japan	20.9%	France	18.7%	Japan	25.9%
France	7.6%	France	14.6%	Japan	17.7%	Russia	12.7%
Japan	6.9%	USA	8.5%	Vietnam	8.7%	France	11.2%
UK	6.7%	Austria	4.0%	USA	2.8%	USA	7.1%
South Korea	6.0%	UK	2.4%	Austria	1.6%	Germany	2.4%
Germany	2.4%	Germany	2.0%	Germany	1.1%	Belgium	1.9%
Hong Kong	0.5%	Poland	0.5%	UK	0.6%	Austria	1.8%
Austria	0.3%	Spain	0.2%	Hong Kong	0.3%	UK	0.8%
Switzerland	0.1%	Switzerland	0.2%	Sri Lanka	0.3%	Netherlands	0.4%

Source: UN COMTRADE; India Exim Bank Research

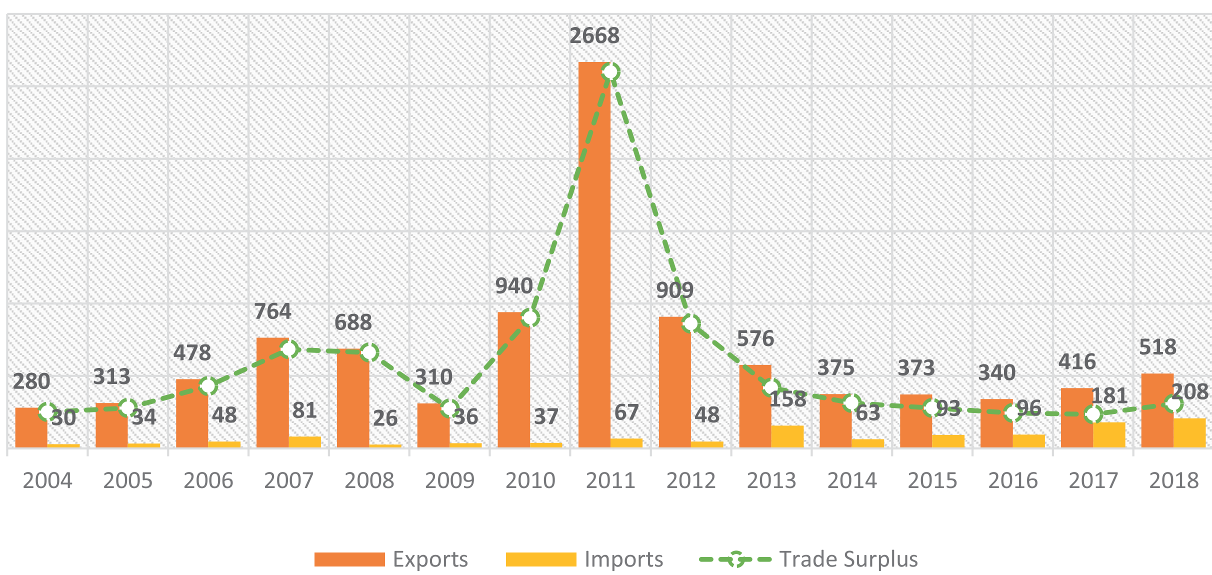
Case of China

China's exports of rare earth elements were registered at US$ 518 million in 2018, up from US$ 280 million in 2004, growing at an average annual rate of 24.7%.

During this period, the trade surplus of China in REEs increased from US$ 251 million in 2004 to US$ 310 million in 2018. It is important to observe that the trade surplus for China in REEs segment reached as high as US$ 2601 million in 2011.

As mentioned before, this was the time when China brought down the export quota, due to which the quantity exported reduced and price rose. Therefore, in value terms, exports increased by almost 184%.

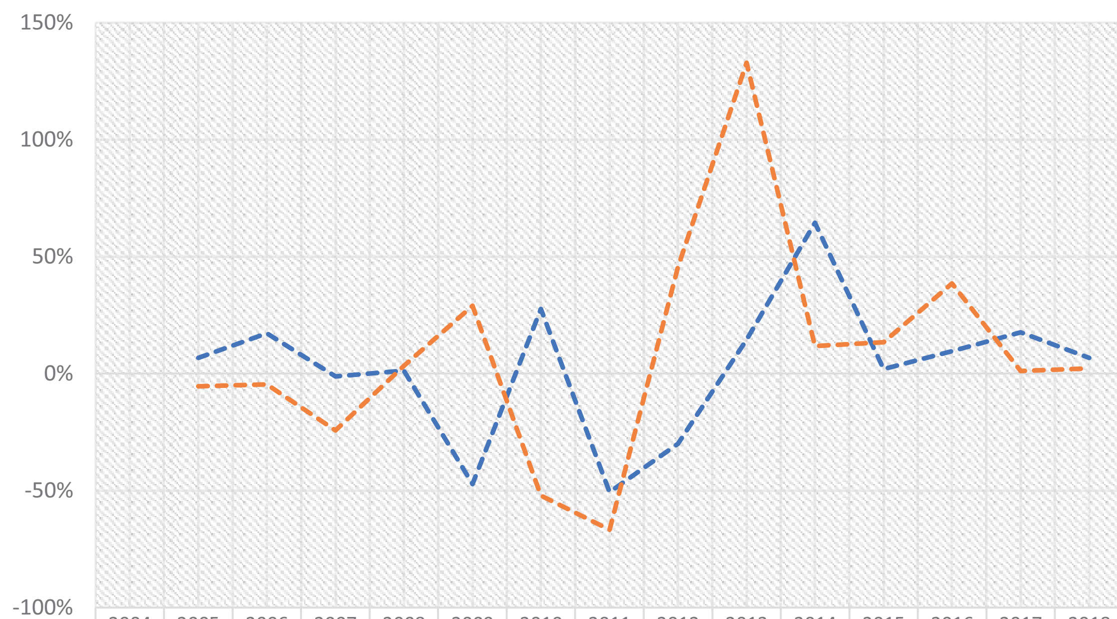
Figure 6: China's Trade in Rare Earth Elements (US$ million)



Source: UN COMTRADE; India Exim Bank Research

Major exporting destination for China's rare earth elements exports in 2018 were Japan (46.4%); and the USA (17.1%) in terms of value. Further, analysing the quantities exported by China to these countries, it is observed that with the 2010 incident, and subsequent reduction in exports, China's exports to Japan and to the USA fell by (-) 50.6% and (-) 66.7%, respectively, in 2011.

Figure 7: Growth in China's Exports of REEs to Japan and to the USA by Quantity



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Japan		6.7%	17.2%	-1.2%	1.2%	-47.3%	27.6%	-50.6%	-30.0%	14.5%	64.5%	1.9%	9.5%	17.6%	6.7%
USA		-5.5%	-4.6%	-24.3%	3.3%	29.0%	-52.1%	-66.7%	45.5%	132.8%	11.8%	13.4%	38.6%	1.1%	2.1%

Source: UN COMTRADE; India Exim Bank Research

4.

Need to Secure India's Rare Earths

After the implementation of the new economic policy in 1991, the Indian economy has recorded a series of impressive growth rates. However, the growth has mostly been services driven. Realizing these limitations, the successive Governments in India have time and again focused on the manufacturing sector in India.

The Government of India intends to increase the share of manufacturing in India's GDP to 25% by 2022, up from the present range of 14%-16%. It may also be noted that the share of high-tech exports in India's total manufactured exports is less than 10%. In order for India to achieve the manufacturing target of 25% in national GDP, the country will have to focus on the domestic manufacturing activity in various industries and this will further be dependent upon securing the availability of various critical minerals.

Electric Vehicles

With the rising pollution and India's commitments at the international platform to reduce the carbon emissions, the focus on Electric Vehicles has been increasing each passing day. In fact, the Government of India announced an outlay of `10,000 crore for Phase 2 of the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles, or FAME 2 scheme in 2019, to boost electric mobility and increase the number of electric vehicles in commercial fleets.

The outlay of `10,000 crore has been made for three years till 2022 for FAME 2 scheme. Plug-in hybrid vehicles and those with a sizeable lithium-ion battery and electric motor are also included in the scheme and fiscal support offered depending on the size of the battery. The Government has a target of 30% of vehicles in India as electric vehicles by 2030.

With respect to EVs, like many low carbon technologies, EVs use a number of exotic metals in their design. Many of these metals are considered critical in the sense that they are required for effective functioning of the EVs.

A number of vehicle designs utilise electricity for drive, including hybrids, plug-in hybrids, fuel cell vehicles and battery electric vehicles. Common to these designs are electric motors and batteries, both of which contain critical metals. While a number of competing battery technologies exist, lithium-based battery chemistries are the current choice of batteries for electric vehicle manufacturers. Many electric motors use high-powered magnets in their design. These magnets contain neodymium and dysprosium, which are both rare earth elements often cited as critical metals[4]. Increased adoption of EVs is also likely to lead to a slowdown in growth of internal combustion engine (ICE) vehicles, which will have a direct impact on metals such as platinum and palladium, used in catalytic converters of ICE vehicles[5].

Renewable Energy

Ahead of COP 21, India submitted its Intended Nationally Determined Contribution (INDC) to the UNFCCC, outlining the country's post-2020 climate actions. India's INDC builds on its goal of installing 175 gigawatts (GW) of renewable power capacity by 2022. India has set a target to

[4] Strategic Energy Technologies Information System, European Commission
[5] Produce or Procure? Securing strategic minerals for India's development, Ernst & Young

increase the country's share of non-fossil-based installed electric capacity to 40% by 2030. The INDC also commits to reduce India's GHG emissions intensity per unit of GDP by 33% to 35% below 2005 levels by 2030, and to create an additional carbon sink of 2.5 to 3 billion tonnes of carbon dioxide through additional tree cover[6].

In fact, India's current renewable energy installed capacity has grown from 3.9 GW in 2003-04 to about 83.4 GW in October 2019. In fact, the share of renewable energy in the total installed capacity was recorded at 22.8% in October 2019. Within the renewable energy, while wind energy accounts for almost 45% of the renewable capacity, 38% is accounted by the solar capacity. With huge targets lying ahead to be achieved, the focus on the renewable energy is not going to be any less in the near future.

Most of the renewable energy sources such as solar, wind and nuclear depend on components such as solar photovoltaic cells, turbines (geared or direct drive) and reactor control rods for efficient functioning of equipment. These components in turn, are manufactured from various minerals including copper, indium, boron, dysprosium, neodymium and hafnium among others. With the Indian government being clear in its preference to manufacture components like solar panels locally, there is expected to be a spike in demand for the associated minerals in the near to medium term[7].

Defence Sector

India's requirements on defence front are catered largely by imports. In fact, according to Stockholm International Peace Research Institute (SIPRI), India was the world's second largest importer of major arms during the period 2014-18, and accounted for 9.5% of the global total.

As a result, 'Make in India' programme is being used by the Government of India for defence procurements by categorising the capital acquisition proposals under 'Buy (Indian-IDDM)', 'Buy (Indian)', 'Buy and Make (Indian)', 'Make' and 'Strategic Partnership Model' categories of Defence Procurement Procedure (DPP)-2016.

DPP -2016 focuses on institutionalising, streamlining and simplifying defence procurement procedure to give a boost to 'Make in India' initiative of the Government of India. During 2015-16 to 2018-19, out of the total 210 contracts, 135 contracts have been signed with Indian Vendors including Defence Public Sector Undertakings/ Public Sector Undertakings/ Ordnance Factory Board and private vendors for capital procurement of defence equipment for Armed Forces such as Helicopters, Naval vessels, Radars, Ballistic Helmets, Artillery Guns, Simulators, Missiles, Bullet Proof Jackets, Electronic Fuses, and Ammunition. However, for the Make in India campaign to be successful in the defence sector, high capital investment and technological upgradation will be required.
The global aerospace industry consumes around 15% of beryllium, employing its high performance alloys for aircraft components, spacecraft and satellites. Thus it is likely to see a higher consumption in India's growing defence industry.

Further, for defence purposes, rare earth elements are found in two types of commercially available, permanent magnet materials. They are samarium cobalt (SmCo), and neodymium iron boron (NdFeB). NdFeB magnets are considered as the world's strongest permanent magnets and are essential to many military weapons systems. SmCo retains its magnetic strength at elevated temperatures and is ideal for military technologies such as precision-

[6] Ministry of New and Renewable Energy
[7] Produce or Procure? Securing strategic minerals for India's development, Ernst & Young

guided missiles, smart bombs, and aircraft. The superior strength of NdFeB allows for the use of smaller and lighter magnets in defence weapon systems.

Following are a variety of defence-related applications where there is use of rare earth elements.

- Fin actuators in missile guidance and control systems, controlling the direction of the missile;
- Disk drive motors installed in aircraft, tanks, missile systems, and command and control centres;
- Lasers for enemy mine detection, interrogators, underwater mines, and countermeasures;
- Satellite communications, radar, and sonar on submarines and surface ships; and
- Optical equipment and speakers[8].

Electronics

In the modern high-tech world, electronics is one of the most important industry, given its huge demand globally. Even India's demand for the electronics has grown exponentially in the last two decades, driven by its impressive GDP growth. As the domestic production has not grown as much as the demand due to the rising incomes of Indian population, there has been a significant increase in the imports.
According to Ministry of Commerce and Industry, Government of India, in FY 19, the trade deficit of India was recorded at US$ 184 billion. Out of this, the 'electronics items' segment accounted for US$ 47 billion, which is over 25% of the total deficit. While the exports of 'electronics items' recorded an AAGR of 9.9% during FY 15 to FY 19, the AAGR for imports was registered at 11% during the same period.

In fact, Government of India's National Policy on Electronics, 2019 seeks to promote domestic manufacturing and export in the entire value-chain of Electronics System Design and Manufacturing (ESDM) for economic development to achieve a turnover of US$ 400 billion (approximately INR 26,00,000 crore) by 2025. In such a scenario, securing rare earth supplies becomes even more important.

Rare earths are metallic elements, and therefore contain unique properties, including high heat resistance, strong magnetism, and high electrical conductivity. These specific properties make them well suited for use in a variety of products, including cell phones, batteries, loudspeakers, lights, and magnets.

Table 6: India's Trade Deficit in Electronic Items (US$ billion)

Year	Exports	Imports	Trade Deficit
FY 15	6.0	36.9	-30.8
FY 16	5.7	40.0	-34.3
FY 17	5.7	41.9	-36.2
FY 18	6.1	51.5	-45.5
FY 19	8.4	55.5	-47.1
FY 20 (April-Feb)	10.5	49.3	-38.8

Source: Ministry of Commerce and Industry; India Exim Bank Research

[8] Rare Earth Elements in National Defense: Background, Oversight Issues, and Options for Congress

5.

Strategies Adopted by Select Economies Securing Rare Earths

The USA

During 1960s to 1980s, the United States was one of the largest producer of the rare earth elements in the world. However, China declared rare earth to be a protected and strategic mineral. As a consequence, foreign investors were prohibited from mining rare earths and are restricted from participating in rare-earth smelting and separation projects except in joint ventures with Chinese firms. As a result, today, the US imports almost 80% of rare-earth compounds and metals from China.

Given the volatility with respect to the trade between the US and China, the US Department of Commerce released 'A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals' in 2019.
The strategy came out after the order of the US Government which stated that "It shall be the policy of the Federal Government to reduce the Nation's vulnerability to disruptions in the supply of critical minerals, which constitutes a strategic vulnerability for the security and prosperity of the United States. The USA envisages to further this policy in a safe and environmentally responsible manner, by:

- Identifying new sources of critical minerals;
- Increasing activity at all levels of the supply chain, including exploration, mining, concentration, separation, alloying, recycling, and reprocessing critical minerals;
- Ensuring that our miners and producers have electronic access to the most advanced topographic, geologic, and geophysical data within the U.S. territory to the extent permitted by law and subject to appropriate limitations for purposes of privacy and security, including appropriate limitations to protect critical infrastructure data such as those related to national security areas; and
- Streamlining leasing and permitting processes to expedite exploration, production, processing, reprocessing, recycling, and domestic refining of critical minerals."

The Paper calls for various actions, each of which has multiple goals.

I. *Advance Transformational Research, Development, and Deployment across Critical Mineral Supply Chains*

- Develop a R&D strategy to enhance scientific and technical capabilities across critical mineral supply chains; and
- Increase U.S. private industry investment in innovation and improve technology transfer from federally funded science and technology

II. *Strengthen America's Critical Mineral Supply Chains and Defence Industrial Base*

- Understand and support the critical minerals industry and related supply chain;
- Leverage critical mineral expertise from stakeholders outside of the Federal Government;
- Develop, expand, modernize, and sustain U.S. critical minerals downstream materials production capacity and supply

chain resiliency; and

- Stabilize and strengthen the NDS Program's abilities to respond rapidly to urgent and unanticipated military and essential civilian requirements during U.S. wartime and other national emergencies

III. *Enhance International Trade and Cooperation Related to Critical Minerals*

- Increase international exchanges with partner nations to share best practices and identify opportunities for trade and collaboration; and
- Secure access to critical minerals through trade and investment with international partners, while ensuring that the foreign trade practices do not harm U.S. industries and broader national interests.

IV. *Improve the Understanding of Domestic Critical Mineral Resources*

- Use critical mineral supply and consumption data to develop metrics to enable commodity-specific mitigation strategies addressing strategic vulnerabilities;
- Conduct critical mineral resource assessments and identify methods to encourage the use of secondary and unconventional sources of critical minerals;
- Improve the geophysical, geological, topographical, and bathymetrical mapping of the United States and associated coastal and ocean territory; and
- Improve the discoverability, accessibility, and usability of geophysical, geological, topographical, and bathymetrical data.

V. *Improve Access to Domestic Critical Mineral Resources on Federal Lands and Reduce Federal Permitting Timeframes*

- Revise the Bureau of Land Management's (BLM) and U.S. Forest Service's (USFS) land-use planning process to identify and protect access to mineral resources;
- Complete a thorough review of withdrawals from applicable mining laws and areas restricted from mineral exploration and development on the Federal mineral estate;
- Review travel management plans and existing infrastructure capabilities on Federal lands for impacts to mineral exploration and development;
- Adopt a model of mineral resource development to track permitting requirements and timelines;
- Evaluate the National Environmental Policy Act (NEPA) and other regulations to provide timely processing of permit applications for mineral projects.
- Evaluate the Clean Water Act and the Rivers and Harbors Act to improve the permitting processing;
- Review regulations and consider proposing legislation to facilitate offshore critical mineral development; and
- Evaluate the feasibility of including high-priority mineral projects for review as part of Title 41 of the Fixing America's Surface Transportation (FAST) Act and One Federal Decision Framework.

VI. *Grow the American Critical Minerals Workforce*

- Bolster education in mining engineering, geology, and other fields related to critical minerals mining and manufacturing;
- Promote interdisciplinary collaboration among material science, computer science, and related disciplines to modernize the minerals supply sector industry and make the field more attractive to new talent;
- Implement personnel and management reform to ensure appropriate human capital to support exploration and

- development of critical minerals on Federal lands; and
- Facilitate sustained interaction with critical mineral stakeholders and the general public.

Japan

Japan is one of the world's largest consumer of the REEs. Rare earths are a mainstay of Japan's export business as it is required to produce both consumer electronics and cars.

It may be noted that after a collision of a Chinese fishing vessel with Japanese coast guard vessels near the Senkaku Islands in 2010, China used its dominance over REEs to effectively implement its ban on exports to Japan. Further, China slashed its export quotas post-2010 leading to a huge jump in the rare earth prices. In the consequent years, China cut its shipments outside the country to 30,184 tonnes in 2011 from about 60,000 tonnes in 2007. However, according to China, this was an effort to clean up a highly polluting domestic rare-earth mining industry.

The US, the EU and Japan in 2012 raised the issue in WTO, essentially explaining that China was using the quota to push up global rare-earth prices in violation of WTO rules. Subsequently, China had to drop quotas limiting exports of strategically important minerals. But since then, the world has reduced its reliance on the minerals from China, albeit marginally, as other producers ramped up supply. China still holds the majority share of global rare-earth output. In fact, lately many countries have been pro-active in reducing their reliance on China's rare earth minerals. The Japanese government's policy now is to source more than 60% of its rare earths requirements from outside China. To achieve this, major Japanese corporations are developing mining projects in cooperation with local entities in Australia, India, and Kazakhstan.

A US$ 1.5-billion fund has been earmarked for developing alternative sources of rare earths, notching up the push for joint venture partnerships to secure supplies of these elements. Japanese firms are also being backed by the Japanese government, which is entering into international partnerships in the same regions.

Further, in its commitment to R&D, recently, a research team in Japan used technological innovation in deep-sea exploration, and discovered a deposit of rare-earth minerals off the coast of Japan that could supply the world for centuries. The deposit contains 16 million tons of the valuable metals.

Such discoveries could be a consequential event that provides resource security for Japan and other nations dependent on China's rare earth exports.

However, there are certain challenges too. The minerals are buried 6000 metres deep in the ocean. Currently, there are no profitable methods of producing rare earth minerals embedded more than 5 kilometres below the seabed.

Based on the current methods, producing only 1000 tons of metals would require mining more than one million tons of mud. In addition, questions remain as to whether a timeline which allows Japan to wean itself off its dependence on Chinese rare earth materials within the foreseeable future is feasible.

Currently, it takes an average of 10 years to advance a rare earth discovery on land to a producing mine.

Australia

Australia has large reserves of critical minerals, including the world's third-largest deposits of lithium. However, environmental and financial costs of rare earth production have hindered its progress in the area. Unlike resources such as gold, rare earths cannot simply be dug out of the ground and immediately processed. That is because they are found inside other, non-rare-earth deposits. The materials that are dug up need to be broken down in order to isolate the rare earths, which involves acid being used to separate minerals contained in rocks or sediment which remains a hazardous exercise.

The Australian Government recently came up with its Critical Minerals Strategy in 2019 examining the lists of critical minerals published in several markets and matched those against Australia's known geological

Table 7: Critical Minerals in Australia

S No.	Critical Mineral	Australia's Geological Potential	Australia's Economic Demonstrated Resource	Australia's Production	Global Production	Market Value (Global) (US$ million)
1	Antimony	Moderate	138 kt	5.5 kt	150 kt	185.2
2	Beryllium	Moderate	-	-	230 t	918.6
3	Bismuth	Moderate	-	-	14 kt	69.2
4	Chromium	High	-	-	31000 kt	4,705.30
5	Cobalt	High	1221 kt	5 kt	110 kt	541.8
6	Gallium	High	-	-	495 t	918.6
7	Germanium	High	-	-	134 t	918.6
8	Graphite	Moderate	7140 kt	0	1200 kt	1,076.10
9	Hafnium	High	756 kt	-	-	918.6
10	Helium	Moderate	-	4 hm3	160 hm3	591
11	Indium	High	-	-	0.72 kt	918.6
12	Lithium	High	2803 kt	14.4 kt	43 kt	1,430.60
13	Magnesium	Moderate	-	0	1100 kt	716.4
14	Manganese	High	231000 kt	3200 kt	16000 kt	5,443.70
15	Niobium	High	216 kt	-	64 kt	1,709.50
16	Platinum-group elements	High	24.9 t	2.6 t	200 kt	19,316.60
17	Rare-earth elements	High	3270 kt	14 kt	130 kt	415.4
18	Rhenium	Moderate	-	-	52 kt	918.6
19	Scandium	High	-	-	-	-
20	Tantalum	High	55.4 kt	-	1.3 kt	1,552.90
21	Titanium	High	Ilmenite: 276500 kt Rutile: 32900 kt	Ilmenite: 1400 kt Rutile: 300 kt	Ilmenite: 6700 kt Rutile: 750 kt	1609.9
22	Tungsten	Moderate	386 kt	0.11 kt	95 kt	164
23	Vanadium	Moderate	3965 kt	0	80 kt	1,709.50
24	Zirconium	High	52662 kt	600 kt	1600 kt	1,003.40

Source: Department of Industry, Innovation and Science, Australia Government endowment. It is observed that Australia has moderate to high geological potential in 24 minerals that are deemed critical by many countries.

In its Strategy, the Australian Government lists down various action plans along with the goals for each[9]. The Strategy aims to refine Australia's policy settings to enable the resources sector to supply the growing markets for raw and refined critical minerals.

❖ Attracting investment into Australia's critical minerals sector
  - Increase investment into the critical minerals sector (including downstream processing capabilities) and secure markets for Australian critical minerals products.

❖ Spurring innovation in the critical minerals sector
  - An innovative critical minerals sector that is globally competitive across a broader range of minerals.

❖ Infrastructure Investment
  - Connecting critical minerals opportunities with infrastructure developments.

Further, the Government of Australia has also been strengthening links with the US, since the US released an Executive Order in December 2017 directing the development of a United States Critical Minerals Strategy. In February 2018, Australia and the US agreed to work together on exploration, extraction, processing, research and development. In December 2018, both the countries signed a letter of intent committing Geoscience Australia and the U.S. Geological Survey to work together on critical minerals issues.

And recently, in November 2019, the Australian and the US mineral agencies signed a deal to jointly develop a better understanding of their critical minerals reserves. This will see Australian and American scientists and companies collaborate to find what minerals exist and where, in addition to mining data to model what minerals the market wants.

Australia is also launching the Critical Minerals Facilitation Office, which is aimed at helping miners to secure investment, financing and market access for critical mineral projects from January 2020.

Projects which boost Australia's ability to extract and process critical minerals will be eligible for financial support through Export Finance Australia or EFA, including the Defence Export Facility.

[9] Australia's Critical Minerals Strategy 2019; Australia Government

6.

India's Strategy to Secure Rare Earths

India has been making efforts to domestically produce and manufacture products and make India more self-reliant. Such an approach gives the country a valid reason to increasingly looking at furthering the exploration securing REE assets. India's efforts toward securing a supply of such minerals, is crucial at a time when some countries are putting restrictions in export of rare earths as part of geo-political issues.

REEs are integrated into multiple industries that contribute to a nation's economy and security. Some of these elements are considered as strategic minerals because of their use in defence, energy and other strategic sectors. The usage of rare earths in the manufacturing sector is growing, as also the growth in demand from the existing end-user sectors. Thus, it is important to develop a national strategy with regard to application, consumption, exploration of REEs in the domestic economy, as also its trade and mineral cooperation in the international arena.

Seventeen REEs, including neodymium and dysprosium, are used in the manufacturing of products ranging from electric motors and hard disk drives to drones and home appliances. Securing these minerals is vital for India as the country is giving a major thrust to the manufacturing of electric vehicles in India.

It may also be noted that India aims to have a 30% share of electric vehicles in the manufacture of new vehicle fleet by 2030. Apart from electric vehicles, the growth of other end-use industries such as advanced electronics is expected to drive the demand for other minor minerals and rare earths in the country, which has a growing middle class.

As a way forward, India could explore through its diplomatic associations in other countries for collaboration in joint exploration activities and thereby securing REE assets within the country and abroad. It may be noted that in 2019, three Indian state-run companies, namely National Aluminium Company Ltd., Hindustan Copper Ltd., and Mineral Exploration Corporation Ltd., formed a joint venture (Khanij Bidesh India) to explore mines in Argentina, Bolivia, Chile and other countries for minerals used to produce EV batteries, besides building strategic reserves of tungsten, nickel, and rare earths.

It should also be noted that India has the fifth largest reserves of rare earth in the world. However, Indian companies are not investing in exploration activities domestically. Only a few private players like Cochin Minerals and Rutile Ltd (CMRL), Beach Minerals Co. Pvt. Ltd, V.B. Minerals and Resins Pvt. Ltd etc. are operating in this sector. Though, at present, the demand is catered through imports, especially from China, the uncertainty in the area of international trade is high. Thus, it is very essential to look at investments in the sector strategically.

Some of the possible strategies which India can adopt to secure its access of REEs would include:

1. Indian state-run companies can form joint venture to secure minor mineral assets such as lithium and cobalt that could fuel India's plan for mass adoption of electric vehicles by 2030.

The learnings of International Coal Ventures Limited, jointly formed by SAIL, RINL, Coal India Ltd, National Mineral Development Corporation (NMDC) and NTPC Ltd. which had tied up may be looked into while forming such strategic joint ventures.

2. Indian companies may look at opportunities for international collaborations in this space. The partnership could also be in the areas of joint exploration, and refining, and trading of critical minerals. Exploration should also be strengthened within the country as India is presumed to be having world's fifth largest reserves of REEs. With such collaborations and local manufacturing, the trade deficit of India could be reduced, especially in the areas such as electronics.

3. The country also needs to promote R&D in order to find better substitutes for priority minerals, as also in the recycling and material recovery areas.

4. In China, financial institutions like ICBC Investment Banking, Agricultural Bank of China Limited, and China Construction Bank are major players in promoting REEs in the country. The mining and refining of rare earth in China is monopolized by six major state-owned enterprises (SOEs). Non-SOEs, on the other hand, only have access to downstream industries like the production and application of rare earth materials, namely, permanent magnet materials, catalytic materials, luminescent materials, polishing materials, and hydrogen storage materials. Further, China's goals in mapping out this strategic approach to its rare-earth industry can be viewed as twofold, with the underlying aim of adding value to this important resource. First, it can be argued that China sought to ensure that it could service its domestic REE needs and Chinese consumers at prices lower than those of exported. Second, China also aimed to continue to provide access to international companies that would move and maintain their manufacturing facilities in China. These companies would be required to pay more than Chinese consumers, but prices would still be lower for them than that are prevailing in the international markets. With such focused domestic priorities, international consumers would need to find other sources for purchasing rare earth[10].

Learnings for India from Other Country Models

In December 2018, Geoscience Australia and the U.S. Geological Survey agreed to collaborate and work together on critical minerals issues

The Australian Government recently came up with its Critical Minerals Strategy in 2019 examining the lists of critical minerals published in several markets and matched those against Australia's known geological endowment

In November 2019, the Australian and the US mineral agencies signed a deal to jointly develop a better understanding of their critical minerals reserves. This will see Australian and American scientists and companies collaborate to find what minerals exist and where, in addition to mining data to model what minerals the market wants.

Multiple Japanese companies are developing mining projects in cooperation with local entities in Australia and Kazakhstan, in order to reduce dependence on China

In order to secure supplies of rare earth elements, a US$ 1.5-billion fund has been earmarked by Japan for developing alternative sources of rare earths, notching up the push for joint venture partnerships

USA has released 'A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals' in 2019, given the recent trade tensions between US and China, with rare earths playing a vital role in it.

[10] Cindy Hurst, "Common Misconceptions of Rare Earth Elements," *Journal of Energy Security*

China's Overseas Investment in Agriculture

One of China's guiding strategies for agricultural investment aims to reduce its reliance on India and other countries from where agricultural products are imported by China, by nurturing new suppliers, trading and logistics companies; improving China's capacity to develop its own agricultural technology; and using commercial agricultural projects as a platform for dispensing China's foreign aid. The scale of China's outbound agricultural investments havegrown at a rapid pace. As per the latest data available from the China's National Bureau of Statistics, overseas ventures in agriculture, forestry, and fisheries increased from US$ 300 million in 2009 to US$ 3.3 billion in 2016.

It is important to note that a national food security strategy was outlined for China in a Five-Year Plan from 2006 to 2010. The Plan advocated for the country to "Go Global" using China's large labour resources to develop foreign land, water, and energy resources. The plan encouraged large-scale, competitive food conglomerates to produce grains, oilseeds, and sugar crops on rented land in South and North America and Africa and then to transport these crops back to China to balance the supply and demand. Interestingly, China's agricultural investors are mainly small companies focusing on neighbouring countries in Southeast Asia, Russia's Far East, and Africa that have unexploited land, and are often receptive to Chinese investment. Agricultural investment is now closely tied to China's One Belt One Road initiative, which targets countries that are in between China and Western Europe. Chinese companies seeking sources of dairy, beef, and lamb imports have focused their investments and partnerships withNew Zealand and Australia.

China's Outward Industrial Investment and the Institutional Support

In line with the strategy that has guided China's outbound investment in the Agriculture sector, through the OBOR initiative, China seeks to leverage the goals of "international production cooperation" to redirect the investments in the industrial sector. It is worth noting that China has emerged as the single largest creditor to the African continent in the last few decades accounting for 20% of all the African debt. Further, Chinese officials draw a distinction between interest-free, government-to-government credits, and "preferential" loans from the China Export-Import Bank and China Development Bank that represent the largest part of China's overseas lending.

Lastly, a vast majority of China's commercial loans, but also a sizeable portion of the concessional ones, is directed at two sectors: energy and infrastructure. This means that China's "development finance" is overwhelmingly in the form of commercial loans for energy and transport infrastructure deals, often to middle or even high-income countries (for instance, the China Development Bank's largest energy loans portfolios are to Venezuela and Russia). Hence, it is important to relook at the overseas lending behaviour of China's policy banks in the context of China's broader industrial strategy and state-capitalist form of economic statecraft: the idea that state-owned banks engage in commercially-oriented lending is not on the same lines with the rest of China's political economy.

India Looking Ahead

A dedicated overseas strategic investment fund for the purpose of securing REE assets could be thought through, which could be housed and administered by a specialised government financial institution. The Fund's resources could be used for strategic investments by Central and State PSUs.

The proposed fund could also become an arm of an existing financial institution with specialised operations in diverse areas. While India today exhibits global aspirations to seek foothold across geographies, it is largely bereft of any such dedicated fund to boast of. However, the demand here is not to create a Sovereign Wealth Fund whose objectives are to get better returns from its investments, amongst other purposes.

The argument here is for establishing a strategic fund which facilitates India's investments overseas in critical areas. For example, India aspires to shift to battery-led electric vehicles by 2030, but to achieve that, it would require lithium and cobalt for the batteries. The same would also be vital if India would like to reduce its imports of electronic items.

The way ahead essentially means to finalise a course of action. There are several Indian manufacturing companies both in private and public sector which has the wherewithal to secure India's needs. A suitable and a concerted strategy could secure India's aspirations in the long run.

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