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FROM EXTRACTION TO INNOVATION

A Blueprint for Enhancing Rare Earth Magnet Ecosystem in India's EV Roadmap

Foreword

Davinder Sandhu

Co-Founder & Chairperson
Primus Partners

India today stands at a pivotal juncture in its journey towards self-reliance and global leadership in advanced manufacturing and clean energy technologies. At the heart of this transformation lies a small but mighty component—rare earth permanent magnets, especially neodymium–iron–boron (NdFeB) magnets. These critical materials are indispensable to a wide array of strategic applications spanning electric vehicles, renewable energy systems, consumer electronics, and national defence. The Report on Rare Earth Magnets highlights both the urgency and the vast potential India holds to become a global hub in this vital sector.

The Ministry of Heavy Industries (MHI), in close coordination with the Government of India, has taken proactive steps in this national endeavour. From spearheading the EV Taskforce under the National Mission on Transformative Mobility and Battery Storage to driving cross-sectoral alignment through the Production-Linked Incentive (PLI) schemes, MHI has been instrumental in laying the groundwork for a robust domestic ecosystem. Through initiatives like the Critical Minerals Mission, support for technology development, and promotion of domestic and global strategic partnerships, the Ministry is actively nurturing an end-to-end value chain—right from mineral extraction and processing to advanced magnet manufacturing.

India's inherent strengths—significant monazite reserves, a strong scientific and R&D base, a vibrant manufacturing sector, and a growing appetite for clean-tech solutions—provide a unique window of opportunity. With global demand for NdFeB magnets expected to surge in the coming decades, India is well-positioned to not only meet its domestic needs but also serve international markets as a sustainable and reliable supplier.

As we look ahead, it becomes imperative to scale domestic capabilities, invest in indigenous innovation, and deepen scientific and industrial collaboration. Initiatives like the establishment of a National Rare Earth Innovation Hub, coupled with the development of specialised magnet manufacturing clusters, will be key enablers.

We must seize this opportunity to transform India into a self-sufficient, globally competitive leader in rare earth magnet technology—powering the next generation of electric mobility, renewable energy, and strategic industries, and securing a sustainable future for the nation.

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Executive Summary

Neodymium–iron–boron (NdFeB) rare-earth magnets are essential to the performance of electric vehicle (EV) motors and a range of advanced components in defence, electronics, and clean energy systems. These magnets, containing neodymium and dysprosium, enable the compact, high-efficiency drive motors that power India's emerging EV sector. However, India currently relies almost entirely on imports for NdFeB magnets, over 80–90% of which are sourced from China, a country that controls approximately 85–95% of global rare-earth magnet production.

The global permanent magnet market, valued at $17.85 billion in 2018, is expected to grow at a CAGR of ~9.5% from 2021 to 2026, reaching $54.1 billion by 2030. The National Electric Mobility Mission targets 30% EV penetration in new vehicle sales by 2030. Given that each EV requires ~1 to 2 kg of NdFeB magnets, India's demand is projected to rise to an estimated 7,154 tonnes by 2030. This dependency represents a strategic vulnerability, especially as rare-earth magnets are critical not only to EVs but also to industrial automation, electronics, renewable energy systems, and defence applications.

Recent export restrictions imposed by China have already created bottlenecks in the supply chain. Industry bodies have reported that more than 20 Indian companies (including Bosch, TVS, and Mahle) have experienced delays due to licensing and customs clearance hurdles in China. The risk of geopolitical tensions affecting domestic production creates an urgency to build resilient and diversified supply chains.

The experience of countries like Japan, which plans to reduce its reliance on Chinese rare earths from ~90% in 2010 to ~60% by 2023 through stockpiling and diversification, offers a useful benchmark for India. In response, the Government of India is advancing a comprehensive strategy to promote rare-earth security and magnet self-reliance. Announced in the Union Budget 2024–25, the Critical Minerals Mission focuses on enhancing domestic exploration, supporting downstream processing, enabling innovation and recycling, and launching offshore mining auctions with duty exemptions.

India holds significant reserves of monazite (a rare-earth phosphate mineral that serves as one of the most important primary sources of light rare earth elements (LREEs), particularly neodymium (Nd) and praseodymium (Pr); both critical inputs for NdFeB permanent magnets), a key rare earth-bearing mineral classified as a prescribed substance under the Atomic Energy Act, 1962. As of 2023, India's estimated monazite deposits stand at 13.07 million tonnes across 130 coastal and inland sites, containing 55–60% total rare earth oxides (TREO). The country currently has an installed monazite separation capacity of 6,240 tonnes per year, led by IREL.

In 2022, India's domestic consumption of NdFeB magnets was 1,700 tonnes, with the market valued at ₹1,245 crore and average prices ranging from ₹4,186 to ₹4,605 per kg. By 2030, this demand is projected to rise exponentially to ~ 7,154 tonnes, with market value reaching ₹7,295 crore. India currently produces 1,500 tonnes of neodymium-praseodymium (NdPr) annually through IREL, with 500 tonnes allocated to Toyotsu Rare Earth under an Indo-Japanese bilateral agreement. This marks an essential step in integrating India into global rare earth supply chains and advancing long-term strategic autonomy.

India's rare earth strategy has gained renewed momentum, driven by a shared commitment from industry and government under the broader vision of Atmanirbhar Bharat and Make in India. Proposed initiatives such as a Production-Linked Incentive (PLI) scheme aimed to catalyse domestic manufacturing of NdFeB magnets. Complementing this, India is proactively securing upstream resources through Khanij Bidesh India Limited (KABIL), a joint venture between National Aluminium Company Limited (NALCO), Hindustan Copper Limited (HCL) and Mineral Exploration & Consultancy Limited (MECL) in ratio 40:30:30 respectively, under the aegis of Ministry of Mines, Government of India, to acquire critical mineral assets overseas. Private industry is also stepping up with Sona Comstar, one of India's largest importers of rare earth magnets (importing 120 metric tonnes in FY2023–24), announcing plans to become the first Indian company to manufacture rare earth magnets domestically. In the short term, the government has expressed intent to expedite import clearances through green channel customs and explore bilateral engagements with the People's Republic of China to fast-track export licensing.

Simultaneously, long-term capacity building is being advanced through strategic R&D investments, including a pilot-scale NdFeB magnet fabrication unit set up by the International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI) under the Department of Science and Technology. These efforts are pivotal to achieving India's target of 30 per cent electric vehicle penetration by 2030 and positioning the country as a global hub for sustainable and advanced manufacturing.

However, building on this momentum, further action is imperative. The recent export restrictions imposed by China have exposed the fragility of global supply chains and underscored the urgency of advancing India's rare earth self-reliance agenda. A decisive national strategy can enable the creation of a resilient, end-to-end value chain within the next few years to secure India's critical industries, including electric mobility, renewable energy, electronics, and defence.

To this end, we recommend five strategic interventions. To build a resilient and self-reliant rare earth magnet ecosystem, India must move decisively to address longstanding structural gaps across the supply chain. First, a government-backed framework for market assurance is essential. This includes long-term price guarantees and structured offtake agreements with anchor buyers across the automotive, defence, and renewable energy sectors. Such instruments can de-risk investment and create predictable demand for emerging domestic manufacturers. Second, India should establish pilot-scale, integrated hubs in key mineral-rich states to demonstrate the feasibility of co-locating upstream and downstream units. These hubs must be coupled with the identification and support of a few industrial champions—firms with the technical depth and manufacturing capability to scale quickly with the right policy and financial backing.

Third, upstream security must be prioritised by empowering Indian Rare Earths Limited (IREL) to expand monazite processing and NdPr refining capacities, while also creating a strategic magnet reserve to cushion critical sectors from supply

Fourth, a dedicated National Rare Earth Innovation Hub should be launched to support applied R&D, scale domestic process innovation, and facilitate technology collaborations with trusted global partners. Finally, these efforts require coordinated implementation. A Magnet Ecosystem Coordination Cell should be established under NITI Aayog or DPIIT to align the efforts of key ministries and monitor progress against clear, time-bound milestones.

These five pillars, implemented together, can enable India to transition from dependency to leadership in sustainable magnet manufacturing.

India is in a pivotal position to ensure its strategic future by becoming self-sufficient in rare earth resources. India can lessen its reliance on imports and become a competitive centre for clean technology and advanced manufacturing by increasing its domestic capacity along the mining-to-magnet value chain, encouraging innovation, and facilitating international collaborations.

02

Introduction

2.1 Rare Earth Elements

Rare Earth Elements (REEs), comprising a group of 17 metallic elements that include lanthanides, scandium, and yttrium, are essential in contemporary emerging technology across numerous industries. Despite their misleading name, these elements are relatively abundant but pose significant challenges in extraction and processing. Their distinctive chemical and physical properties render them indispensable for various high-tech applications, including clean energy technologies, electronics, and defence. Particularly within the electric vehicle (EV) industry, REEs are crucial due to their role in enhancing motor efficiency, battery performance, and other vital components.

21 Sc scandium	39 Y yttrium	57 La lanthanum	58 Ce cerium	59 Pr lutetium	60 Nd neodymium
61 Pm promethium	62 Sm samarium	63 Eu europium	64 Gd gadolinium	65 Tb terbium	66 Dy dysprosium
67 Ho holmium	68 Er erbium	69 Tm thulium	70 Yb ytterbium	71 Lu lutetium	

REEs are classified into a single family of elements because of their chemical similarities. They are further subdivided into two categories based on their atomic weights, which also influence their natural occurrence:

01 Light Rare Earth Elements (LREEs)

This group includes Cerium (Ce), Lanthanum (La), Praseodymium (Pr), Neodymium (Nd), and Samarium (Sm).

02 Heavy Rare Earth Elements (HREEs)

This group comprises Europium (Eu), Gadolinium (Gd), Terbium (Tb), Dysprosium (Dy), Holmium (Ho), Erbium (Er), Thulium (Tm), Ytterbium (Yb), and Lutetium (Lu).

REEs in Electric Vehicles: Lifecycle Supply Chain

01 Raw Materials Production

This includes mining and processing of REEs, production from secondary and unconventional sources, and other materials.

02 Processed Materials Production

This phase involves separation of individual REEs into oxides and refining of RE metals.

03 Sintered Magnet Manufacturing

This includes both metal alloying and processes involved in magnet fabrication.

04 Manufacturing of Components and Final Products

This step covers manufacture of components for end-use and assembly of final products.

05 End-of-Life Product Recovery and Magnet Remanufacturing

This involves recovery of end-of-life products and remanufacturing of magnets.

2.2 NdFeB Magnet: Supply Chain Lifecycle

Upstream: Raw Material Production

The upstream stage encompasses production of materials from primary sources (mining), secondary sources (recycling), and unconventional sources. This phase also includes the concentration and beneficiation of mined products into a mixed rare earth (RE) concentrate.

Primarily, REEs are mined with ores processed using gravity, magnetic, electrostatic, and flotation methods to enhance RE concentration. Secondary sources include recycled end-of-life products, particularly spent magnets, although current production from these sources is minimal but promising. Unconventional sources, such as byproducts of other mining processes or industrial activities include coal, coal ash, geothermal fluids, mine tailings, acid mine drainage, and red mud. Among these, coal ash, a byproduct from coal-fired power plants, holds significant promise due to its regulated collection and potential for quicker development compared to mining projects, despite having lower RE concentrations.

Midstream: Processed Material Production

This stage involves separation of individual REEs from concentrates, typically in oxide form, and the subsequent refining of these oxides into metals. Initially, monazite is separated from other minerals post-mining through pre-concentration using gravity, electromagnetic, and electrostatic techniques, followed by cracking with alkali to extract soluble REEs. Subsequent stages remove phosphate and radioactive elements, refining the REEs into a high-purity form.

Rare Earth Element Separation

Separates light REEs like Nd and Pr from heavy REEs like Dy and Tb, involving significant consumption of acids, caustics, and water.

Rare Earth Element Metal Refining

RE oxides or chlorides are refined into metals such as NdPr, pure Nd, Tb, and DyFe for use in magnets. The primary refining processes are electrowinning and sodium reduction.

Downstream: Magnet Manufacturing

Magnets are produced from alloys or powders combining rare earth metals such as Nd and Pr with iron and boron.

The properties of a magnet are optimised based on its intended use, focusing on:

- **Coercivity:** Resistance to demagnetisation.
- **Maximum Energy Product**: The measure of the magnetic energy stored in the material, dependent on its coercivity and magnetisation.
- **Maximum Operating Temperature:** The highest temperature at which the magnet can operate effectively.

In most applications, a trade-off is made between these properties, the final product weight, and cost.

Rare Earth Permanent Magnets are categorised into:

A. **Neodymium-Iron-Boron (NdFeB) Magnets:** These magnets have high energy product up to about 180°C, allowing manufacturers to reduce component size and weight or achieve higher efficiency with components of the same size. NdFeB magnet grades (e.g., N35, N42) indicate their energy product and maximum operating temperature. Nd constitutes 65-70% of RE consumption by value in magnets, while magnets account for 95% of Nd demand. Conversely, magnets represent 85% of Pr demand, averaging 13% of the magnet composition by value. Nd and Pr are introduced into magnet alloys either as separated metals and compounds or as alloyed metal products such as Nd-Pr metal. HREs like Dy, Tb, and Ho constitute a smaller portion of NdFeB magnet demand.

They can be bonded and sintered:

- **Bonded NdFeB:** Uses plastic resins to bind magnetic particles, which are suitable for complex shapes but results in lower energy products and brittleness.

- **Sintered NdFeB:** Follows a powder metallurgy route - induction melting, strip casting, hydrogen decrepitation, jet milling, alignment, pressing in a magnetic field, and sintering at 1,000-1,100°C. Machined and coated with Nickel to prevent corrosion., they contain 30% rare earth material, 69% iron, and 1% boron by weight. Heavy REs (Dy and Tb) is primarily used in sintered magnets to enhance resistance to demagnetization at temperatures above 120°C. Direct-drive generators and traction motors rely on sintered NdFeB magnets for their reliability and high performance.

B. **Samarium Cobalt (SmCo) Magnets:** These magnets are more resistant to demagnetization at higher temperatures, making them suitable for high-temperature applications where weight is not a concern. Samarium (Sm) and Gadolinium (Gd) are the primary REs used in these magnets. Demand for SmCo remains steady, but production has seen significant increases, boosting Rare Earth Oxide (REO) consumption to 1.0ktpy in 2019 and 2020.

Output: Component & Final Product

Rare earth magnets are utilized across a diverse range of applications, including wind turbines, electric vehicle drives, hard disk drives, cell phones, loudspeakers, industrial motors, non-drivetrain motors in vehicles, power tools, and electric bicycles. These applications often employ permanent magnet motors and drives, which are known for their low maintenance requirements and high-power density. Notably, they consume approximately 2% less energy compared to efficient induction motors in variable speed applications.

Currently, consumer electronics and industrial motors constitute the largest share of the demand for NdFeB magnets. However, the demand from wind turbine and vehicle sectors is significant and rapidly increasing. Each application necessitates different grades of magnets to meet specific requirements.

Vehicle drives need high-coercivity magnets for high temperatures, often using Dy, while low-heat devices like hard drives and speakers use NdFeB magnets with minimal or no Dy. In wind energy, NdFeB magnets power PMSGs, preferred offshore for low maintenance, high efficiency, and reduced weight, allowing larger turbines. Many turbines still use non-RE systems like DFIGs. Magnet usage averages 2.7–3.2 tonnes per MW, typically SH grade, with scope for substitution based on design.

In electric vehicles (EVs), NdFeB magnets are utilized in electric synchronous traction motors for propulsion systems in both battery and hybrid electric vehicles. Similar to wind turbines, there are various other electric propulsion systems available; however, synchronous motors are preferred due to their lighter and more compact design, higher efficiency—attributable to the absence of an external power system to generate a magnetic field—and greater torque.

It is projected that in 2025, between **90%** and **100%** of battery and hybrid electric vehicles will incorporate synchronous traction motors with NdFeB magnets.

Generally, traction drive motors operate at high temperatures and therefore require EH and AH grade magnets. Beyond their use in EV motors, NdFeB magnets also serve various automotive applications, such as in audio speakers, electronic sensors, transmissions, and power steering. However, these applications require relatively small amounts of magnets, making the demand negligible compared to that for traction motors.

Recycling

REEs are emerging as a significant environmental pollutant with electronic waste (e-waste) as a major source of pollution, containing high concentrations of REEs often handled in ways that are hazardous to the environment. Hence, naturally occurring as mixtures in ores, REEs must be purified before use, a process that is both complex and costly.

Consequently, recycling processed REEs is more economical than mining, which would not only provide a steady supply for manufacturers but also reduce waste and mitigate the substantial environmental impact.

Recent advancements in recycling technology have made the extraction of REEs from electronic waste more feasible. Japan has operational recycling plants capable of processing an estimated 300,000 tons of REEs stored in unused electronics. In France, efforts are underway to establish two factories aimed at producing 200 tons of REEs annually from used fluorescent lamps, batteries, and magnets. Additionally, coal and its byproducts are identified as potential sources of REEs, with an estimated production capacity of about 50 million metric tons.

Currently, most REE recycling involves swarf, the residue from cutting magnets during manufacturing. Recycling end-of-life magnets into new magnets or separated REEs is still limited in scale, but various promising methods have been developed for potential expansion. The complexity of the recycling process depends on factors such as the composition of the magnets, target products, whether they are sintered or resin-bonded, and the type of protective coating.

Generally, the recycling process for magnet-containing end-of-life products involves two steps:

- **Magnet Recovery:** Separating magnets from the products they are embedded in.
- **REE Recovery:** Separating REEs from the rest of the magnets.

Development of efficient and economical strategies for REE recycling depends on factors such as price, deposit sizes, disposal costs and hazard potential.

Methods employed by developed nations for recycling REEs from used electronics include:

- **Shredding and Grinding:** Gadgets are shredded and ground into a powder form from which essential components, including REEs, are extracted.
- **Pyrometallurgical Methods:** Elements are separated from electronic waste by heating to very high temperatures, a method that requires significant energy.
- **Liquid-Liquid Extraction:** Wastes are dissolved in strong acids, and REEs are extracted using a series of solvents.

These recycling methods, while currently limited in scope, show great promise for future expansion, contributing to a more sustainable and environmentally friendly approach to managing REE resources.

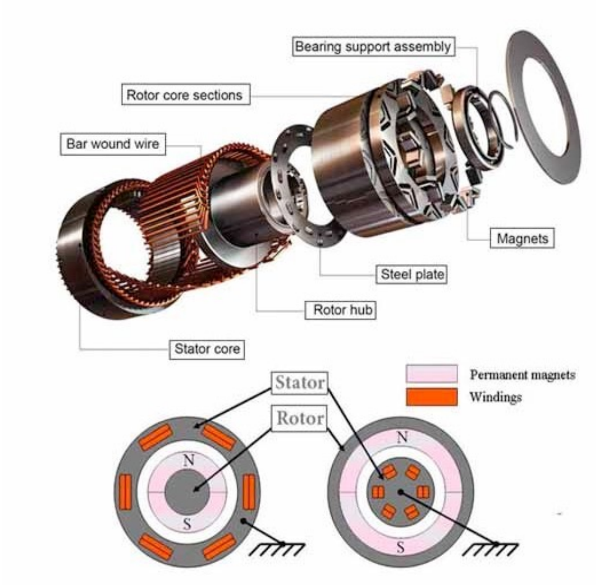
Okon Recycling, USA's leading recycler of neodymium magnets, has been closing the loop since the 1980s.

Using direct recycling—demagnetizing, dismantling, and reprocessing—Okon supplies hundreds of tonnes of high-quality scrap magnets annually to OEMs for reuse in advanced equipment. With one of the world's most advanced magnet processing facilities, Okon helps reduce reliance on rare earth mining and cuts environmental impact.

2.3 Usage of REEs in EVs

REEs have enabled the development of a technology-driven society, driving the soaring demand for modern electronics. These elements possess exceptional properties, including luminescence, magnetism, and energy transition capabilities. Neodymium, Praseodymium, Dysprosium, and Terbium are particularly vital for producing the permanent magnets used in electric vehicles (EVs).

The two most commonly used rare earth magnets are Neodymium Iron Boron (Nd-Fe-B) and Samarium Cobalt (SmCo).



Rare Earth Magnets used per EVs	
EV Type	**NdFeB Magnets User (per EV)**
2-wheelers	500-700 gm
3-wheelers	Approx. 500 gm
4-wheelers	2 kg

2.4 Applications of Magnets in EVs

Electric Motors

REMs, particularly neodymium magnets, are the core components of electric motors in EVs. They generate magnetic field necessary for motor operation, significantly contributing to the motors' efficiency and power density, thereby enhancing overall vehicle performance. Neodymium magnets are favoured for their high magnetic strength, which allows for the design of smaller and lighter motors without compromising performance. The magnetic field emitted by these magnets opposes that produced by a coil, creating a repulsive effect that causes the coil to rotate at high speed. When attached to a vehicle's axle, this rotation generates motion. The grade of Neodymium magnets used in EV motors varies depending on specific requirements, with commonly used grades including N35, N40, and N42, which denote the magnet material's strength.

Regenerative Braking

Magnets are integral to regenerative braking systems, which convert kinetic energy into electrical energy during deceleration, thereby improving energy efficiency and extending the vehicle's range. These systems use magnets in sensors or actuators to control braking force and energy regeneration. Neodymium magnets are commonly employed in this application, with specific grades selected based on performance requirements and environmental conditions.

Power Electronics

Magnets are also crucial components in various power electronics within EVs, such as inverters and transformers, aiding in the conversion and control of electrical energy.

Battery Systems

Magnets are utilized in various components related to the battery systems of electric vehicles. For instance, they may be used in battery cooling systems or in the assembly of battery modules. Depending on the application, magnets with superior thermal properties, such as grades N42SH or N45SH (where SH stands for high-temperature stability), may be employed.

Power Steering

In electric power steering systems (EPS) of electric vehicles, magnets are found in components like sensors and actuators. Neodymium-based magnets are preferred due to their strength and compact size. Different grades of Neodymium magnets may be used depending on the specific requirements of the EPS system.

Significance of Magnets in EVs

01

Efficiency

The use of high-performance magnets in electric motors enhances efficiency by minimizing energy losses, resulting in increased range and reduced energy consumption.

02

Compactness

Compared to traditional internal combustion engines, electric motors with magnets offer higher power-to-weight ratios, allowing for more compact and lightweight drivetrains in EVs.

Table: Maximum Operating Temperature, Associated Dy Content & Example Application of NdFeB Magnet Grades

Grade Suffix	Max operating temperature (in Celsius)	Approx Dy content (in %)	Approx Nd + Pr content (in %)	Applications
M	100	1.4%	28.6%	Hard disk drives, CD/DVD, MRI machines, sensors, refrigeration, etc.
H	120	2.8%	27.2%	Gauges, hysteresis clutch, magnetic separation, etc.
SH	150	4.2%	25.8%	Wind power generators, electric bicycles, energy storage systems, magnetic braking, industrial motors, general automotive applications, etc
UH	180	6.5%	24.5%	Commercial and industrial generators, waveguides, undulators, etc.
EHz/AH	200/220	8.5%-11%	19%-21.5%	Hybrid and electric traction drives, high temp. motors and generators, etc.

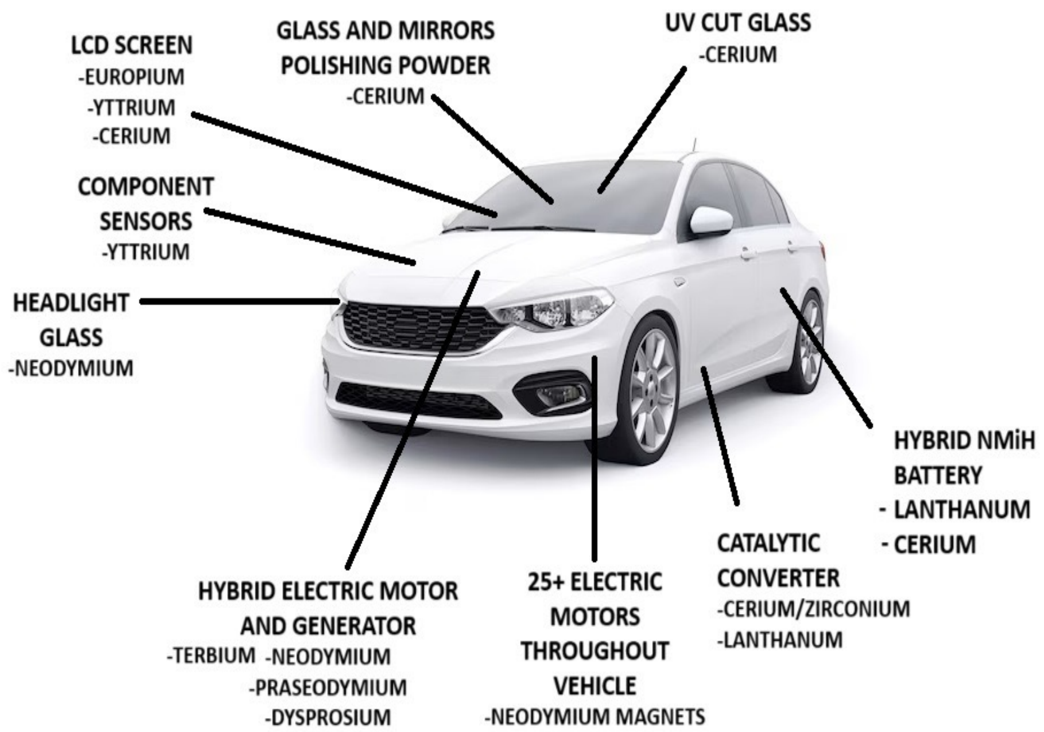
Table: REMs Used in Hybrid & Electric Vehicles

Hybrid & EV Parts	Quantity (in gr)	Type of REM
HVAC Systems	45-50	Mostly Nd & Dy
Steering, transmission, braking systems	160-200	Mostly NdFeB
Hybrid engine or electric motor compartment	800-5,000 gr	Mostly Nd & Dy
Others (security, seats, cameras)	20-30 gr	Mostly Nd
Door & window systems	67-85 gr	Mostly NdFeB
Entertainment (speakers, radio, etc)	40-50 gr	Mostly NdFeB
EV batteries	3,800-4,200 gr	Nd
Fuel & exhaust system for hybrids	70-80 gr	Mostly Ce

Within EVs, NdFeB magnets are used in electric synchronous traction motors for propulsion systems in battery and hybrid electric vehicles. Although a variety of other electric propulsion systems are available; however, synchronous motors are preferred as they allow for a lighter and more compact design, higher efficiency (due to the lack of an external power system to produce a magnetic field), and higher torque.

Hence it is evident that REEs are an essential part of many high-tech devices. According to the U.S. Geological Survey news release "Going Critical", REEs are necessary components of more than 200 products across a wide range of applications, especially high-tech consumer products and defence applications including electronic displays, guidance systems, lasers, and radar and sonar systems.

An EV motor requires **1-2 kg** of NdFeB magnet material, and the EV as a whole contains **2-4 kg** of permanent magnets.



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Global Scenario

The geopolitical competition surrounding REEs lies in the strength of their geographic concentration leading to building of resilient and diversified supply chains. Hence to transition from an integrated global economy to a more diversified one, it is imperative to establish a robust supply chain that acts as the litmus test for the emergence of REMs as pivotal components in EV manufacturing, where green energy and future technologies intersect with geopolitical and resource dynamics.

According to International Energy Agency's Global EV Outlook 2024, the performance of companies within the electric vehicle (EV) sector—including vehicle manufacturers, battery producers, and entities involved in extraction and processing of battery metals—has consistently outperformed general stock markets and traditional automotive manufacturers since 2019. The market capitalization of pure-play EV manufacturers surged from USD 100 billion in 2020 to a peak of over USD 1.6 trillion in 2021. Similarly, battery manufacturers and companies specializing in battery metals also experienced substantial growth in market capitalization during this period.

A study by Astute Analytica valued the global EV market at USD 340.2 billion in 2023 and projects a significant revenue increase to USD 72,798 billion by 2050. The global EV market is expected to grow at a compound annual growth rate (CAGR) of 21.99% in terms of revenue and 21.73% in terms of volume from 2023 to 2050. This rapid expansion will necessitate a critical role for REMs in supporting the development and scaling of EV industry.

3.1 Global Capacity: Supply Side

The economic significance of rare earth value chain is evident when considering the burgeoning electric vehicle market.

In 2023, global REE reserves were estimated at approximately 110 million metric tons (MT), with a total mine production of around 350,000 MT. In the same year, mining of magnet rare earth elements (REEs) was dominated by the top three producers, which accounted for 85% of the global output. China alone contributed a substantial 62% of this mined production.

In refining sector, the concentration of control was even more pronounced, with top three countries commanding majority share of refined output. China's dominance was stark, representing 92% of global refined output in 2023.

Although Chinese dominance in 2023 remained unchallenged, notable refineries outside China including those owned by Lynas in Malaysia, VTRE in Vietnam, and Neo Performance Materials in Estonia (Silmet) show prominence.

The Global Rare Earth Magnet Segmentation

S

BY TYPE

- Neodymium-Iron-Boron Magnet (NdFeB)
- Samarium Cobalt Magnet (SmCo)

N

S

BY PRODUCT

- Countersunk Magnets
- Circular Disc Magnets
- Hook & Eyebolt Magnets
- Cylindrical Rod Magnets
- Circular Ring Magnets
- Rectangular
- Self-Adhesive
- Pot & Clamping Magnets

N

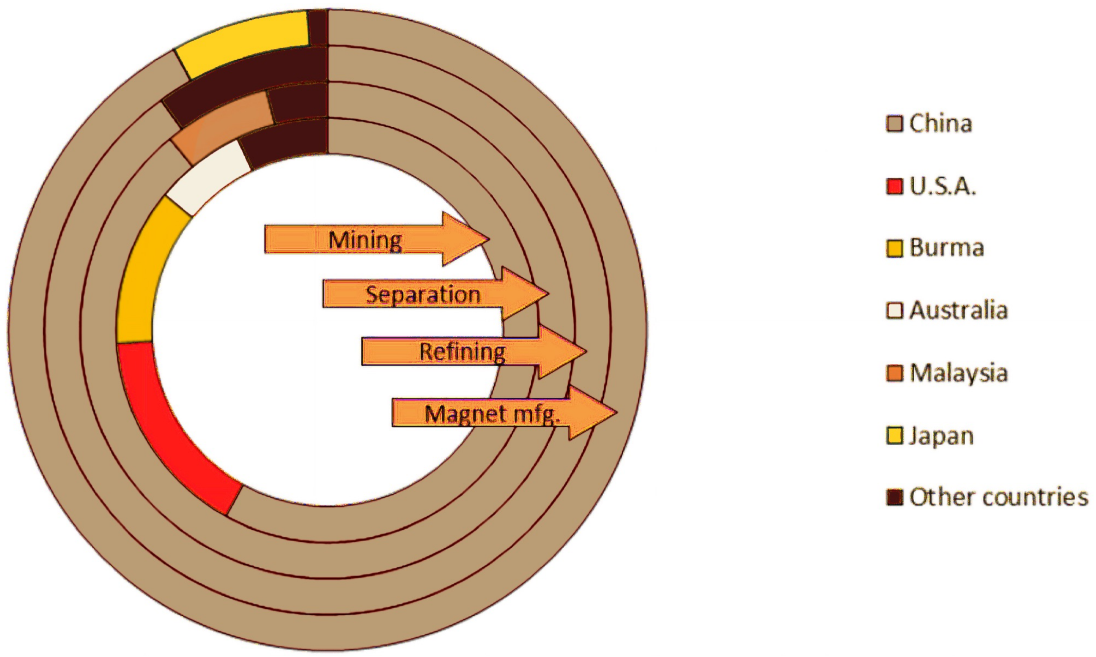
S

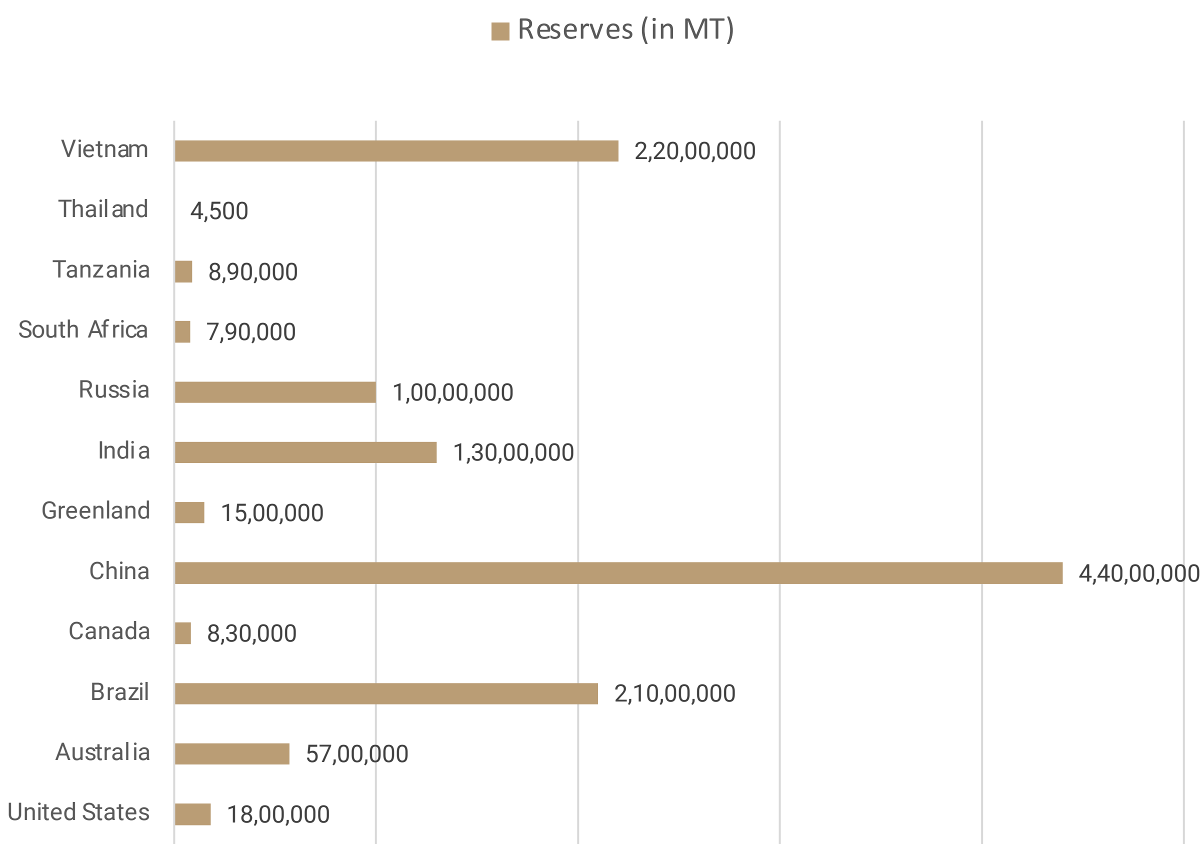
BY APPLICATION

- Automotive Industry
- Food & Drink Processing
- Aerospace Industry
- Renewable Energy
- Consumer Electronics
- Deep Sea Exploration
- Others

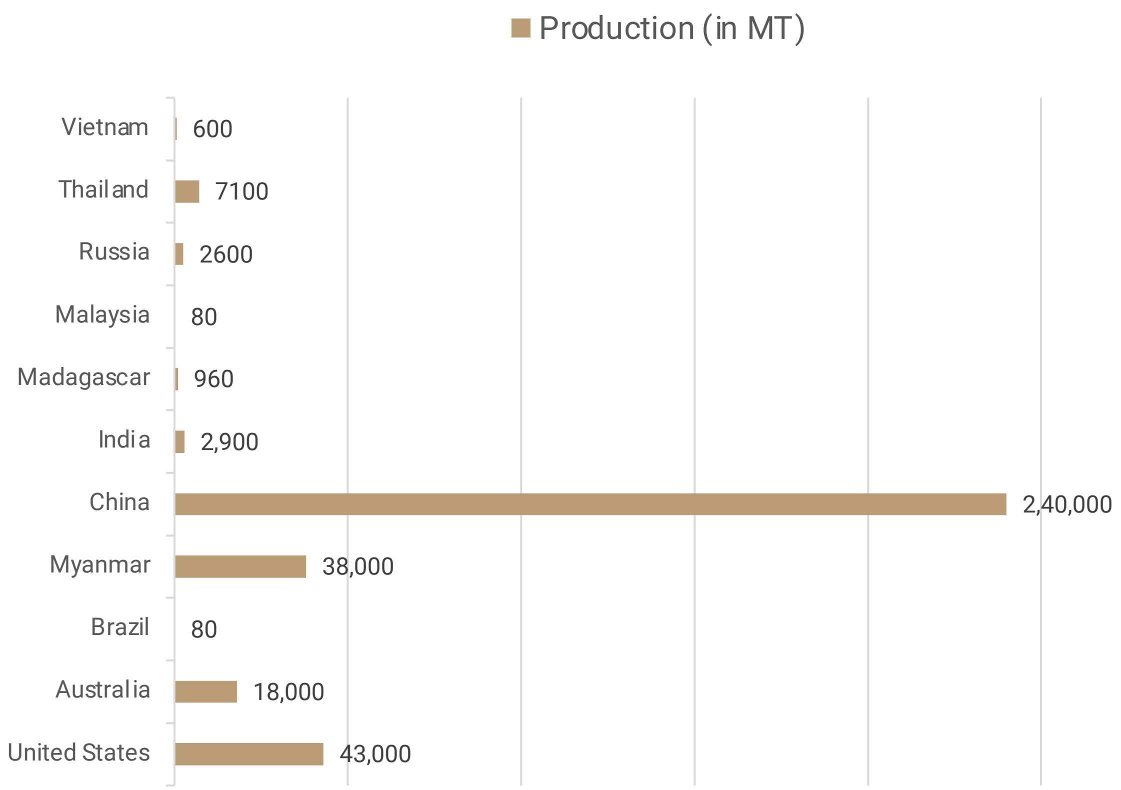
N

Geographical Concentration of Supply Chain Stages of Sintered NdFeB magnets

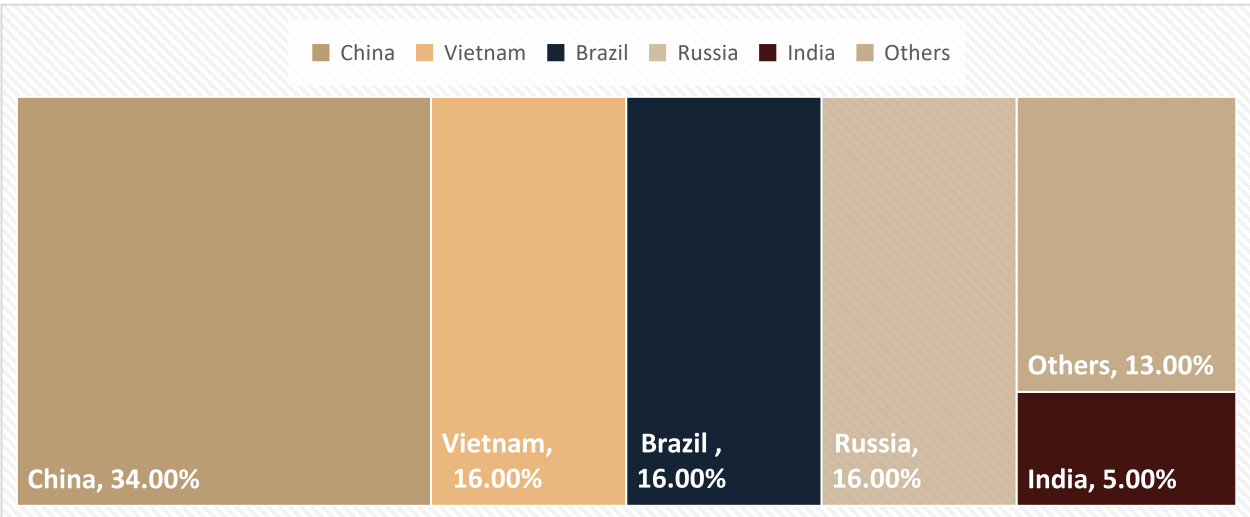




World Mine Reserves



World Mine Production

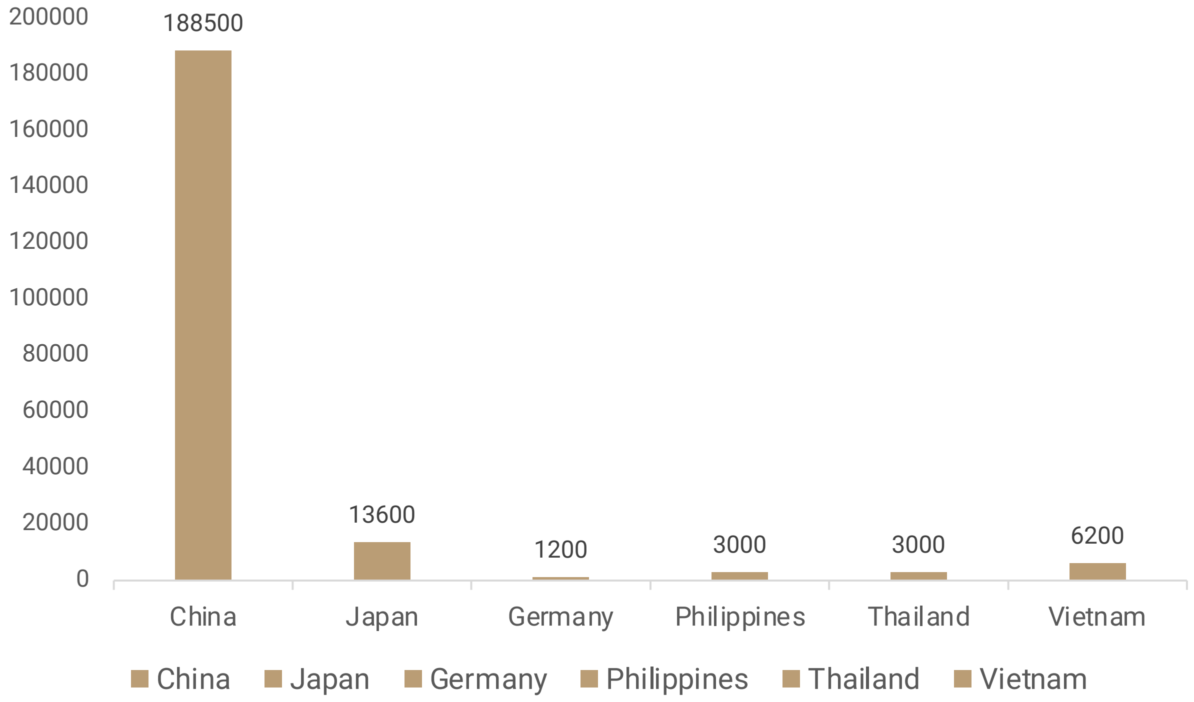


Rare Earth Oxides (REO) Equivalent Content

Table: REE Supply (Unit: kt REE)					
MINING			REFINING		
COUNTRIES	2030	2040	COUNTRIES	2030	2040
China	58	62	China	81	86
Australia	19	20	Malaysia	13	13
Myanmar	10	10	United States	4	4
United States	7	7	Australia	4	4
Rest of the World	13	14	Rest of the World	6	5
World	107	114	World	106	110
Top 3 share	81%	81%	Top 3 Share	92%	93%

Of the total world reserves of rare earth oxides equivalent content (REO), China alone accounts for 34% followed by Vietnam, Brazil & Russia (16% each) and India (5%). Projections for magnet REE supply indicate significant growth, with output from operating and announced mining projects expected to increase by 44% and 52%, respectively, surpassing 107 kilotons (kt) in 2030 and reaching 114 kt in 2040. Despite this growth, dominance of top three mining countries is projected to decrease slightly, from 85% to around 81%.

Similarly, refined supply is expected to rise to 106 kt in 2030 and over 110 kt in 2040. The share of top three refining countries remains high, marginally decreasing from 98% to 92% by 2040. By 2030, China's share of global refined output is projected to decline to 77%. The major producers of NdFeB magnets, alloys, and powders are China (92%), Japan (7%), Vietnam (1%) and a few other countries such as Germany, Philippines, Thailand among others having relatively limited capacity.

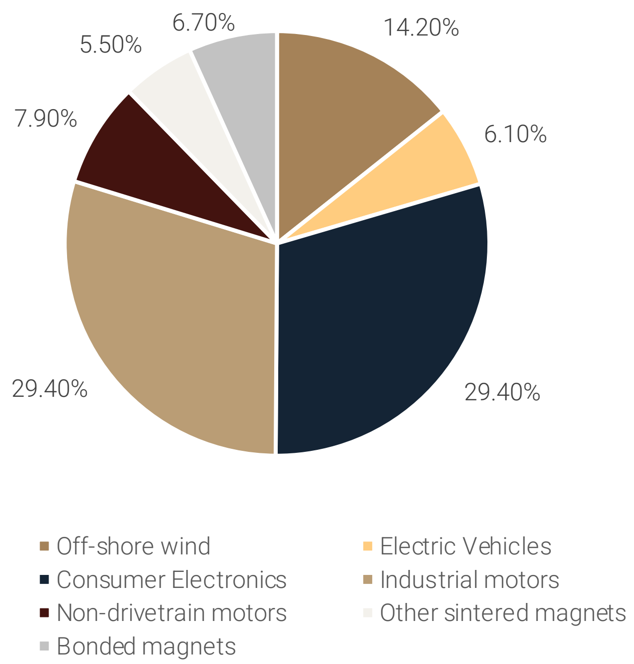


NdFeB Magnet Production in 2022 (TPA)

3.2 Global Capacity: Demand Side

Global demand for magnet rare earth elements (REE) nearly doubled between 2015 and 2023, reaching 93 kilotons (kt). During the same period, share of clean energy technologies in this demand, driven by the surge in new electric vehicle (EV) sales and wind turbine installations to meet climate goals, increased from 8% to nearly 18%.

By 2019, advancements in REE technology had resulted in 95% of electric vehicles (EVs) utilizing permanent REMs, valued for their superior energy efficiency that directly enhances driving range.



In the same year, approximately 5,000 tons of rare earth permanent magnets were employed in EVs worldwide. Concurrently, global production of NdFeB rare earth permanent magnets reached around 130,000 tons, with a market value estimated at approximately €6.5 billion.

In the Announced Pledges Scenario (APS), total magnet REE demand is projected to reach 131 kt by 2030 and further increase to 181 kt by 2050. The demand for EV motors is expected to rise significantly, from 7% in 2023 to nearly 30% by 2050. The Net Zero Emissions (NZE) Scenario predicts a slightly faster increase in EV sales and wind turbine deployments compared to the APS, resulting in total demand being 15 kt higher by 2030.

According to International Energy Agency, demand for REE is projected to increase three to seven times current levels by 2040. Meeting the commitments of 2016 Paris Agreement, which requires signatory nations to reduce emissions and cap global temperature increases, will necessitate a fourfold increase in global mineral supply within the same period. However, at the current growth rate, supply is on track to only double.

The demand of neodymium iron boron (NdFeB) permanent magnets is expected to increase significantly to meet demand for clean energy transition. This will be driven primarily by deployment of offshore wind turbines and hybrid electric vehicles, creating additional demand of critical materials including Neodymium (Nd), Praseodymium (Pr), Dysprosium (Dy), and Terbium (Tb).

However, **supply risks** in REE market arise from challenges in **diversifying production**. Currently, supply from existing projects is **sufficient** to meet demand, a trend expected to continue until **2025**.

Table 5: REE Demand (Unit: kt REE)

	Historical		Stated Policies			Announced Pledges			Net Zero by 2050		
	2021	2023	2030	2040	2050	2030	2040	2050	2030	2040	2050
Clean Energy	11	16	40	48	57	46	64	78	62	72	80
EV	3	7	23	36	40	25	46	51	33	48	52
Wind	8	10	17	12	17	22	19	27	29	24	28
Other uses	67	76	87	105	123	87	105	123	86	104	123
Total Demand	78	93	127	153	180	134	169	200	148	176	202
Share in Clean Energy	14%	18%	31%	32%	32%	35%	38%	39%	42%	41%	39%

Table 6: Expected Magnets Contained in a Global Demand for Selected NdFeB Magnets Application

Application	Demand in 2020		Projected Demand in 2030		Projected Demand in 2050	
	Amount (kt)	Share	Amount (kt)	Share	Amount (kt)	Share
Offshore wind turbines	16.9	14.2%	139.2	36%	273.7	36.3%
Electric Vehicles	7.3	6.1%	114.1	29.5%	266	35.3%
Consumer electronics (hard disk drives, cell phones, loudspeakers, others)	35.1	29.4%	41	10.6%	65.4	8.7%
Industrial motors	36.0	30.2%	53.7	13.9%	85.7	11.4%
Non-drivetrain motors in vehicles	9.4	7.9%	18.3	4.7%	29.3	3.9%
Other sintered magnets (power tools, electric bikes)	6.5	5.5%	9.6	2.5%	15.3	2%
Bonded magnets	8.0	6.7%	11.1	2.9%	17.7	2.3%
Total	119.2	100%	387	100%	753.2	100%

Most supply increases up to 2040 are projected to come from expansions of existing mines, such as Bayan Obo in China and Mount Weld in Australia. However, post-2025, a gap between projected primary supply requirements and supply additions emerges, particularly in scenarios such as the Net Zero Emissions (NZE) Scenario and the Announced Pledges Scenario (APS). The NZE Scenario anticipates a supply gap of 5 kilotons (kt) in 2030 and 14 kt in 2040. The primary concern for magnet REEs is not significant supply-demand gap but high geographical concentration of mining and refining projects, primarily in China, which heightens the risk of supply disruptions.

Secondary supplies from recycling are expected to play an increasingly important role. By 2030, around 35-40 kt of total magnet REE demand could be met through secondary supplies, which are projected to expand to 60-67 kt by 2050. Innovations in recycling technologies, such as the Hydrogen Processing of Magnet Scrap (HPMS) technique by HyProMag and MagREEsource, offer less energy-intensive and more efficient methods of recycling. Despite a recent decline in REE prices due to oversupply from China, long-term demand remains robust, driven by factors such as EV sales and wind turbine deployment. Efforts to diversify supply include government-backed investments in rare earth projects outside China and strategic partnerships, such as the US Export-Import Bank's funding for projects in Brazil and Australia. However, challenges persist, particularly due to higher energy costs and trade taxes for magnets produced outside China, which deter original equipment manufacturers (OEMs) sourcing from these regions.

3.3 Market Analysis & Predictions

Rare Earth Magnet Market

Study Period	2024-2030
Base Year	2023
CAGR	7.90%
Largest Market	North America
Fastest Growing Market	Asia Pacific

The global permanent magnet market was valued at $17.85 billion in 2018 and is projected to achieve a compound annual growth rate (CAGR) of 7.9% between 2024 and 2030. From 2021 to 2026, market is expected to increase at a CAGR of 9.5%, rising from $34.5 billion to $54.1 billion.

The market size of Asia Pacific was USD 13.82 billion in 2018, making it the fastest-growing region due to rising demand for permanent magnets in automotive, consumer electronics, and energy applications. China leads in production and consumption of these magnets, owing to its abundant rare-earth deposits. The Asia Pacific region is poised for a CAGR of 8.2% over the forecast period, driven by the expansion of wind energy generation plants, escalating demand for electric vehicles due to burgeoning populations, and increasing need for electricity in China and India. In 2018, Asia Pacific dominated the permanent magnet market with a 77.42% market share.

In North America, growth of hard magnets market is attributed to increasing demand for consumer electronics such as wearable devices, personal computers, medical devices, and mobile phones.

The European hard magnet market is expected to rise significantly, driven by rapidly growing automotive industry and rising demand for electric and hybrid electric vehicles, supported by government regulations promoting use of these vehicles over conventional ones.

Despite this growth, there is a critical dependency on China, which in 2020 controlled 58% of rare earth mining and a staggering 92% of magnet manufacturing globally, highlighting an exceedingly concentrated production landscape. Production, consumption, and processing activities have been markedly uneven, with only a handful of countries dominating the landscape.

The permanent magnet market is primarily driven by rising demand for consumer electronics, as these magnets' beneficial properties, such as attraction, repulsion, and energy conversion, enhance their use in various devices including laptops, televisions, music systems, computers, and smartphones.

Technological advancements and shifting consumer preferences are expected to create significant growth opportunities. Additionally, increasing use of NdFeB magnets, known for their high magnetic stability, field strength, and low Curie temperature, in automotive parts, wind turbines, actuators, speakers, electronic equipment, and domestic appliances, is anticipated to drive market growth further.

However, the market faces significant challenges from fluctuations in raw material prices, particularly due to rising energy costs and variable availability of rare-earth element alloys, which can impact magnet quality and pricing. These supply chain disruptions pose difficulties for manufacturers striving to deliver quality products at competitive prices, potentially hindering market growth in coming years. Additionally, overall upward trend in market is marked by considerable volatility. Supply chain disruptions, battery metal price fluctuations—especially following Russia's invasion of Ukraine—and increasing competition and price wars underscore the geographic constraints of rare earth supply chain.

Given China's dominant role in REE supply chains, prices are heavily influenced by the country's policies and market dynamics. The REE market has experienced significant price spikes, notably in 2010-2011 due to export restrictions and a crackdown on illegal mining, and in 2021-2022 due to COVID-related disruptions and increased demand for clean energy. This price volatility affects various REEs, as many are extracted from the same ores. Spot markets for REE metal oxides exist on the Shanghai Metals Exchange and in dedicated exchanges in Jiangxi and Inner Mongolia. Neodymium prices, for instance, have fluctuated between US$50/kg and US$280/kg since 2011, peaking in early 2022. Dysprosium, currently at US$528/kg, has shown even greater volatility, with historical prices ranging from US$28.50/kg in 2003 to US$3,410/kg in 2011. Prices for Praseodymium and Terbium also surged significantly in 2022 before stabilizing.

THE CHINA FACTOR

China achieved its pre-eminence in REE mining and processing through a combination of early moves into the industry, state investment along the full length of supply chain, export controls, low labour costs, and decades of weak environmental regulation and illegal mines and processing plants.

Early Moves and Investments

- China discovered REEs in 1927, started production in 1950s, and ramped up R&D and investments in 1980s.
- Classified REEs as strategic minerals in 1990s, excluding foreign companies from mining.

Tax Reforms

- In 2015, China shifted from quantity-based to value-based resource taxes, aligning with international practices..

Production Growth

- By 2020, REE mine output reached 140,000 tonnes, and by 2022 it was 210,000 tonnes, 70% of global total.
- China maintained 90% of global REE processing capacity.

Regulatory and Economic Strategies

- Introduced export quotas and taxes in early 2000s to control industry and reduce international competition.
- In 2010, began consolidating the industry to address pollution, illegal mining, and excess capacity.
- Government efforts in 2010s focused on reducing the number of mines and processing plants.

Development Plans

- The Rare Earth Industry Development Plan (2016-2020) focused on resource management, environmental protection, industry consolidation, and overseas resource exploitation.
- By 2021, industry consolidation reduced major players to four, controlling 70% of production.

Trade Fluctuations

- Exports of REE compounds and metals peaked in 2018 at 53,031 tonnes, declining to 35,448 tonnes in 2020.
- Imports of REE ores peaked at 70,600 tonnes in 2018, declining to 47,641 tonnes in 2020.

Industry Consolidation and Regulations

- Reduced number of mines and processing plants significantly by 2010.
- Introduced strategic reserves, increased export taxes, and started differentiating HREEs from LREEs.

AMERICAN COUNTERSTRATEGY

USA views China's dominance in the global REE supply chain as a major strategic vulnerability, comparable to the energy security crisis of the 1970s Arab oil embargo. In response to this dependency, the U.S. has identified 35 critical minerals, including 17 REEs, as essential for national and economic security. Despite producing 12.2% of REEs in 2019, compared to China's 62%, and holding only 1.1% of global REE reserves versus China's 36.7%, the U.S. is taking significant steps to counter China's dominance.

The Trump-administration initiated efforts to increase domestic extraction, refinement processes, and supply chain activities through Executive Orders 13817 and 13953, which prioritized expanding and protecting mineral supply chains and authorized the Defence Production Act for domestic mine construction. The Biden administration has continued and expanded these efforts, incorporating investments in rare-earth separation processes into the $2 trillion infrastructure plan and establishing a supply chain disruptions task force to strengthen U.S. critical mineral supply chains. U.S. corporations, in collaboration with the federal government, are enhancing domestic supply lines. For instance, Lynas Rare Earths Limited received grants to build heavy and light rare earth refinement facilities in Texas.

Moreover, the U.S. is looking at allies for cooperation, such as the U.S.-Canada partnership in the Energy Resource Governance Initiative and discussions with Canadian miners to enhance production. Additionally, Japan aims to reduce its reliance on Chinese REEs to less than 50% by 2025, following past supply cut-offs by China.

The U.S. also explores opportunities in Mexico and Africa. Mexico's mining industry, crucial to its economy, is being targeted for investment in critical minerals, while potential projects in Africa, like those in Malawi, are being considered for diversification. Despite these efforts, the U.S. remains years away from providing a steady domestic supply of critical minerals and rivalling China's production. Achieving this will require substantial policy commitments, deregulation, and investment. The U.S. government's focus on diversifying supply chains and supporting public-private sector cooperation with allies highlights the strategic importance of reducing reliance on Chinese REEs and ensuring long-term mineral security.

EMERGING RARE EARTH ECONOMIES OF SOUTHEAST ASIA: THE CASE OF VIETNAM

Vietnam is rapidly positioning itself as a significant player in the global REE market, aiming to counter China's dominance. With an estimated 22 million tonnes of rare earth reserves, second only to China, Vietnam plans to raise its rare earth production to 2.02 million tonnes annually by 2030 and to 2.11 million tonnes by 2050. Concentrated in the Northwest and Central Highlands, Vietnam's rare earth mining primarily includes light rare earth groups of hydrothermal origin.

To bolster its position, Vietnam is investing in refining facilities with a target of producing 20,000-60,000 tonnes of rare-earth oxides (REO) annually by 2030, increasing to 40,000-80,000 tonnes by 2050. This strategic move is driven by global demand for rare earths, essential for clean energy technologies, electronics, medical applications, and military equipment.

Vietnam's favourable investment climate, significant infrastructure investments, and skilled, low-cost workforce make it an attractive destination for investors.

The government has streamlined procedures for obtaining mining licenses and established pro-mining industrial zones with tax incentives.

Despite past challenges, such as fluctuating prices and regulatory hurdles, the growing demand for EVs has renewed interest in Vietnam's rare earth sector.

Collaborations with international partners are crucial to Vietnam's strategy. The U.S. and Vietnam signed a Memorandum of Understanding (MOU) to quantify Vietnam's rare earth resources and attract investment. South Korea has also established a joint supply chain centre for rare earths with Vietnam, and Australian investors, including Blackstone Minerals, are exploring opportunities in the region.

Vietnam's geographical location, with access to key importers like China, Japan, and South Korea, further strengthens its position. The Vietnam Rare Earth JSC (VTRE) has already entered into contracts to export significant quantities of rare earth to South Korea. Additionally, partnerships with companies like CAVICO Vietnam and the Vietnam Institute of Radiation Technology are advancing the development of Scandium rare earth deep processing plants.

Vietnam's efforts to develop its rare earth industry aim not only at economic benefits but also at enhancing its strategic importance amid the U.S.-China rivalry. By becoming a reliable supplier of rare earth products for the U.S. and its allies, Vietnam could significantly enhance its standing in global strategic considerations, integrating into high-tech global supply chains and supporting its ambition to become an industrialized, high-income economy by 2045.

3.4 Global Trade

Several factors determine a country's resilience and competitiveness in the rare earth magnet supply chain, including geographical concentration, the geopolitical sensitivity of trade partners, net import reliance, price volatility, and substitutability throughout the supply chain. The Chinese government exerts significant influence on markets through a variety of policies and regulations. These include economic and trade policies such as export quotas, subsidies, tariffs, and exchange rate targeting, as well as economic and trade regulations like trade embargoes and price controls. Additionally, environmental regulations, encompassing permitting, emission standards, and clean water standards, play a crucial role.

A more diverse global supply chain, supported by strong trade relationships with suppliers, would mitigate supply risks by addressing gaps where domestic supply is insufficient and by ensuring a more stable and diverse supply base. This objective can also be achieved by encouraging investments in operations in countries outside of China.

India's Export and Import of REEs with the World				
COUNTRY	2019-20		2020-21	
EXPORTS				
	Qty (tons)	Value (Rs`000)	Qty (tons)	Value (Rs`000)
All Countries	8.41	3990	3.67	4178
Bhutan	7.55	3405	0.44	247
Canada	-	-	+	19
China	-	-	0.03	11
Czech Republic	-	-	+	35
Denmark	0.04	41	+	104
Ghana	0.01	3	-	-
Israel	-	-	+	23
Korea, Rep of	0.06	6	-	-
Netherlands	-	-	+	79
U A E	0.75	490	3.2	3659
U S A	+	44	-	-
IMPORTS				
All Countries	473.64	162 305	470.60	175172
Belgium	+	5	+	7
China	437	145447	444.8	15044000
Germany	+	131	+	273
Hong Kong	34	10827	0.05	774
Japan	2	1304	11	8409
Sweden	-	-	10	519
UAE	-	-	0.04	257
UK	0.08	638	0.03	1560
USA	0.56	3954	4.69	12933

3.5 Key Companies

Outside of China, prominent manufacturers of alloys and powders include Hitachi Metals (a Japanese company currently being acquired by U.S. investment firm Bain Capital), Shin-Etsu Chemical (Japan), TDK (Japan), Vacuumschmelze (a German company owned by U.S. private equity firm Apollo) and its subsidiary Neorem (Finland), Neo Performance Materials (Canada), Less Common Metals (UK), and potentially Magneti (Slovenia). Many of these companies have production facilities in various countries.

For instance, Hitachi Metals, Shin-Etsu Chemical, TDK, and Vacuumschmelze manufacture some of their magnets in China. Additionally, Shin-Etsu Chemical produces magnets in Vietnam through its subsidiary, Shin-Etsu Magnetic Materials Vietnam, while Neo Performance Materials (formerly Magnequench) manufactures powders for bonded magnets in China and Thailand. The top three companies—Hitachi Metals Group, Shin-Etsu Chemical, and TDK—collectively hold approximately 20% of market share.

3.6 Global Policies & Partnerships

The strategic importance of REEs and NdFeB magnets has prompted both the USA and the EU to implement comprehensive policies and forge international partnerships aimed at securing a stable and sustainable supply chain.

The dominance of China in the entire rare earth magnet value chain not only raises concerns regarding price volatility and efficient delivery within the global supply chain but also strategic significance of REEs to national security and its source. The grip of China significantly pushes other nations for the need for resilient, diversified and shockproof supply chains.

UNITED STATES OF AMERICA

National Materials and Minerals Policy:

- Ensures a stable supply of materials critical to national security and economic well-being through federal program coordination, research and development, and fostering private enterprise.

State Department Initiatives:

- Minerals Security Partnership (MSP): Enhances global mineral security, particularly in developing countries. India joined MSP to diversify critical mineral supply chains.
- Energy Resource Governance Initiative (ERGI): Promotes sound mining sector governance and resilient energy mineral supply chains.

Executive Orders:

- Executive Order 13817: Federal Strategy for Critical Minerals to reduce vulnerability in supply chains. Actions include identifying new sources, increasing supply chain activity, and streamlining processes.
- Executive Order 13953: Department of Energy strategy to mitigate critical minerals challenges by diversifying supply, developing substitutes, and improving recycling.

Public-Private Alliances and International Cooperation:

- Public-Private Alliance for Responsible Minerals Trade (PPA): Fosters collaboration to ensure ethical sourcing.
- European Raw Materials Alliance: Promotes global best practices, environmental protection, and innovation investments.

State Department Initiatives:

- Improve governance, environmental protection, and community welfare in developing countries.

CORE-CM Initiative

- Accelerates carbon ore and critical mineral development in U.S. basins.

Research and Development Efforts:

- Focuses on resource characterisation, critical mineral processing, and advanced extraction technologies.

Environmental and Safety Considerations:

- Ensures responsible sourcing, processing, and recycling practices.

EUROPEAN UNION

Raw Materials Initiative (RMI):

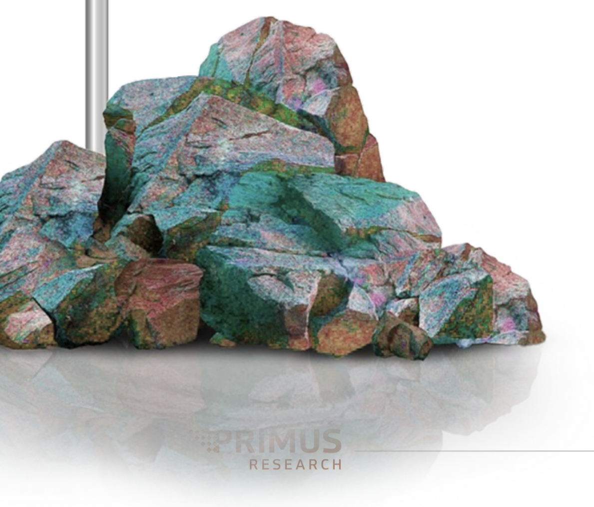
- Ensures sustainable supply of raw materials to the EU economy, emphasizing diversification, sustainable extraction, recycling, and substitution.

Concerted European Action on Magnets (CEAM):

- Supports research and innovation in rare earth magnets through significant EU funding.

Financial and Policy Measures:

- Raw Materials Investment Platform: Facilitates investments in magnet manufacturing and recycling.
- IPCEI on Rare Earth Magnets and Motors: Supports large-scale sector investments to enhance EU competitiveness.



Critical Raw Materials Action Plan (2020):

- Secure supply of rare earth materials and promote circular economy practices.
- Develop strategic international partnerships for diversified supply.

European Raw Materials Alliance (ERMA):

- Addresses critical raw materials supply challenges, focusing initially on rare earth magnets and motors.

European Rare Earths Competency Network (ERECON):

- Precursor to ERMA, addressing Europe's rare earth supply chain opportunities and challenges.

Circular Economy Action Plan (CEAP):

- Promotes sustainable growth and job creation, targeting product life cycles and waste prevention.

European Innovation Partnership (EIP) on Raw Materials:

- Promotes innovation in the raw materials sector, aiming to increase the industry's contribution to the EU's GDP.

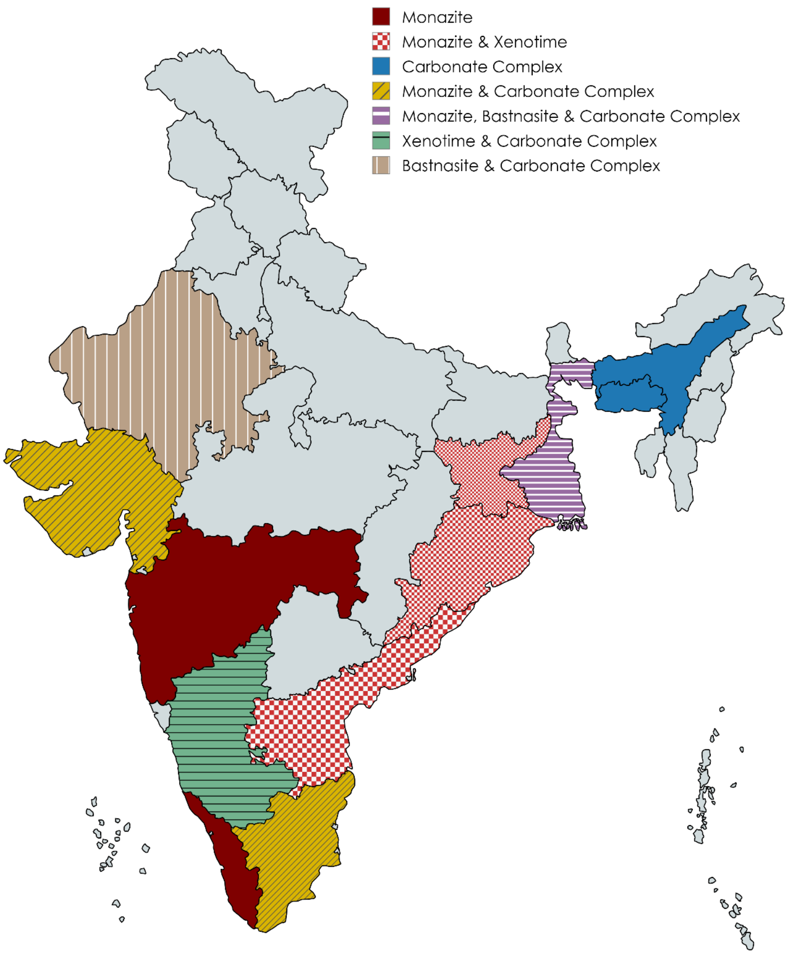
Strategic Partnerships:

- EU-Canada: Enhances trade and investment in resilient raw materials and downstream value chains.
- EU-Ukraine: Diversifies and secures critical raw materials and battery supply, promoting sustainable mining and joint ventures.

04

India's Rare Earth Landscape

India holds the fifth-largest rare earth resources globally, primarily located in coastal beach placer sands across Kerala, Tamil Nadu, Odisha, Andhra Pradesh, Maharashtra, Gujarat, and inland states like Jharkhand, West Bengal, and Tamil Nadu.



Rare Earth Minerals Deposits in Indian States	
Minerals	**Deposits**
Monazite	Odisha, Andhra Pradesh, Kerala, Tamil Nadu, Gujarat, Jharkhand, Maharashtra, West Bengal
Xenotime	Jharkhand, Tamil Nadu, Gujarat, Odisha, Andhra Pradesh, Karnataka
Bastnasite	West Bengal and Rajasthan
Carbonate Complex	Gujarat, Meghalaya, Assam, Tamil Nadu, Karnataka, West Bengal, Rajasthan

Under the Atomic Energy Act of 1962, monazite is classified as a prescribed substance. They are present in 130 deposits in coastal bleacher sands and inland alluvium states of India.

In 2023, India's rare earth resources comprised 13.07 million tons of in-situ monazite, containing approximately 55-60% total rare earth elements oxide. Extraction and preliminary processing of these resources are spearheaded by government-operated Indian Rare Earths Limited (IREL) and entities like Kerala Minerals and Metals Limited (KMML) in Kerala.

Annual Installed Mining, Production & Processing Capacities (2021-22)	
Installed capacity of monazite (96% pure) separation plants	**Tonnes per year (tpy)**
IREL at Manavalakurichi	6,000 tpy
KMML at Chavara	240 tpy

The Atomic Minerals Directorate (AMD)'s resource evaluation study revealed that REEs in India are found alongside heavy minerals such as Ilmenite, Rutile, and Zircon, in concentrations ranging from 0.4-4.3% in beach and inland placer deposits. These resources are low-grade and radioactive, making extraction complex and costly. Indian deposits mainly contain Light Rare Earth Elements (LREEs) like Lanthanum, Cerium, and Neodymium, which are more abundant and easier to extract compared to the scarcer and more valuable Heavy Rare Earth Elements (HREEs) such as Dysprosium and Yttrium. More than 80% of the value of rare earth usage is in RE permanent magnets, essential for energy transition initiatives, requiring magnetic REEs like Neodymium, Praseodymium, Dysprosium, and Terbium. However, Indian reserves lack extractable quantities of HREEs like Dysprosium and Terbium. Consequently, current extraction efforts in India focus on Neodymium and Praseodymium, achieving purity levels up to 99.9%, with these elements occurring in the BSM ore of Indian deposits at concentrations of 0.0011% to 0.012%.

From **1,000 tons** of NdPr oxides, approximately **2,500 kg** of NdFeB magnets can be produced. It is projected that production could increase fourfold by 2032, aiming for **3,000-4,000 tons** of NdPr oxides by 2030, with no indication of production exceeding **4,000 tons**.

Production of REEs in India is dependent on the availability of suitable deposits and industrial demand. India boasts capabilities in REE processing and aims to triple its REO production capacity by 2032.

Major Sites, Deposits and Monazite Resources (in million tonnes) Present in Indian States

STATE	NO. OF DEPOSITS	RESOURCES (in million tonnes)	MAJOR SITES
Andhra Pradesh	24	3.78	Bhimunipatnam beach sand deposit
			Kandivalasa beach sand deposit
			Kalingapatanam beach sand deposit
			Srikurmam beach sand deposit
			Bhavanapadu beach sand deposit
Gujarat	2	0.07	
Jharkhand	1	0.21	
Kerala	35	1.84	Chavara Barrier beach and Eastern Extension, Kollam
Maharashtra	5	0.004	
Odisha	12	3.16	Gopalpur Beach sand deposit
			Chhatarpur beach sand deposit
			Brahmagiri beach sand deposit
Tamil Nadu	50	2.47	Manavalakurichi beach sand deposit, Kanyakumari
			Sathankulam Teri sand deposit
			Ovari Manapadu Teri Sand deposit
			Navaladi-Ovari Teri Sand deposit
			Kuduraimoli Teri Sand deposit
West Bengal	1	1.20	
All India 2022	130	12.73	
All India 2023		13.07	

Despite increasing production, NdFeB magnets are currently not produced domestically and are entirely imported. India lacks hard rock mines for rare earth elements, sourcing them instead from beach sand deposits along the Bay of Bengal, from Kerala to Odisha. Although these resources are economically viable, they have not been fully explored by IREL due to concerns about ecological disruption.

It is to be noted that IREL initially focused on extracting Thorium, a radioactive element used in nuclear energy, rather than REEs. The primary challenge is the limited availability of raw materials, necessitating more investment.

4.1 Market Analysis

A key driver of India's permanent magnet market is the increasing demand for energy-efficient technologies across various industries. As sustainable practices become more prevalent, permanent magnets, which maintain magnetism without external power, are instrumental in the production of energy-efficient products such as electric vehicles, wind turbines, and other renewable energy systems. With the automobile industry concentrating on incorporating lightweight, compact, and affordable electrical components inside the vehicle system to assure reduced costs and optimal space utilisation, this surge in demand is propelling the growth of the permanent magnet market.

The Indian rare earth market is experiencing significant growth, driven by rising demand in electronics, automotive, and renewable energy sectors. Rare earth magnets, particularly Neodymium (NdFeB) and Samarium Cobalt, are highly sought after due to their exceptional magnetic properties. India's expanding manufacturing sector and its increasing focus on clean energy further amplify the demand for these magnets. With India holding the fifth-largest rare earth resources globally and having indigenous raw material availability through Indian Rare Earths Limited (IREL), the country recognizes the potential to manufacture NdFeB magnets domestically, aligning with its climate goals and electric mobility vision.

Potential REE Markets in India

END-USE	REE REQUIRED	PRESENT STATUS	EXPECTED (2030)
Magnets for wind turbines	Nd, Pr, Dy, Tb (high strength magnets have 30% RE)	12,000 MW of wind power capacity	~ 50,000 MW
EVs, Hybrid Vehicles (batteries, motor, catalytic converter)	La (15 kg per car) Nd (1 kg per car), Dy, Tb, Ce	Negligible EV	Up to 1 million vehicles
LED	Y, Eu, Tb	Negligible	~ 1 million bulbs
Al, Steel, Mg industry, grain refinement	Ce, La, mischmetal	-	Huge growth rate
Screen brighteners (cell phones, computers, TV screens)	Eu	Mostly imported	Huge growing market
Other magnets	Pr, Sm, Gd	Mostly imported	Computer hard disks, microphones

Strategic importance of NdFeB magnet manufacturing for India lies in eliminating import dependency on countries like China, thus advancing towards an 'Aatmanirbhar Bharat' (self-reliant India). Government initiatives are accelerating the growth of NdFeB magnet market in India. Despite having sufficient rare earth raw material in the form of monazite, India currently does not produce NdFeB magnets due to a lack of technological know-how. This illustrates the stark contrast between India's current production capabilities and its consumption needs- in 2022, while there was no domestic production of NdFeB magnets, consumption stood at 1,700 tonnes, reflecting a market size of ₹1,245 crore. By 2030, consumption is expected to soar to 7,153 tonnes growing at a CAGR of 20%, with market size projected to reach ₹7,295 crore. This highlights the urgent need for technological advancements and investments in domestic production to meet the growing demand and support India's strategic goals.

India's NdFeB Market Size & Projections	
Production of NdFeB Magnets in 2022	0 ton
Consumption of NdFeB Magnets in 2022	1700 tonnes
Indian NdFeB Magnet market size in 2022	1245 Crore
Consumption Forecast of NdFeB Magnets in 2030	7154 tonnes
Indian NdFeB Magnet market size in 2030	7295 Crore

For energy-efficient appliances, about 70-80 grams of magnet are needed per ceiling fan, with an anticipated transition of 20-30 million appliances from induction motors to magnet-based motors.

4.2 Key Drivers

According to retail data published on the Government of India's Vahan website, a total of 1,675,800 electric vehicles (EVs) were purchased in India between April 1, 2023, and March 31, 2024. This equates to an average of 4,591 EVs sold daily in FY2024, an increase of 1,349 units compared to the 3,242 EVs sold daily in FY2023. Between 2014 and 2024, India saw the sale of 3,955,021 EVs. Currently, magnet requirement per vehicle varies, with 500-700 grams needed for two-wheelers, 500 grams for three-wheelers, and 2000 grams for four-wheelers.

The Economic Survey 2023 predicts a **49%** CAGR in India's domestic EV market from 2022 to 2030, with annual sales expected to reach **10 million** by 2030. On the other hand, the EV-Ready India dashboard has forecasted a **45.5%** CAGR in EVs between 2022 and 2030.

India's primary energy demand is projected to increase to between 1,250 and 1,500 million tons of oil equivalent (toe) by 2030. This surge, driven by rising incomes and economic growth, defines the need for enhanced energy supply to improve living standards. The country's wind energy sector, bolstered by a robust domestic industry, boasts an annual manufacturing capacity of approximately 15,000 MW, positioning India as the fourth largest globally in installed wind energy capacity. The magnet requirement for manufacturing indigenous wind turbines is around 250-300 kg per megawatt of capacity for each turbine.

4.3 Trade

India's trade in rare earth minerals has grown in significance as these materials become increasingly vital for various high-tech industries. The country's rare earth reserves offer immense potential for both economic growth and strategic advantage.

On raw material inputs for NdFeB magnet manufacturing in India, import duty can be 0% (subject to the condition that the imported material shall be used for solely for the same). Exports of rare earth metals (Scandium & Yttrium) in 2020-21 decreased substantially by 56% to 3.67 tons from 8.41 tons in the previous year. UAE (87%) and Bhutan (12%) were the main buyers from India. The imports of rare earth metals (Scandium & Yttrium) in 2020-21 marginally decreased by 0.64% to 470.61 tons compared to 473.64 tons in 2019-20. China (94%) and USA (1%) were the main suppliers to India.

4.4 Domestic Pricing

Typically, NdFeB magnets average between INR ₹4186 and INR ₹4605 but can fluctuate from INR ₹3349 to INR ₹5860 based on market conditions. This dynamic pricing indicates the influence of dominant market shareholders and Chinese manufacturers setting prices, which can impact global supply chain and competitiveness of alternative producers. India's pricing has notably remained consistent over the years which indicates its potential in the larger ecosystem.

4.5 Key Companies

- Jai Mag Industries
- Star Trace Private Limited
- Magna Tronix
- Kumar Magnet Industries
- JD Magnetic Impex
- Shree Shakti Indusries
- Dura Magnets
- Ashvini Magnets
- Entellus Industries
- Kalyani Steels Limited

These companies play a crucial role in advancing India's capabilities in producing REE magnets, which are essential for various high-tech applications, including the rapidly growing electric vehicle sector. Their contributions are pivotal in strengthening domestic supply chain and reducing dependence on imports.

4.6 Current Policy Landscape

India's policies on REE mining and processing are supportive but currently insufficient to meet the rising demand driven by the EV sector. Key challenges include restrictive mining licenses, stringent environmental regulations on radioactive elements in Monazite, and a lack of specific incentives for REE processing industries.

The existing policy framework creates an enabling ecosystem for attaining self-reliance in manufacturing. In 2023, critical and strategic minerals became a focal point for India's economic development and national security.

With the future global economy relying heavily on minerals such as Lithium, Graphite, Cobalt, Titanium, and REEs; India has committed to achieving **50%** of its cumulative installed power capacity from non-fossil sources by **2030**, driving demand for electric cars, wind and solar energy projects, and battery storage systems.

To address these needs, India has undertaken initiatives to strengthen supply chain of critical minerals. In August 2023, the Central Government amended the Mines and Minerals (Development and Regulation) Act (MMDR Act) to notify 24 minerals as Critical and Strategic Minerals. The amendment includes Section 11(D), conferring the power of auctioning Critical and Strategic Mineral Blocks to the Central Government. The Mineral (Auction) Amendment Rules, 2023, were also notified to prescribe the auction procedure for these minerals. The revenue from these auctions will accrue to State Governments, and royalty rates have been rationalized to encourage participation. For example, royalty rates have been set at 3% for Lithium and Niobium, and 1% for REEs. On October 12, 2023, the government specified these rates, and on December 19, 2023, Ministry of Mines conducted a roadshow on critical minerals to further disseminate information. These strategic steps aim to enhance India's capabilities in the REE sector, reduce reliance on imports, and ensure a stable supply of critical materials essential for technological and economic growth.

Existing Policies & Notifications, Scope & Impact:

Digital India Initiative (2015)

- Encourages sustainable digital infrastructure, including responsible disposal and recycling of electronic components.

National Policy on Electronics (NPE) 2019

- Promotes development of a robust ecosystem for electronics manufacturing and emphasizes sustainable practices, including e-waste management.

Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors (SPECS) 2020

- Strengthen electronics manufacturing ecosystem and increase domestic value addition, positioning India as a global hub for Electronics System Design and Manufacturing (ESDM), leading to the expansion and diversification of existing units.

Production Linked Incentive (PLI) Scheme for Large Scale Electronics Manufacturing 2020

- Boost domestic manufacturing, attract large investments, and position India as a global electronics manufacturing hub by addressing various challenges in infrastructure, supply chain, logistics, finance, power, design, R&D, and skill development, specifically targeting mobile phone manufacturing and specified electronic components and ATMP units.

Foreign Trade Policy (ITC(HS), 2022 Schedule 1

- The import and export policy on ores & concentrates of rare-earth metals (HS Code 25309040) permitted 'freely'.
- Freely exportable, except those notified as prescribed substances and controlled under Atomic Energy Act 1962.

Mines and Minerals (Development and Regulation) Amendment Bill, 2023

- Rare earth minerals not containing Uranium and Thorium are mentioned in Part D of the First Schedule for Critical & Strategic minerals.
- The amendment removes six minerals from the atomic minerals list, allows the Central Government to auction critical mineral concessions with revenue going to State Governments, and introduces exploration licenses for deep-seated minerals.
- Notification No. S.O.2685 (E) dated 27.07.2019 issued. Reserved prospecting and mining rights of offshore minerals to Government or a Government-owned company or corporation.

Offshore Areas Mineral (Development and Regulation) Amendment Bill 2023

- The Act introduces auction-based operating rights for private entities, including production leases and composite licenses for exploration and production.
- PSUs granted rights in reserved areas and for atomic minerals.
- Production leases are fixed at 50 years, and offshore mineral acquisition is limited.
- A trust funded by a production levy will support exploration and mitigation efforts.
- The Act also simplifies license transfers, sets production timelines, and ensures that all offshore mineral revenues go to the Government of India.

Pradhan Mantri Khanij Kshetra Kalyan Yojana (PMKKKY, implemented by the District Mineral Foundations) 2024

- Implements various developmental and welfare projects/programs in mining-affected areas, mitigates the adverse impacts, during and after mining, on the environment, health and socioeconomics of people in mining districts and ensures long-term sustainable livelihoods

Critical Mineral Mission 2024

- Announced in the Union Budget 2024-25, to boost the domestic output and recycling of critical minerals like copper and lithium while supporting adequate supply through imports.

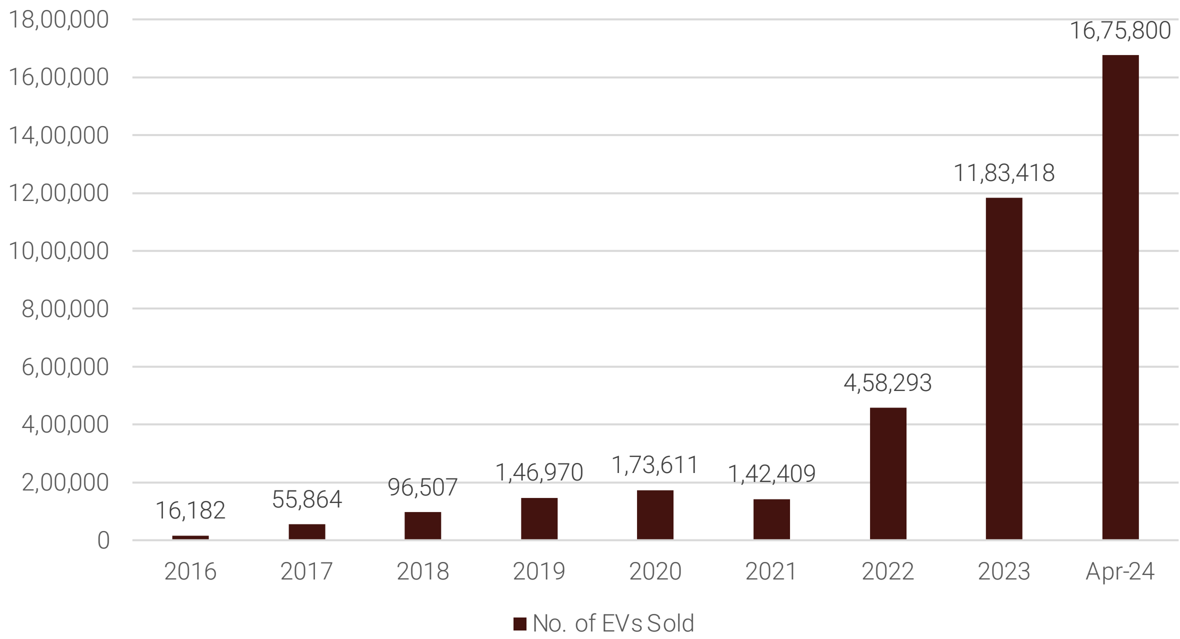
Export of Beach Sand Minerals

- Brought under STE (State Trading Enterprise) and shall be canalised through Indian Rare Earths Limited (IREL).
- Regulated as per policy under Sl. No. 98A of Chapter 26 of Schedule 2 of the Export Policy.

Gazette Notification No: GSR.134 (E) dated 20.2.2019

- Threshold values for atomic minerals in respect of Beach Sand Minerals (BSM) regulated as Schedule A [Rule 2(1)(m) and Rule 36].

Number of EVs sold in India (FY 2016-2024)



HS Codes for Direct Trade of NdFeB Magnets in India [in Thousand Units (kgs)],as of 25th July 2024

HS Code	Import				Export			
	2021-22	2022-23	2023-24	2024-25	2021-22	2022-23	2023-24	2024-25
85051900 Magnets – Permanent	20,265	19,641	5,488	5,424	456	571	453	102
85051110 Magnets - Ferrite Cores	7,612	7,609	9,500	1,237	3,685	3,217	2,079	304
85051190 Magnets – Others	11,639	13,653	19,165	2,972	755	416	402	82
85059000 Magnets - Lifting Heads	5,488	5,424	6,022	945	1,698	1,617	1,944	210

HS Codes for In-Direct Trade of NdFeB Magnets in India [in Thousand Units (kgs)],as of 25th July 2024									
HS Code	Description	Import				Export			
		2021-22	2022-23	2023-24	2024-25	2021-22	2022-23	2023-24	2024-25
8501XXXX (all HS Codes of Chapter 8501)	Import of NdFeB magnets as part of Motors / knocked down kit for motor assembly in India	-	-	-	-	-	-	-	-
73269099	Articles of Iron and Steels - other, not mentioned elsewhere	142,002	147,735	189,610	28,784	254,206	238,043	252,624	42,628
72029912	Ferro Alloys (Ferro-Selenium)	NA	NA	NA	NA	4.93	0.20	0.20	NA
8708xxxx	Parts And Accessories of The Motor Vehicles	-	-	-	-	-	-	-	-

Import-Export Trends from 2021-2024 [Quantity in Thousand Units (kgs), as of 25th July 2024									
HS Code	Description	Import				Export			
		2021-22	2022-23	2023-24	2024-25	2021-22	2022-23	2023-24	2024-25
28053000	Rare Earth Metals	761	792	1,185	208	8	5	11	0.50
2846xxxx	Rare Earth Oxide, Fluorides, Chlorides etc	-	-	-	-	-	-	-	-
26140031	Rare Earth Oxide	10,076	7,906	7,342	1,208	53	NA	216	NA

Domestic Prices of REs 2012-2016, in INR per KG, as per the Department of Atomic Energy				
Grade	Price (2012 – 2013)	Price (2013 – 2014)	Price (2014 – 2015)	Price (2015 – 2016)
RE chloride	180	180	180	180
RE fluoride (Lumps)	450	450	450	450
Dicarbonate -Wet	150	150	150	150
Difluoride	285	285	285	285
Cerium hydrate - Dry	500	500	500	500
Cerium oxide B	550	550	550	550
Neo oxide - 95%	3420	3420	3420	3420
Neo oxide - 99%	3800	3800	3800	3800

4.7 Recycling & Re-Use

In India, approximately 90% of used batteries are either processed by the unorganized sector or disposed of in landfills and garbage dumps, posing significant environmental and human safety risks. To address these issues, the Government of India released the draft Battery Waste Management Rules 2022, which mandates a minimum of 90% materials recovery by 2027. Additionally, NITI Aayog predicts that India's EV battery recycling market will expand to 128 GWh by 2030.

India generates approximately 3.2 million metric tons of e-waste annually, with projections increasing due to rising electronic consumption (CPCB, 2021). However, the recycling rate is currently only around 10%. To combat this, Ministry of Environment, Forests, and Climate Change introduced the E-Waste (Management) Rules 2022, effective from April 2023. These regulations require manufacturers, producers, refurbishers, and recyclers of electrical and electronic equipment to register on a designated portal and manage e-waste responsibly. Entities must register under their specific categories and comply with stringent guidelines to prevent unauthorized operations. They are also required to submit quarterly and annual returns in the specified format within stipulated deadlines.

The rules cover all stages from manufacture to recycling, applying to a comprehensive list of electrical and electronic equipment. The Central Pollution Control Board (CPCB) is authorized to levy registration and maintenance fees based on the volume of e-waste handled, aiming to enforce sustainable practices through extended producer responsibility (EPR).

These regulations, an improvement over previous ones, promote cost reduction, environmental protection, enhanced brand reputation, and sustainable development through efficient e-waste management practices.

In addition to these measures, India has policies addressing REM and EV scrappage, recycling, and reuse. These policies, along with initiatives for battery and e-waste recycling, underscore India's commitment to sustainable practices and the development of a robust circular economy.

4.8 Current Projects & Industry Ecosystem

In the period from 2019-2022, IREL has initiated several significant projects in rare earth mineral mining and magnet production. These include capacity expansion of the Mineral Separation Plant at OSCOM, establishment of a Rare Earth Permanent Magnet Plant, and the creation of a Rare Earth Theme Park. These projects are expected to be commissioned within the next 2-3 years and expand the organisations' rare-earth-mineral processing capacity to 20,000 tonnes per annum.

IREL Projects & Operations:

IREL's Plant at Udyogamandal, Aluva

- Location: Ernakulam district, Kerala
- Monazite from Manavalakurichi is chemically treated.
- Separation of rare earths in their composite chloride form.
- Separation of thorium as hydroxide upgrade.

IREL's Rare-Earth Extraction Plant (REEP)

- Location: OSCOM, Odisha
- MRCL is processed at IREL's plant at Rare Earth Division (RED) in Aluva, Kerala.
- Produces separated High Pure Rare Earth (HPRE) Oxides/Compounds.
- Products: Mixed Rare-earth chloride (MRCL) Tri-sodium phosphate.

Rare Earth Permanent Magnet Plant

- Location: BARC campus, Achitapuram, Vizag
- Production of Samarium-Cobalt permanent magnet for use in Atomic Energy, Defence, and Space sectors.
- Detailed engineering completed; site activities underway on EPC model.

Subsidiary IREL-IDCOL Limited (IIL)

- Location: Beach sand mineral deposits.
- Establishment of a Joint Venture company to harness beach sand mineral deposits.
- Final stages of area declaration, completion of DGPS survey, and preparation of cadastral map. DPR prepared.

Gadolinium Oxide Production

- Developed by BARC
- Produced 50 kg Nuclear Grade Gadolinium Oxide (99.99%)
- Can be converted into Gadolinium Nitrate used by NPCIL.
- Invited research projects on value chain products of ilmenite, zircon, and rare-earth compounds, improvement in recovery and energy efficiency.
- Products: Gadolinium Oxide (Nuclear Grade)

Greenfield Operations

- Location: Kanyakumari district, Tamil Nadu and Bramhagiri district, Odisha
- Proposal with TAMIN for beach sand mineral deposits.
- Under consideration by State Government.
- New areas in Odisha and Tamil Nadu for Atomic Minerals.

Ambadungar RE Project

- Location: Gujarat
- Carbonatite deposit exploration by AMD.
- Initial harnessing of about 1.55 Ha, with potential for extension.
- Establishing technical and financial viability.

Capacity Expansion of Mineral Separation Plant

- Location: OSCOM, Odisha
- Expanded mineral separation capacity

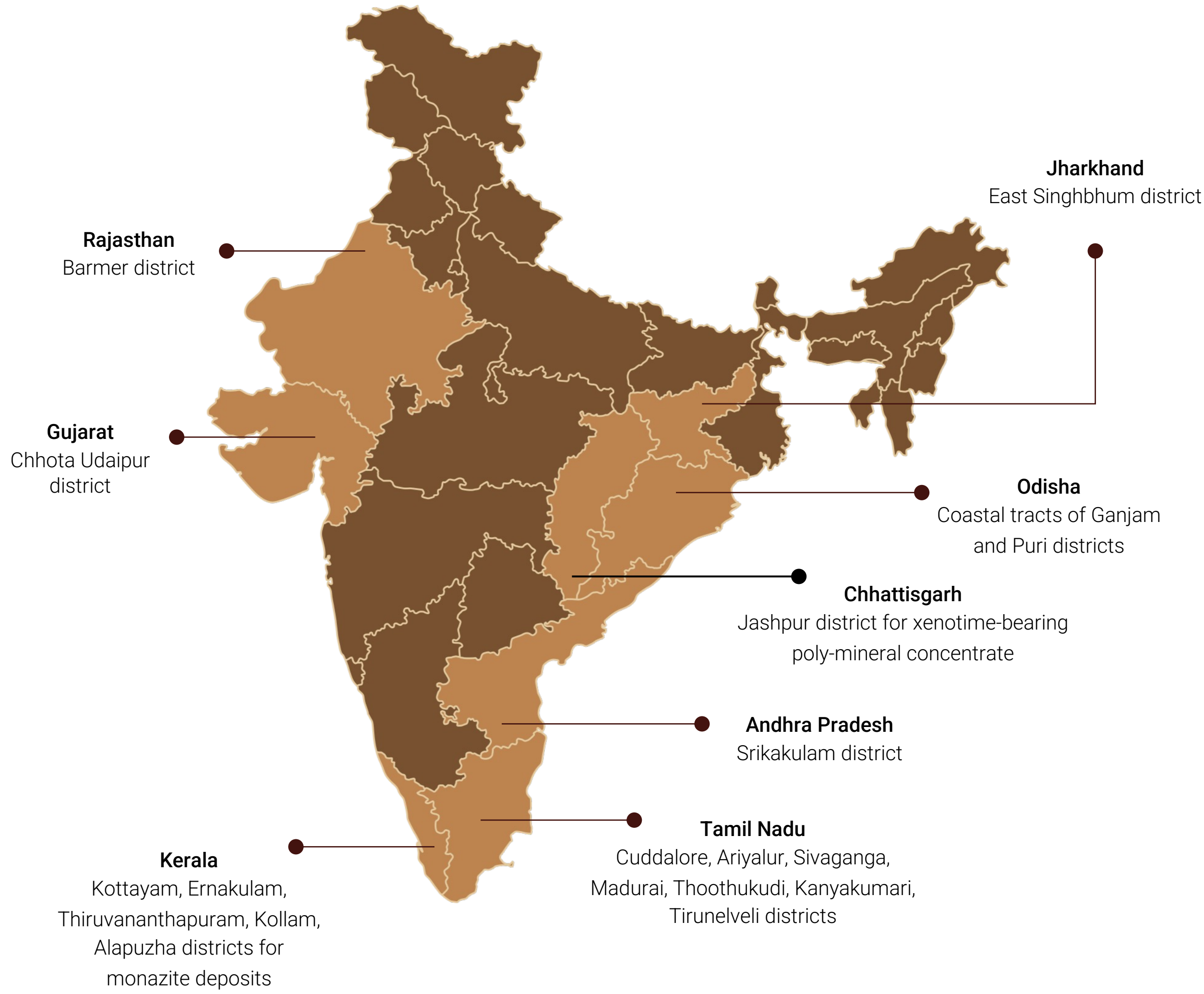
New operations are underway in Ambadungar, Gujarat, and Atomic Minerals in Odisha and Tamil Nadu. A Rare Earth Permanent Magnet Plant is being set up at the BARC campus in Achitapuram, Vizag, for the production of Samarium-Cobalt magnets for use in atomic energy, defence, and space sectors. This plant has received all necessary environmental and safety clearances, and detailed engineering is complete with site activities set to commence soon. IREL's subsidiary, IREL-IDCOL Limited (IIL), is progressing on harnessing beach sand mineral deposits in Odisha, with pre-project activities like environmental clearance and mining plan preparation in advanced stages.

Past Projects in India			
Aspects	2019	2020	2022
Key Plants and Locations	Udyogamandal, Aluva (Kerala)	Udyogamandal, Aluva (Kerala); REEP at OSCOM, Odisha	Udyogamandal, Aluva (Kerala); REEP at OSCOM, Odisha
Production	RE chloride (45% min), High Pure RE compounds (78% min)	RE chloride (45% min), High Pure RE compounds (78% min)	RE chloride (45% min), High Pure RE compounds (78% min)
Key Products	Yttrium, ADU, thorium oxide	Samarium, Gadolinium, Dysprosium	Samarium-Cobalt permanent magnet, Gadolinium Nitrate
Projects and Developments	MoU with BARC, DMRL for RE magnets	Capacity expansion at OSCOM, Rare Earth Theme Park	Greenfield operations in Kanyakumari (TN) and Bramhagiri (Odisha)
Research & Development	Development of RE Phosphors	Production of high-tech zirconia ceramic components	Research projects on Ilmenite, zircon, RE compounds
Policy Changes	Export policy under ITC (HS) Classification	Atomic Mineral Concession Rules (AMCR) 2016 amendment	Notification for reserving prospecting and mining rights
New Initiatives	Setting up industry in the value chain of minerals	License to Operate (LTO) office established	Ambadungar RE Project, Gujarat
Production Capacity (tpy)	11,200 RE chloride, 2250 High Pure RE compounds	11,200 RE chloride, 2250 High Pure RE compounds	11,200 RE chloride, 2250 High Pure RE compounds
Environment and Compliance	Regulatory compliances with BARC, NFC	Centralised monitoring & control of statutory compliances	Environment clearance for mining lease areas
International Collaborations	Agreement with Japan for RE development	MoU with M/s UstKamenogorsk, Kazakhstan for Ti Slag plant	Ongoing collaborations for greenfield operations

India's rare earth landscape holds immense potential, given its substantial reserves and strategic importance in global market. While current policies and infrastructure have laid a foundation for growth, significant enhancements are needed to meet the rising demands of the EV sector and other high-tech industries.

Prospective growth dimensions emphasize the necessity of establishing new REE processing facilities by 2025, achieving near self-sufficiency by 2030 and emerging as a major exporter of EV-grade magnets by 2035 thereby fostering sustainable growth and supporting its ambitious EV and clean energy goals.

Atomic Minerals Directorate's Explorations



Defence Metallurgical Research Laboratory

Defence Metallurgical Research Laboratory (DMRL) is a research laboratory of the Defence Research and Development Organisation (DRDO).

DMRL is the premiere laboratory working on research and development of rare earth permanent magnets (REPM) in the country, with state-of-the-art facilities for processing and characterisation of REPM in India. The lab has successfully developed several grades of NdFeB magnets for use in commercial and strategic applications using imported NdFeB metal.

Directed by NITI Aayog, DMRL took up initial NdFeB magnet development using indigenous Nd metals supplied by BARC and IREL and this testing prove the final products were at par with magnets made using imported metals.

Strategic Investments by Japan

The Government of India and Japan signed an MoU designating IREL, on behalf of the Department of Atomic Energy India, and Toyota Tsusho Corporation (TTC), on behalf of the Ministry of Economy, Trade, and Industry of Japan, to finalize modalities of a contract for cooperation on separation and refining of rare earth products supplied by IREL.

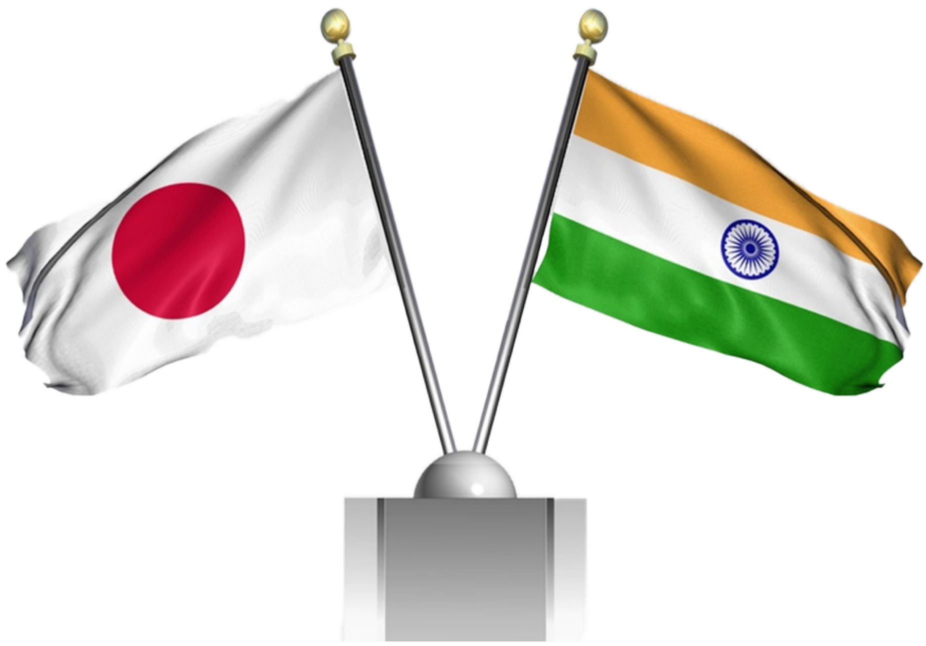
Toyotsu Rare Earths India Pvt Ltd., a joint venture between IREL and TTC, began operations.

IREL established a supply agreement with Toyotsu Rare Earths, Japan, for REO (monazite) concentrates in India and Japan.

The Indian subsidiary, Toyotsu Rare Earths India Pvt Ltd., purifies the concentrates in India and further beneficiates them in Japan with an annual target of 4000 tons.

Currently, India produces 1,500 tons of NdPr (Neodymium Praseodymium) annually through IREL, with 500 tons allocated to Toyotsu Rare Earth under an agreement between India and Japan.

Japanese companies have increased their efforts to become world leaders in the EV sector, leading to Musashi and Toyota (Japan) and Delta Electronics (Taiwan) entering a joint venture to manufacture and sell EV drive units for two-wheelers in India.



05

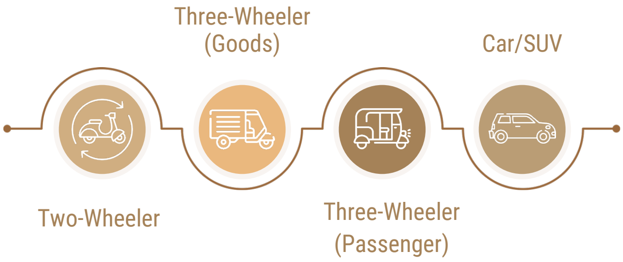
Projections of EV Sales and Rare Earth Magnet Demand

5.1 Data Collection and Categorisation

EV Sales Data

The data for projections till 2030 was sourced from the EV OMI Dashboard. The dashboard utilises the Vahan Dashboard for data on EV sales, focusing on vehicles with an electric fuel type (BOV) and excluding hybrids due to the complexity of determining their electric usage. EVI OMI dashboard collects Vahan data from the previous month on the 10th of every month.

Vehicle Categories



EV OMI dashboard mapped Vahan categories into the above categories. For instance, Light Passenger Vehicle is categorised as Car/SUV, and Two-Wheeler Non-Transport (NT) and Transport (T). Three-wheelers were further subdivided into three-wheelers (Goods) and three-wheelers (Passenger), using the Vehicle Class filter in Vahan.

5.2 Sales Forecast Generation

The EV OMI Dashboard employed the Meta Prophet model, an open-source tool from Facebook's core data science team, for time-series data forecasting.

The model produces three forecast ranges: Normal, Lower, and Upper. Given the current trajectory and macroeconomic trends, utilized the upper range for forecasting, considering government support at both the central and state levels.

Electric Vehicle Sales Projections

The EV OMI Dashboard forecasts EV trends only until 2030. To extend projections to 2047, various growth scenarios were analysed. These scenarios—ambitious, moderate, and conservative—provide a comprehensive picture of potential EV annual sales for each year till 2047. Each scenario is described in detail in this chapter.

Ambitious Scenario:

- **2024 to 2030:** Exponential growth with a high CAGR driven by aggressive policies, technological advancements, and increased consumer awareness.
- **2031 to 2040:** Stabilising growth rate of 16.5%, reflecting market maturity.
- **2041 to 2045:** Growth rate adjusts to 10% as the market further matures.
- **2046 to 2047:** A final phase growth rate of 5%, indicating market saturation.

Projected CAGR For EV Sales till 2047			
Years	Ambitious	Moderate	Conservative
2031-40	16.5%	14.5%	10.5%
2041-45	10.0%	8.0%	6.0%
2046-47	4.0%	2.0%	1.0%

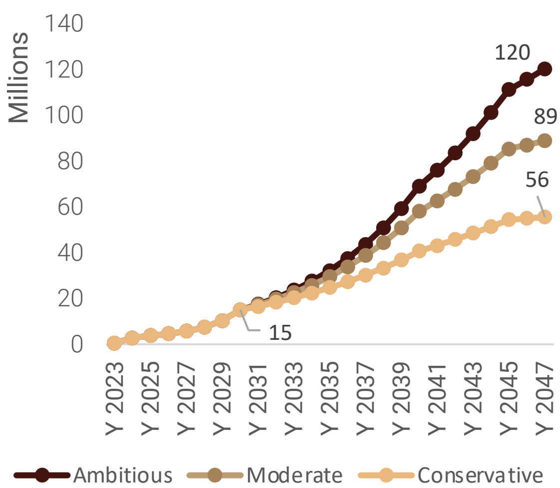
Moderate Scenario:

- **2024 to 2030:** Exponential growth with a high CAGR driven by aggressive policies, technological advancements, and increased consumer awareness.
- **2031 to 2040:** Growth rate moderates to 14.5% as the market evolves.
- **2041 to 2045:** Adjusted growth rate of 8% reflecting market transition.
- **2046 to 2047:** Minimal growth rate of 2% as the market reaches near-complete penetration.

Conservative Scenario:

- **2024 to 2030:** Exponential growth with a high CAGR driven by aggressive policies, technological advancements, and increased consumer awareness.
- **2031 to 2040:** Growth rate drops to 10.5%, indicating slower market development.
- **2041 to 2045:** Modest growth rate of 6% suggesting ongoing challenges in market penetration.
- **2046 to 2047:** Stabilized growth rate of 1%, reflecting a mature but constrained market.

EV Projections Till 2047



5.3 Implications for Rare Earth Magnet Demand

The projected increase in EV sales will drive demand for REMs, particularly NdFeB magnets used in EV motors. To meet the anticipated demand, ensuring a stable supply chain and investing in domestic production capabilities will be crucial. These projections are essential for understanding the potential demand for REM, which are a critical component in the manufacturing of EVs. The transition towards a significant share of EVs in the automotive market will drive up the demand for REMs.

Rare Earth Magnet Demand Forecast

We assessed the REM demand based on the following assumptions, founded on all three scenarios in the previous section. Multiplying sales forecast numbers by the magnet weight in kg of respective form factors:

Vehicle Type & Approximate Weight of REM Used	
Vehicle Type	Approximate Weight of REM
2-Wheeler	600 grams
3-Wheeler	500 grams
Passenger Cars	2 kilograms

Demand Forecast for Magnets for 2 Wheelers

The demand projection for REM in two-wheelers shows a significant increase over the years. Under the *ambitious* scenario, the demand is expected to rise from **5538.3 tonnes** in 2030 to **44429.3 tonnes** by 2047. The *moderate* scenario projects a rise to **32791.0 tonnes,** while the *conservative* scenario forecasts a demand of **20519.9** tonnes by 2047.

Demand Forecast for Magnets for 3 Wheelers

For three-wheelers, the demand for REM is projected to grow steadily. By 2030, the demand is estimated to be **903.2 tonnes**. In the *ambitious* scenario, this demand will increase to **7245.2 tonnes** by 2047. The *moderate* scenario projects a demand of **5347.3 tonnes**, and the *conservative* scenario anticipates **3346.2 tonnes** by 2047.

Demand Forecast for Magnets for Passenger Vehicles:

Passenger vehicles show a similar trend in demand growth. The forecast indicates a demand of **712.7 tonnes** by 2030. Under the *ambitious* scenario, the demand is expected to reach **5717.5 tonnes** by 2047. The *moderate* scenario estimates a demand of **4219.8 tonnes**, and the *conservative* scenario projects a demand of **2640.7 tonnes** by 2047.

These projections suggest a substantial increase in the requirement for REMs, driven by the growth in sales of EVs across all categories. It is projected that the requirement for magnets by 2030 for two-wheelers would be **5538.3** tonnes, **903.2** tonnes for three-wheelers and **712.7** tonnes for passenger vehicles, projecting a total demand of over **7 thousand tonnes in 2030** and more than **27 thousand tonnes by 2040.**

5.4 Demand Forecast Analysis

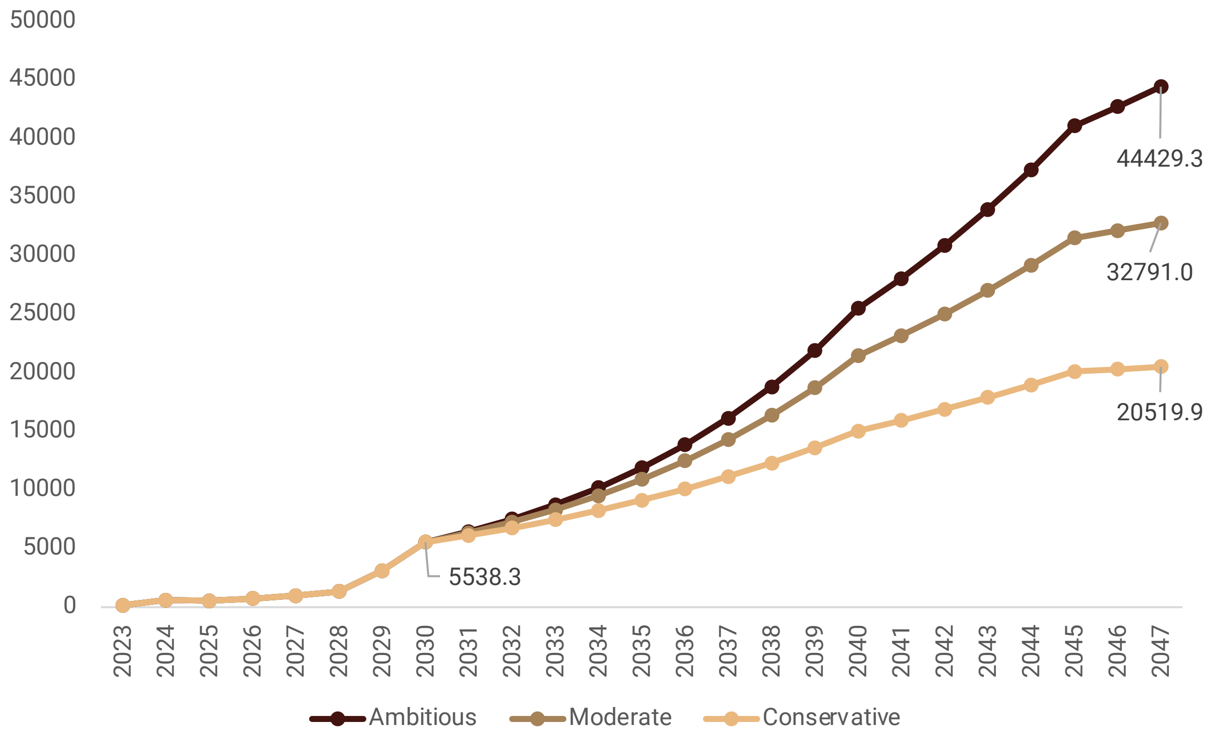
The forecasting above preludes to the growth in demand for EVs, be it the most ambitious or conservative projection. This further implies the growing need for REMs. This transition, when supported by a robust policy and framework, can be a crucial step towards actualising the nation's GHG emission targets and the vision of a 'Viksit Bharat'.

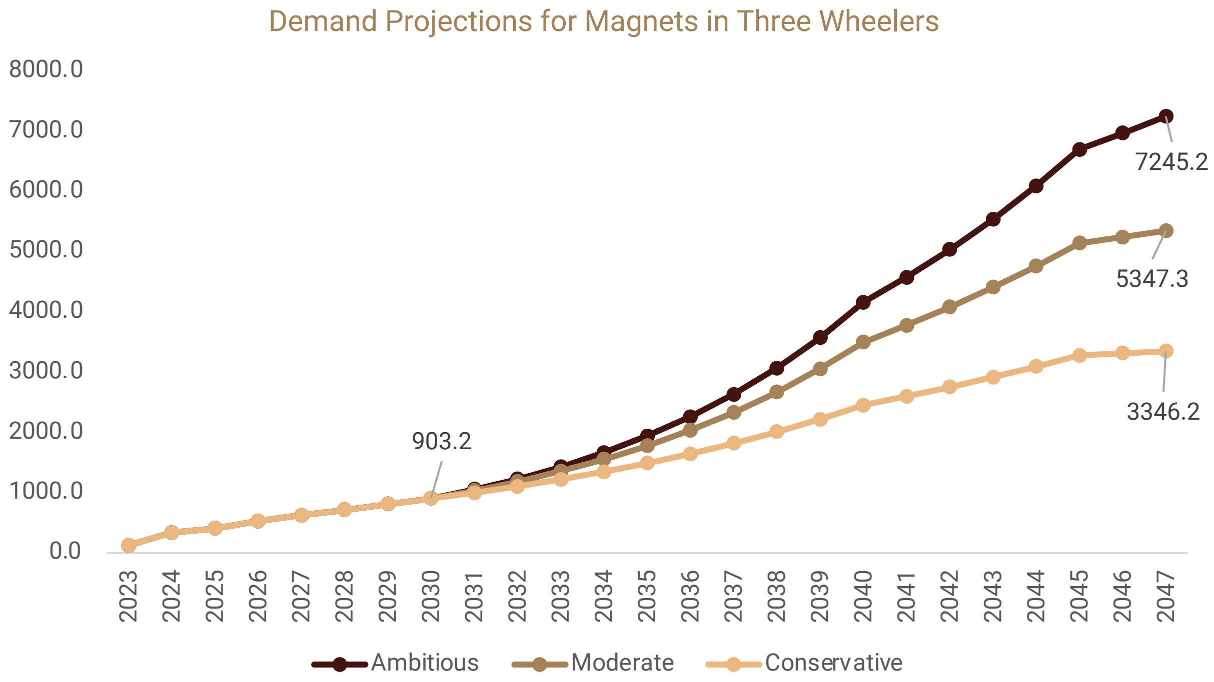
The expected increase in EV sales will significantly boost the demand for rare earth magnets, especially neodymium-iron-boron (NdFeB) magnets used in EV motors.

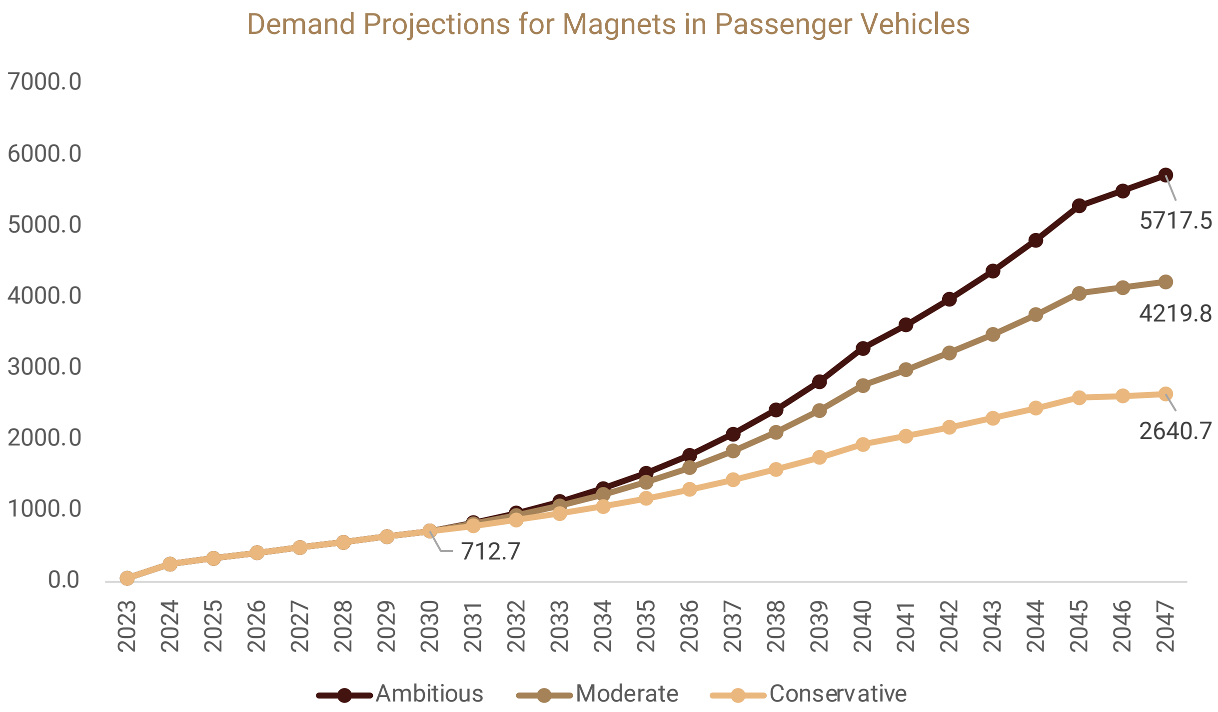
Ensuring a stable supply chain and investing in domestic production capabilities will be crucial to meet this demand.

By understanding and preparing for these trends, stakeholders can take advantage of the growing EV market, leading to sustainable growth and innovation in the automotive sector. This will not only support the transition to EVs but also drive the development of a robust rare earth magnet industry, essential for the future of EV manufacturing.

Demand Projections for Magnets in Two-Wheelers




Demand Projections for Magnets in Three Wheelers
8000.0
7000.0
6000.0
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
903.2
7245.2
5347.3
3346.2
2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047
Ambitious
Moderate
Conservative


Demand Projections for Magnets in Passenger Vehicles
7000.0
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2000.0
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712.7
5717.5
4219.8
2640.7
2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047
Ambitious
Moderate
Conservative

06

Stakeholder Inputs

Ministry of Heavy Industries (Government of India), a nodal agency for electric mobility in India, is committed to achieving the goals of 30% EV penetration by 2030 and net zero emission by 2070. In pursuit of these targets, an EV Taskforce has been constituted to develop a comprehensive action plan, detailing milestones and strategies across the EV ecosystem.

In line with this strategic initiative, addressing the critical area of rare earth magnets—a strategic asset of the EV ecosystem that will significantly determine the competitiveness and success of the industry—is essential.

Hence, a comprehensive mapping of relevant stakeholders within the rare earth magnets sector has been conducted. These stakeholders span various categories- including government bodies, regulatory and policy institutions, research organisations, magnet manufacturers, magnet extraction organisations, developers of alternative motor technologies, and organisations involved in recycling rare earth from batteries. Discussions centred on a series of questions pertaining to the extraction process, the current market landscape, challenges encountered, emerging and alternative technologies, recycling and end-of-life management, relevant policy interventions/support, etc. These questions were provided to participants in advance of the consultations. Insights were gathered from two meetings conducted as a part of this process, aiming to address the critical areas within the rare earth magnets sector essential for the success of the EV industry. Thus, the success of this EV Taskforce relied on active participation and invaluable insights from industry leaders and specialists involved.

Stakeholders: Government Agencies

Various government bodies, including the Ministry of Mines and the Ministry of Heavy Industries, play pivotal roles in policy formulation, regulatory frameworks, and support mechanisms related to the mining, processing, and utilisation of REEs. Departments such as Science & Technology actively fund and promote R&D in material science, focusing on innovations that enhance the efficiency and sustainability of REE extraction and processing.

Stakeholders: Industrial Entities

Chara Technology and Kalyani Steels are at the forefront of developing alternative motor technologies and pushing for an indigenous magnet manufacturing capability. They focus on reducing dependence on imported REEs by enhancing domestic capabilities. Lohum and Chakr Innovation are key players in the recycling segment, advocating for sustainable practices and local supply chain development to diminish reliance on international imports. Lohum specifically focuses on effective recycling technologies and partnerships, such as cooperating with HyProMag in the UK. They advocate for Extended Producer Responsibility (EPR) credits to bolster recycling initiatives, suggesting that India could become an exporter of recycled magnets, potentially even serving markets like China.

6.1 Current Status

India has made significant strides in the rare earth processing sector, showcasing comprehensive capabilities across the entire ecosystem, which includes upstream mining and concentration, midstream metal alloy formation, downstream manufacturing of magnets, and consumer end products such as BLDC motors. One of the key players in this sector is India Rare Earths Limited (IREL), which is responsible for both mining and processing rare earth elements.

In a significant development, the Hon'ble Prime Minister recently inaugurated India's first facility to produce rare earth permanent magnets in Visakhapatnam. This state-of-the-art plant is poised to offer several strategic advantages:

- Safeguarding India from supply chain disruptions in rare earth metals.
- Supporting the 'Make in India' initiative and boosting demand in the electronics, defence, and aerospace sectors.
- Addressing the growing issue of e-waste generation in India.
- Catering to domestic rare earth metal demand.
- Providing more rare earth metals that are currently imported.

With this facility, India will join a select group of nations capable of producing rare earth permanent magnets.

6.2 PROMOTION OF DOMESTIC INDUSTRY

To reduce imports and bolster the domestic magnet industry, stakeholders discussed the pivotal need for developing an indigenous EV-grade NdFeB magnet manufacturing capability in India. Addressing India's strategic interests, stakeholders quantified both the global and Indian markets for NdFeB magnets, highlighting the significant growth anticipated by. 2030

All stakeholders stressed the importance of domestic exploration and processing, advocating for prioritized geological mapping to identify rare earth deposits within India.

India holds significant potential in rare earth elements (REEs) mining, especially due to its reserves of monazite sands. Under the control of the Department of Atomic Energy and India Rare Earths Limited (IREL), extensive efforts are ongoing to extract and process REEs from beach sand minerals. Consequently, reducing dependency on China will enable India to become self-sufficient in this critical sector.

An analysis of Harmonized System (HS) Codes is essential to understand the imports better. According to the industry, diversification of import sources beyond dominant players is necessary to mitigate geopolitical risks. They also advocate for negotiating free trade agreements with rare earth-rich countries to ensure stable and secure access to these materials. Additionally, they seek relaxation of import duties on critical equipment and raw materials to further support this initiative.

6.3 Policy and Regulatory Support

Implementing policies that incentivise the development of the REE sector is crucial. These could include tax breaks, subsidies for new mining or recycling operations, and grants for technological innovation. Consensus exists on the need for subsidies through the Production-Linked Incentive (PLI) scheme and an import duty waiver to support the industry.

A notable point is that capital equipment necessary for manufacturing is significantly cheaper when sourced from China compared to Japan and Germany. This highlights China's dominance in the midstream value chain, attributed to environmental concerns and regulatory restrictions in the U.S.

6.4 Subsidies & Incentives

Initial support through subsidies is vital for establishing the industry. A comparison with international practices reveals that the U.S. and Europe also provide subsidies to their industries.

Private organisations provided an in-depth analysis of the demand for NdFeB magnets, essential for EV drivetrains, indicating that approximately 2 kg of NdFeB magnets are required per vehicle. They emphasised the strategic need to establish a comprehensive magnet manufacturing plant in India by 2027, scaling up to a capacity of 10,000 tons per annum by 2037 to meet both domestic and global demands. Lastly, advocacy for subsidies and grants to set up processing facilities, skill development programs, infrastructure development such as dedicated industrial parks, and public--private partnerships to catalyse the growth of the domestic rare earth magnets industry.

6.5 Research & Development

Enhancing funding for R&D is crucial for the advancement of extraction technologies, recycling methods, and the development of alternative materials that can replace or reduce the use of rare earth elements (REEs) in various applications. A few Indian companies have been particularly focused on the recycling of rare earth materials, emphasising the importance of developing effective technologies and forming strategic partnerships. An example of such a partnership is their collaboration with HyProMag in the UK, which is aimed at enhancing the efficiency of recycling processes.

6.6 Support for Alternative Motor Technologies

India is pioneering the development of rare-earth-free motor technologies. These motors are designed to be as efficient as conventional Brushless DC (BLDC) motors but without the reliance on REEs, which often necessitates imports. Major companies like ABB and BMW are also investing in R&D for rare-earth-free motors.

The design and development of these motors, facilitated by NFTDC, include PCB Assembly Facilities for Power Electronics Devices. However, these motors are about 10% heavier than conventional motors. Historically, rare-earth-free magnets used in motors were of the switched reluctance type (SRMs), which were relatively inefficient. Recent advancements in control mechanisms have now facilitated a transition to synchronous reluctance motors, addressing many of the inefficiencies previously associated with SRMs.

With respect to localisation content in such products, motors and controllers, as well as the specialised steel used, are currently imported. Stakeholders discussed a plan for localisation efforts while expressing confidence that dependence on critical minerals is a short-term challenge, emphasising the global concerns surrounding rare earth magnet-based motor systems.

The industry has reported achieving an impressive 94% energy efficiency with their innovative motors, comparable to conventional technologies but with significantly reduced costs and carbon footprint.

Their ongoing research and successful pilot programs underscore the potential for these motors to make substantial inroads into the market, contributing to reduced reliance on rare earth elements and supporting India's strategic interests in becoming self-sufficient.

6.7 Recycling

To establish a robust domestic supply chain for rare earth elements (REEs), it is imperative to support the construction of facilities dedicated to the extraction, processing, and recycling of REEs. Policy measures should be put in place to encourage the recycling of rare earth materials. A significant challenge faced in this domain is the difficulty of recovering rare earth materials from ore due to their low concentrations. For instance, extracting 500 milligrams of rare earth elements from one ton of ore is typical, and these materials are often found near radioactive substances, making the process complex and environmentally challenging.

Stakeholders emphasized the importance of urban mining and recycling, suggesting initiatives to recover rare earths from electronic waste and advocating for efficient recycling programs to reduce reliance on virgin materials. They also highlighted the potential of recycling EV scrap through dismantling, recovery, and material extraction to produce recovered magnets.

Stakeholders also suggested that India could establish strategic partnerships with countries rich in rare earth materials to secure long-term supply contracts and engage in joint ventures for exploration and processing. Such collaborations would be critical in securing a stable supply of raw materials while advancing local processing capabilities.

Specialized programs should be developed to train a skilled workforce capable of supporting the advanced technological needs of the REE and EV industries. This trained workforce will be essential for operating and optimizing new recycling and processing facilities.

To ensure secure and stable supplies of REEs, it is crucial to negotiate with rare earth-rich countries. Establishing joint ventures for exploration and processing can diversify sources, reduce supply risks, and help mitigate geopolitical challenges.

6.8 Suggested Policy Interventions

Significant progress has been made at the laboratory level in developing rare earth magnets; however, full-scale industrial manufacturing is yet to be realised. Substantial subsidies provided by China pose competitive challenges.

The lack of mature technology for manufacturing and processing rare earth magnets, coupled with patent issues and the commercial viability of projects, are significant barriers. There is a pressing need for heavy subsidies on the CAPEX side to initiate manufacturing facilities and import duty exemptions for required equipment.

Challenge 1: High Cost of Raw Materials (PrNd Oxide):

- Proposed Solutions: Provision of subsidies and incentives for raw materials to reduce production costs.
- Relevant Ministries/Organisations: Ministry of Mines, Department of Atomic Energy

Challenge 2: High Capital Expenditure (CAPEX) for MSMEs:

- Proposed Solutions: Reform CAPEX subsidies under the IFCI - SPECS scheme to support MSMEs without requiring financial closures upfront. Seek government-backed financial guarantees or subsidies to mitigate risks and make projects more attractive to banks and financial institutions. Additionally, enable procurement of alternative funding sources such as venture capital, private equity, or public-private partnerships.
- Relevant Ministries/Organisations: Ministry of MSME, Ministry of Finance

Challenge 3: Absence of Essential Supply Chain Components and Geopolitical Instabilities:

- Proposed Solutions: Develop domestic supply chains for rare earth elements and manufacturing equipment to reduce dependency on international suppliers. Advocate for policies supporting the establishment of local supply chains, including specialised furnaces, presses, cutting and coating equipment, and raw material production.
- Relevant Ministries/Organisations: Ministry of Commerce & Industry

Challenge 4: Import of Rare Earth Alloys and Magnets

- Proposed Solutions: Monitor, control, and implement "countervailing measures" and levy "countervailing duties" as per WTO guidelines.
- Relevant Ministries/Organisations: Ministry of Commerce & Industry

Challenge 5: Price Undercutting by Chinese Manufacturers

- Proposed Solutions: Implement anti-dumping duties (recommended 20%) on imported magnets to protect domestic manufacturers from price undercutting. Regulate the import of low-grade magnets through quality control norms to ensure quality and protect domestic manufacturing standards.
- Relevant Ministries/Organisations: Ministry of Finance, Ministry of Commerce and Industry, Directorate General of Trade Remedies

Challenge 6: Export of NdFeB Magnet Scrap

- Proposed Solutions: Implement policies to retain NdFeB magnet scrap domestically, ensuring its availability to local industries at competitive prices.
- Relevant Ministries/Organisations: Ministry of Commerce & Industry

Challenge 7: High Electricity Costs Compared to Competitors

- Proposed Solutions: Enhance power subsidies to align with lower electricity costs available to competitors, reducing operational expenses.
- Relevant Ministries/Organisations: Ministry of Power

Challenge 8: Dependence on Chinese Mid-Stream Materials

- Proposed Solutions: Encourage and incentivise indigenous mid-stream projects. Provide subsidies for CAPEX and OPEX of such projects. A 40% front-end CAPEX subsidy (uncapped) would improve project viability through part CAPEX funding via subsidy. Additionally, a 30% subsidy of the NdFeB magnet selling price for 10 years (uncapped) would ensure the sustainability of operations until the required scale and ecosystem are developed.
- Relevant Ministries/Organisations: Ministry of Mines, Prime Minister's Office (PMO)

Challenge 9: Subsidised Rare Earth Oxide Production in China

- Proposed Solutions: Augment, support, and incentivise indigenous rare earth oxide production.
- Relevant Ministries/Organisations: Ministry of Mines, Indian Rare Earth Limited

Challenge 10: Subsidised Conversion of Rare Earth Oxide to Rare Earth Metal in China

- Proposed Solutions: Incentivise indigenous rare earth metal production by at least 30% to benefit and encourage indigenous rare earth alloy and magnet projects.
- Relevant Ministries/Organisations: Ministry of Heavy Industries

Challenge 11: High CAPEX Due to Technology Acquisition and Imported Plant and Machinery

- Proposed Solutions: Provide 100% reimbursement of costs incurred on technology acquisition and assimilation to improve project viability through effective CAPEX reduction. Additionally, offer a 100% waiver on import duty and GST for plant and machinery, where 90% of P&M will be imported.
- Relevant Ministries/Organisations: Ministry of Finance, Ministry of Commerce & Industry

Challenge 12: Lack of Domestic Production Facilities for Essential Equipment

- Proposed Solutions: Streamline rapid procurement policies for importing high-quality equipment necessary for permanent magnet production until indigenization is achieved.
- Relevant Ministries/Organisations: Ministry of Finance, Ministry of Science & Technology

Challenge 13: Limited Availability of Heavy Rare Earths (HRE) for EV Grade Magnets

- Proposed Solutions: Provide a 100% waiver on import duty for rare earth and heavy rare earth metals, and process consumables to ensure sustainable raw material and consumables costs for the plan.
- Relevant Ministries/Organisations: Ministry of Finance, Ministry of Commerce & Industry

OTHER PROPOSED POLICY INTERVENTIONS

- **Invest in Infrastructure:** Support the construction of REE extraction, processing, and recycling facilities.
- **Enhance R&D Funding:** Allocate resources for research into extraction technologies, recycling methods, and alternative materials.
- **Policy and Regulatory Support:** Implement policies offering tax breaks, subsidies, and grants to develop the REE sector.
- **Educational and Training Programs:** Develop programs to train a workforce for advancing the REE and EV industries.
- **International Cooperation and Trade:** Secure supply contracts and joint ventures with rare earth-rich countries to diversify sources and reduce supply risks.

This comprehensive approach, involving multiple ministries, departments, organisations and the industry, aimed to address the critical challenges facing the rare earth elements and magnet manufacturing industry in India. The extensive use of NdFeB magnets across various applications underscores the dependency on these materials and highlights supply chain risks. China controls a significant portion of the global rare earth production and processing market, dominating the midstream value chain. Environmental concerns and regulatory restrictions in the U.S. have shifted the rare earth separation process to China, further cementing its dominance. Hence, the above challenges need to be taken into consideration for India to create a robust supply chain and thereby achieve its EV targets.

By implementing these strategic measures, India can reduce its reliance on imports, enhance domestic manufacturing capabilities, and ensure a stable supply of critical materials for the growing electric vehicle market.

CATEGORY	Key Stakeholders in India's EV Grade Magnet Value Chain
Government Agencies	1. Ministry of Mines; 2. Ministry of Heavy Industries; 3. Ministry of External Affairs; 4. Ministry of Commerce and Industry; 5. Ministry of Finance; 6. Ministry of Environment, Forest & Climate Change; 7. NITI Aayog; 8. Department of Science and Technology; 9. Department of Atomic Energy; 10. Directorate General of Foreign Trade; 11. Bhabha Atomic Research Centre (BARC); 12. Defence Metallurgical Research Laboratory (DMRL); 13. Indian School of Mines (ISM); 14. Council of Scientific & Industrial Research (CSIR); 15. IIT Kanpur; 16. Indian Rare Earth Limited (IREL); 17. Mishra Dhatu Nigam Limited (MIDHANI); 18. Bharat Electronics Limited (BEL); 19. Bharat Heavy Electricals Limited (BHEL); 20. Khanij Bidesh India Limited (KABIL)
Financial Institutions	1. National Bank for Financing Infrastructure and Development (NaBFID); 2. National Investment Infrastructure Fund (NIIF); 3. World Bank; 4. Asian Development Bank
States Involved in Mining Rare Earth	1. Department of Geology & Mining for: Odisha, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka 2. Potential: West Bengal, Gujarat, Maharashtra, and Jammu and Kashmir

Industrial Entities (OEMs; Wind Turbine Manufacturers; Motor Manufacturers; Battery Manufacturers; Potential Magnet/Extraction Partners; International Collaborators and Trade Partners)	1. JBM; 2. Tata Motors; 3. Olectra Greentech; 4. Octillion; 5. Pinnacle Mobility; 6. Sun Mobility; 7. PMI; 8. Mahindra Electric; 9. Piaggio Vehicles; 10. Bajaj Auto; 11. Ather Energy; 12. Kalyani Powertrain Limited (KTPL); 13. Precision Camshafts; 14. TVS Motor Company; 15. Vestas India; 16. Inox Wind Limited; 17. Enercon India Private Limited; 18. Siemens Gamesa Renewable Energy; 19. Suzlon; 20. Mahindra Electric Mobility Limited; 21. Tata Motors; 22. Lohum; 23. Chakr Innovation; 24. Bosch Limited; 25. UQM Technologies India; 26. Tork Motors; 27. ABB India; 28. Delta Electronics India; 29. Bharat Bijlee; 30. Lucas TVS; 31. Chara Technology; 32. Kirloskar Electric Company Limited; 33. Saggu Electrical Industries; 34. Laxmi Hydraulics Private Limited; 35. Exide Industries; 36. HBL Power System; 37. Amara Raja Energy & Mobility Limited; 38. United States Agency for International Development (USAID); 39. GIZ; 40. Kalyani Steels Limited (KSL); 41. Ashvini Magnets; 42. Entellus Industries; 43. Toyotsu Rare Earths India

07

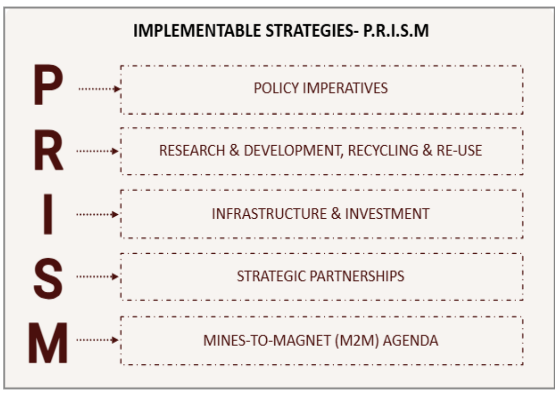
Strategic Action Plan

The importance of critical minerals, particularly for developing economies like India, has become undeniable, with these resources playing a pivotal role in sectors such as high-tech, telecommunications, renewables, and defence.

The Union Budget 2024-25 announced the establishment of a National Critical Mineral Mission, aimed at enhancing domestic production, recycling, overseas acquisition and boosting global competitiveness, with focus on technology development, workforce skilling, and extended producer responsibility. Rare earth minerals must be prioritised within this mission.

To ensure both immediate impact and sustained growth in the rare earth minerals and magnet manufacturing industry, a comprehensive strategic plan under India's Critical Mineral Mission - the "India Mines-to-Magnet Agenda (M2M)" is proposed, with the primary objective to achieve self-reliance ("Aatmanirbharta") and promote the "Make in India" initiative by 2047. M2M, led by experts, would function as a specialised division within the Critical Mineral Mission, serving as the central authority for the coordinated, efficient, and seamless implementation of a comprehensive program aimed at establishing a robust ecosystem for rare earth mining, magnet manufacturing and recycling.

The proposed recommendations can be summarized under the PRISM framework, which conceptually encompasses short-term and long-term implementable strategies to build a sustainable and resilient Indian rare earths ecosystem and position India as a global leader.



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Major Milestones of M2M Agenda (2024-2047)

Immediate Steps

- Enhance REE magnet production.
- Address immediate infrastructure needs.
- Develop short-term partnerships for technology and material supply.

2030

- Establish and expand India's capabilities in rare earth magnet production.
- Establish new REE processing facilities with public and private investment.

2037

- Create scenario-based strategies for infrastructure development.
- Achieving near self-sufficiency in producing essential REEs for EV manufacturing.

2047

- Cultivate partnerships and drive technological innovation.
- Emerging as a major exporter of EV-grade magnets, leveraging

N

7.1 Objectives

1. **Strategic Development:** Formulate comprehensive short-term and long-term strategies to develop rare earth magnet manufacturing facilities, and a design ecosystem within the country, in consultation with government ministries, departments, agencies, industry, and academia.

2. **Supply Chain Security:** Facilitate a secure supply chain for rare earth magnet manufacturing, encompassing raw material procurement, production processes, and recycling mechanisms.

3. **Design & Industry Integration**: Promote substantial growth in the Indian rare earth magnet industry by providing necessary support in the form of engineering expertise and manufacturing capabilities.

4. **Indigenization of Magnets:** Encourage and support the indigenous manufacturing of rare earth magnets and foster the transfer of technologies (ToT) through incentives and enabling frameworks.

5. **Collaborative Partnerships**: Facilitate collaborations and partnership programs with national and international agencies, industries, and academic institutions to drive collaborative research, commercialization, and skill development.

The M2M would ensure the establishment of a sustainable, efficient, and innovative rare earth magnet industry, contributing significantly to India's economic and technological advancements.

7.2 Short and Medium Term Action Points

In the short-run, a three-pronged, integrated strategy is recommended, anchored on technology leadership, mining expansion and scaled private sector manufacturing.

1. **Technology Leadership: Establish a National Rare Earth Innovation Hub**

- Leverage organizations like Non-Ferrous Materials Technology Development Centre (NFTDC) to drive R&D in extraction, separation, and advanced magnet manufacturing technologies, bridging India's technology gap with global leaders.

- Public-private-academic partnerships to accelerate technology transfer, indigenize critical know-how, and promote the development of next-generation, high-performance magnets.

2. **Mining Expansion: Empower and Modernize IREL**

- Scale up IREL's mining and processing capacity to unlock India's 6.9 million MT of rare earth reserves, focusing on rapid expansion of monazite separation and rare earth oxide production.
- Streamline regulatory frameworks to expedite mining approvals, encourage responsible private sector participation, and facilitate offshore resource acquisition through the Critical Minerals Mission.

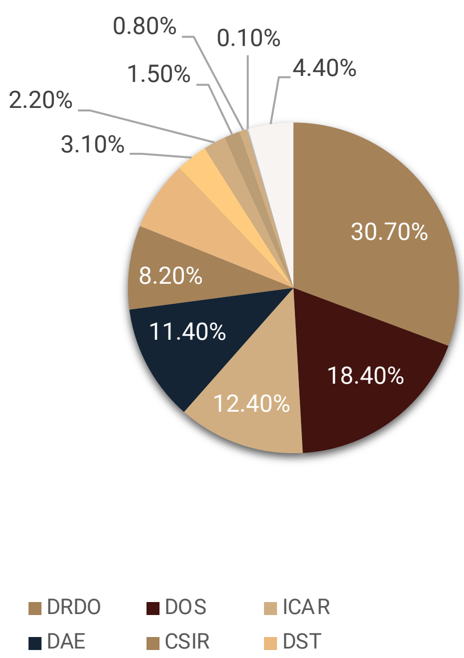
3. **Production & Magnet Manufacturing: Mobilize the Private Sector**

- Incentivize private investment in rare earth refining and NdFeB magnet manufacturing through targeted financial support, tax breaks, and production-linked incentives to provide an initial handholding support.
- Establish dedicated industrial clusters for rare earth processing and magnet fabrication, ensuring seamless integration across the value chain and reducing import dependence.
- Promote joint ventures and technology collaborations with global leaders to accelerate scale-up, achieve quality benchmarks, and access international markets

7.3 Long-term action points

A. Corpus for Research & Development in Rare Earth Supply Chain

The Interim Budget 2024-25 has laid out a significant corpus of INR 1 lakh crore for research and development (R&D) to encourage private sector investment in this field. This funding is designed to provide long-term financing or refinancing with minimal or nil interest, and it comes with a 50-year interest-free loan provision. This initiative aims to stimulate substantial growth in research and innovation, particularly in sunrise domains such as rare earth elements and magnets.



Further, the Union Budget of 2024-25 has attempted to encourage new REE mining projects and promote R&D in REE extraction and processing technologies with the allocation of:

- ₹400 crores for Exploration Activities under National Mineral Exploration Trust, Ministry of Mines;
- ₹50 crores for loans, capital and other outlays to industries and minerals under the Department of Financial Services, Ministry of Finance;
- ₹1679 crores for other outlays on industries and Minerals under the Department for Promotion of Industry and Internal Trade, Ministry of Commerce and Industry; and
- ₹606 crores for Atomic Minerals Directorate for Exploration and Research (Hyderabad), R&D projects of Atomic Minerals Directorate for Exploration & Research (AMDER) and Industries and Minerals Projects under the Department of Atomic Energy.

The goal is to establish a comprehensive framework for the development and utilisation of rare earth elements (REE) in India. This plan includes a pilot phase, followed by progressive scaling up, ensuring sustainable growth and technological advancement in the sector. The timeline extends from 2024 to 2047, aligning with India's long-term strategic goals.

Proposed activities to be undertaken:

- Rare Earth Research Hub/Centre for Excellence: Development of initial infrastructure and capabilities for R&D on rare earth ecosystem, sustainable mining practices, along with initial R&D on recycling technologies;
- Strengthening the domestic exploration & processing ecosystem through geological mapping of new sites and other exploratory activities to assess potential rare earth deposits;
- Forging partnerships with international and domestic stakeholders for enhanced global market expansion through export;
- Policy development & incentivisation;
- Initiation of pilot project and initial commercialisation efforts;
- Expansion of manufacturing, high-efficiency magnets and recycling projects;
- Innovation in new applications of REEs and Integration of REEs in various industries and strengthening ties for practical applications;
- Comprehensive review and strategic adjustments;
- Industrial scale-up to position India as a global leader in REE & REM research and application;
- Commercialization of innovations, large-scale manufacturing, industry-wide integration and ethical technology transfer;
- Comprehensive R&D programs, skill development & employment generation.

B. Rare Earth Mines-to-Magnets Strategic Partnership (REMMSP)

The REMMSP will be a collaboration of the Global South to catalyse public and private investment in responsible rare earth minerals & magnets supply chains globally.

It will aim to accelerate the development of diverse and sustainable rare earth supply chains through working with host governments and industry to facilitate targeted financial and diplomatic support for strategic projects along the value chain.

Potential Partners: India, South Africa, Madagascar, Zimbabwe, Tanzania, Southeast Asia cooperation - Vietnam, Malaysia, Japan, Thailand, Myanmar, Brazil, Australia.

The REMMPS will consider projects along the full value chain, focusing on 5 key vertices:

- Mining, Extraction & Secondary Recovery: Initiatives to responsibly mine and recover rare earth minerals
- Processing: Developing advanced processing capabilities for rare earth minerals,
- Refining: Enhancing refining techniques to produce high-quality rare earth materials,
- Manufacturing: Supporting the downstream supply chain by bolstering the manufacturing of rare earth magnets,
- Recycling: Promoting the recycling of rare earth materials to ensure sustainability.

Framework: The REMMPS will operate through a collection of project-focused working groups that will engage with project proponents, evaluate projects based on ESG standards and alignment with REMMPS goals and assess potential financial, diplomatic or other support methods. The partner governments will engage across a wide range of agencies and departments, including those responsible for foreign affairs, economy, energy, trade, development finance, and export finance.

REMMPS will directly address five major challenges:

- Diversifying and stabilizing global supply chains,
- Investment in those supply chains,
- Promoting high environmental, social, and governance standards in the mining, processing, and recycling sectors,
- Increasing recycling of rare earth magnets,
- Ethical technology transfer.

This partnership, led by the Government of India, is a commitment to responsible and sustainable development, integrating high environmental, social, and governance (ESG) standards to ensure the resilience and integrity of the rare earth supply chains.

C. Development of Comprehensive Rare Earth Minerals Policy

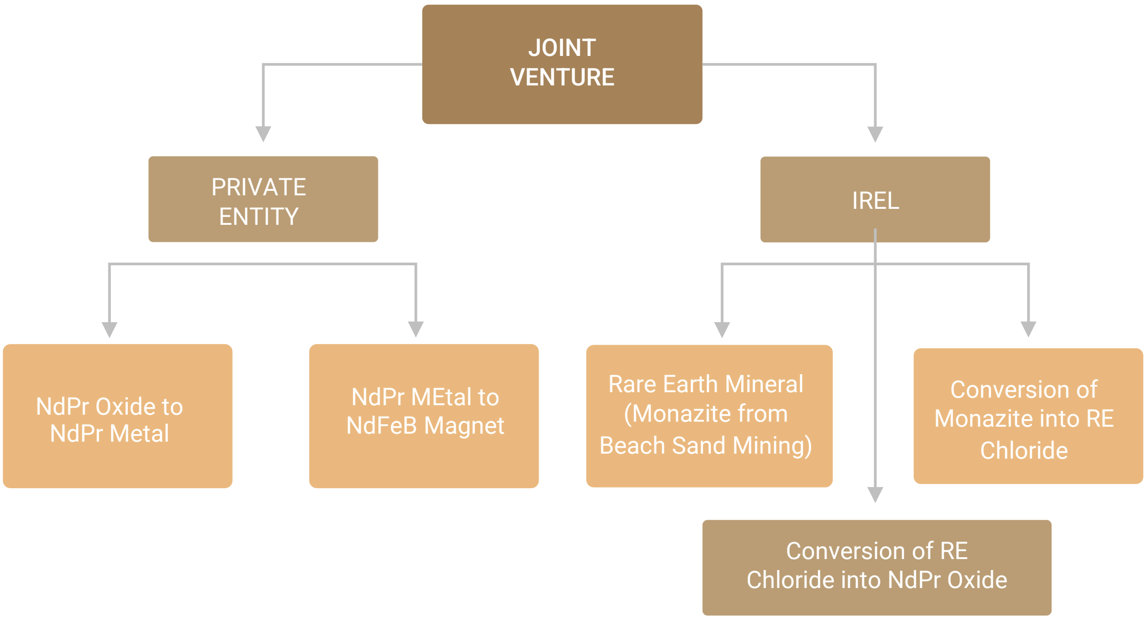
The policy will emerge from a comprehensive development process, effectively driven by M2M through inter-ministerial committees and diverse contributions from the outlined activities. Developing this policy will require close alignment with the government's vision for the Critical Mineral Mission and the interests of key stakeholders across sectors. This policy will include:

- **Comprehensive Industry Assessment:** Evaluate the full spectrum of the rare earth industry and current policies, addressing challenges from mining to magnet production and recycling.
- **Exploration and Mining Opportunities:** Identify potential exploration and mining initiatives through organisations like IREL and BARC, ensuring reliable raw material supplies for magnet manufacturing.
- **Infrastructure Development:** Facilitate government support for research, logistics, and civil infrastructure essential to the rare earth industry.
- **Technology and Capability Review:** Assess existing technologies and manufacturing capabilities, identify gaps, and examine global best practices in collaboration and innovation.
- **Process Innovation:** Explore and refine new processes for exploration and manufacturing, including sector standardisation.
- **Policy and Regulatory Framework:** Establish a robust policy and regulatory framework to advance rare earth magnet production and enable exploration, extraction, processing, usage, and recovery of critical minerals.
- **Financial Framework Development:** Design a financial framework with incentives to encourage the growth and scalability of the rare earth magnet supply chain.
- **Pricing and Cost Optimisation:** Investigate strategies for pricing and cost reduction in exploration and manufacturing technologies.
- **Recycling and Sustainability:** Assess recycling methods for rare earth minerals and magnets, and develop a sustainability roadmap for magnet manufacturing infrastructure.
- **Human Resource & Workforce Development**: Build skills and capacity across the value chain, creating a specialised workforce for R&D and implementation within the industry.
- **Global Competitiveness:** Formulate strategies to enhance India's competitiveness in the global rare earth magnet market.
- **Industry Collaboration:** Promote partnerships among public and private sectors, academia, and international entities to drive innovation and growth.
- **Supply Chain Resilience:** Develop approaches to secure a resilient and stable supply chain, mitigating risks to rare earth magnet availability.

Deliverable: The involved committee(s) will establish a dedicated subgroup to guide policy development. This sub-group will generate inputs for a draft policy targeting the 2047 objectives, providing strategic direction for scaling India's magnet production ecosystem. The report, outlining actionable steps and necessary frameworks, will be submitted within six months and will be instrumental in positioning India as a global hub for rare earth magnet manufacturing, fostering innovation, sustainability, and economic growth.

D. Proposed Pilot: Development of India's State-of-the-art Integrated NdFeB Magnet Manufacturing Plant

The extreme concentration of the rare earth value chain and NdFeB magnet manufacturing in China has resulted in significant supply chain risks for non-Chinese electric vehicle (EV) motor manufacturers. To safeguard India's strategic interests and bolster its manufacturing capabilities, it is essential to develop a state-of-the-art, EV-grade NdFeB magnet manufacturing facility. This plant will be established as a joint venture between IREL and a private entity.



Phase	Start Year	Magnet Manufacturing Capacity (Cumulative)	NdPr Oxide Required
1	2027	1200 TPA	500 TPA
2	2032	5000 TPA	2000 TPA
3	2037	10000 TPA	4000 TPA

Project Introduction: Phase 1	
Project Metric	Details
Project	Setting up of a 1200 TPA high-temperature EV grade NdFeb magnet manufacturing plant in India
Product	a. NdFeB Magnets b. Grade Range – N35 to N54 c. Operating Temperature Grade – Grade M to Grade TH (80 Degree Celsius – 230 Degree Celsius)
Plant Configuration	a. NdPr Metal – 600 TPA b. NdFeB Alloy – 1800 TPA c. Block Magnet Manufacturing – 1800 TPA d. Grain Boundary Diffusion – 1000 TPA e. Grinding Sludge Recycling – 600 TPA f. NdFeB Finished Magnet – 1200 TP
Target Customers	EV motor manufacturers, industrial motor manufacturers, micro motor manufacturers
Target Turnover	> INR 1000 Cr
Scheduled Start (Comm Operation)	July 2027
Plant Land	20 acres
Proposed Location	Hospet, Karnataka
Electricity Requirement	8 MW
Water Requirement	0.1 MLD (inclusive of process water, make-up water and potable water)
Major Raw Materials	a. NdPr Oxide – IREL India b. Fe Metal – India c. Heavy Rare Earth – China d. Alloying Elements - China
Technology, Plant & Machinery	a. Major portion of P&M– China (Import) b. Technology – Japan
All magnet grades are to be produced through	a. Dual Alloy Process b. HRE Free Process c. Grain Boundary Diffusion & Dual alloy process

Note: Phase I of the project will require ~ 2 years from the Zero date for commissioning.

E. Proposed Project: Magnet Reuse and Recycling for New Applications

The production of magnets involves powder metallurgy techniques, which often result in material wastage. To enhance the efficiency of the magnet manufacturing process, it is crucial to adopt net or near-net shape manufacturing techniques. Magnet reuse and recycling have emerged as innovative solutions, addressing both resource scarcity and process efficiency. This approach aims to drive the development of magnets not only for mobility but also for various new applications in India.

The global demand for rare-earth magnets has surged in recent years due to rapid industrial growth, raising significant environmental and geopolitical concerns due to reliance on scarce and environmentally damaging resources. Magnet reuse and recycling present immense potential, enabling the recovery of valuable magnetic materials from production processes and industrial waste streams. To take this forward, "e-Mobility R&D Roadmap for India" published by the Office of the Principe Scientific Adviser to the Government of India in July 2024, suggests a project for robust recycling and reuse of magnets (as given below).

Research Aim: To research and explore innovative techniques for refurbishing magnetic material powders and used magnets to meet the performance requirements and demands of diverse applications.

Project Targets:

- Establish safe and efficient dismantling practices for magnets,
- Investigate methods to recover and recycle rare-earth and other valuable materials from discarded magnets efficiently,
- Explore the design and utilisation of recycled magnets for emerging technologies, such as next-generation motors,
- Develop a comprehensive magnet characterisation facility, covering material collection, characterisation, manufacturing, and complete testing of magnetic materials.

Methodology:

- Identify sources of used magnets, and collect and sort magnets by type, size, and composition,
- Inspect the condition of the magnets and test their properties,
- Dismantle the magnets, separate different materials, and process the separated magnet materials to recover individual elements,
- Purify and refine the recovered materials into a usable form,
- Perform quality control tests on the newly manufactured magnets to ensure they meet performance and safety standards,
- Set up a pilot plant to process magnets, including small-scale production.

Deliverables:

- Establish a dedicated division within the existing magnet research and development facility,
- Develop specifications for magnet reuse and recycling,
- Generate a target compliance report.

Indicative List of Execution Agencies:

- CSIR - National Institute for Interdisciplinary Science and Technology (NIIST), Thiruvananthapuram

- CSIR-Advanced Materials and Processes Research Institute, Bhopal
- Non-Ferrous Materials Technology Development Centre (NFTDC), Hyderabad
- International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI), Hyderabad

Timelines: 18-24 Months

Estimated Budget: ₹15 - 20 Crore

- Research & Development: ₹15 Crore

- Pilot Manufacturing: ₹5 Crore

Administration Mechanism: Research institutions and industries will collaborate to develop the necessary technologies. This project is prioritised to reduce dependencies on imports, enabling the recovery of valuable magnetic materials from both production processes and end-of-life products and industrial waste streams. The mission's success will depend on a "whole-of-government approach" through collaboration and efficient programme management while leveraging international partnerships for knowledge sharing and joint ventures, particularly with both technologically advanced nations and resource-rich countries in the Global South.

As India pursues these goals, the true test lies in the effective implementation of the mission to ensure sustainable and diversified supply chains, essential for balancing environmental sustainability with economic growth.

08

Way Forward and Roadmap to 2047

India's "Viksit Bharat" vision, aimed at achieving net-zero carbon emissions and sustainable energy access, has made significant strides with the Union Budget 2024-25 welcoming customs duty exemptions and reductions on critical minerals and rare earth metals. The cornerstone of this vision is the integration of renewable energy into the national energy mix, a sector where India has been a pioneer, emphasizing sustainable energy practices and particularly benefiting the electric mobility sector.

However, the supply of essential minerals remains concentrated in a few countries, notably China. On the other hand, India's reliance on rare earths has only grown, with imports increasing substantially. To address this, India is actively exploring and developing domestic sources of these minerals, with projects in Jammu and Kashmir, Rajasthan, Jharkhand, and Karnataka. Additionally, Khanij Bidesh India Limited (KABIL) has established partnerships with mineral-rich countries to secure necessary resources.

Until domestic efforts yield substantial results, customs duty exemptions on critical minerals will help reduce input costs, promote domestic manufacturing, and enhance export competitiveness. Policies such as the production-linked incentive scheme and the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles initiative is accelerating India's transition to electric mobility. The 2024 Budget's focus on exempting customs duties on essential minerals underscores India's commitment to its electric mobility ambitions. These measures aim to lower transition costs, ensure a steady supply of critical minerals and support the EV sector. This strategy aligns economic progress with environmental goals, enhancing India's global standing and reducing resource dependency for a sustainable future.

Further, in May 2023, the inauguration of a Rare Earth Permanent Magnet (REPM) facility on the Bhabha Atomic Research Centre campus in Visakhapatnam marked a significant milestone.

Indian Rare Earth Limited (IREL) completed this project with an investment of approximately INR ₹197 crores. The facility, with a production capacity of 3,000 kg per year, positions India among the few nations capable of producing rare earth permanent magnets, essential for various sectors.

POLICY RECOMMENDATIONS

1. Ensure Market Assurance and Demand Certainty

- Price Guarantees: Introduce long-term, indexed price assurance mechanisms for NdPr oxide and NdFeB magnets to protect investors from global price volatility.
- Anchor Procurement: Support structured offtake agreements with large public and private sector buyers, offering financial support to bridge cost differentials and unlock domestic demand.

2. Develop Integrated Magnet Manufacturing Pilots and Support Champions

- Pilot-Scale Hubs: Establish integrated magnet manufacturing pilots in mineral-rich states to demonstrate the economic and operational feasibility of domestic magnet production.
- Industrial Champions: Identify and empower 3–4 capable firms with core strengths in materials science and advanced manufacturing to lead the ecosystem's industrial scale-up.

3. Secure Upstream Supply and Build Strategic Reserves

- Expand Processing Capacity: Empower IREL to scale up monazite mining, rare earth oxide refining, and NdPr production under the Critical Minerals Mission.
- Strategic Magnet Reserve: Create a national buffer stock of rare earth magnets to ensure supply continuity for priority sectors during external disruptions.

4. Strengthen R&D and Technology Access

- National Innovation Hub: Launch a dedicated National Rare Earth Innovation Hub to coordinate R&D, scale up prototyping, and promote industry-academia collaboration.
- Global Partnerships: Facilitate technology transfer through joint ventures with magnet-producing nations to accelerate access to refining, alloying, and fabrication know-how.

5. Establish Unified Governance for Magnet Ecosystem Development

- Coordination Cell: Set up an inter-ministerial Magnet Ecosystem Coordination Cell under NITI Aayog or DPIIT to harmonise regulatory, fiscal, and industrial strategies.
- Time-Bound Implementation: Define clear implementation milestones and monitor progress across ministries to ensure accountability and timely delivery.

Thus, the strategic action plan, encapsulated in this report, particularly the suggested India Mines-to-Magnet Mission (IM3), aims for self-reliance in the entire rare earth magnet value chain by 2047. This mission, under the "Make in India" umbrella, focuses on creating a robust ecosystem for rare earth mining, magnet manufacturing, and recycling. By fostering collaborations, providing capital support, and encouraging technological innovations, IM3 aims to position India as a global hub for sustainable technologies.

To achieve India's ambitious goals of 30% electric vehicle (EV) penetration by 2030 and net-zero emissions by 2070, it is imperative to address the outlined challenges and implement the strategic recommendations derived from the stakeholder consultations. By enhancing its rare earth element (REE) processing capabilities and optimising the supply chain from mining to recycling, India can boost the domestic production of high-performance EV magnets, thereby reducing import dependency.

This strategic advancement will position India as a global leader in sustainable and high-tech industries. By developing its REE sector, India can meet the growing demands of the EV industry and contribute significantly to the global transition towards sustainable transportation solutions.

09

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Contributors

Davinder Sandhu
Co-Founder & Chairperson

Nikhil Dhaka
Vice President

Anshuman Singh
Manager

Mayuri Dutta
Manager

Neetish Kumar
Manager

Ishita Garg
Senior Consultant

Ankush Sharma
Designer

Bhavya Venneti
Management Trainee

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India Offices

Bengaluru
91 Springboard Business Hub 175, 176 Bannerghatta Rd, Dollars Colony, Bengaluru – 560076

Chandigarh
4th Floor, Netsmartz House, Plot No.10, Rajiv Gandhi Chandigarh Technology Park, Chandigarh – 160101

Chennai
147, Pathari Rd, 1st Floor, Block-B, WorkEz Hansa Building, RK Swamy Centre, Thousand Lights, Chennai, Tamil Nadu 600006

Delhi
1 to 7, Upper Ground Floor,Tolstoy House Building,Tolstoy Marg, Connaught Place, New Delhi - 110001

Kolkata
2/1, Russel St, Park Street area, Kolkata, West Bengal – 700071

Mumbai
156/157 Nariman Bhavan, 15th Floor, NCPA Road, Nariman Point, Mumbai - 400021

International Offices

Dubai
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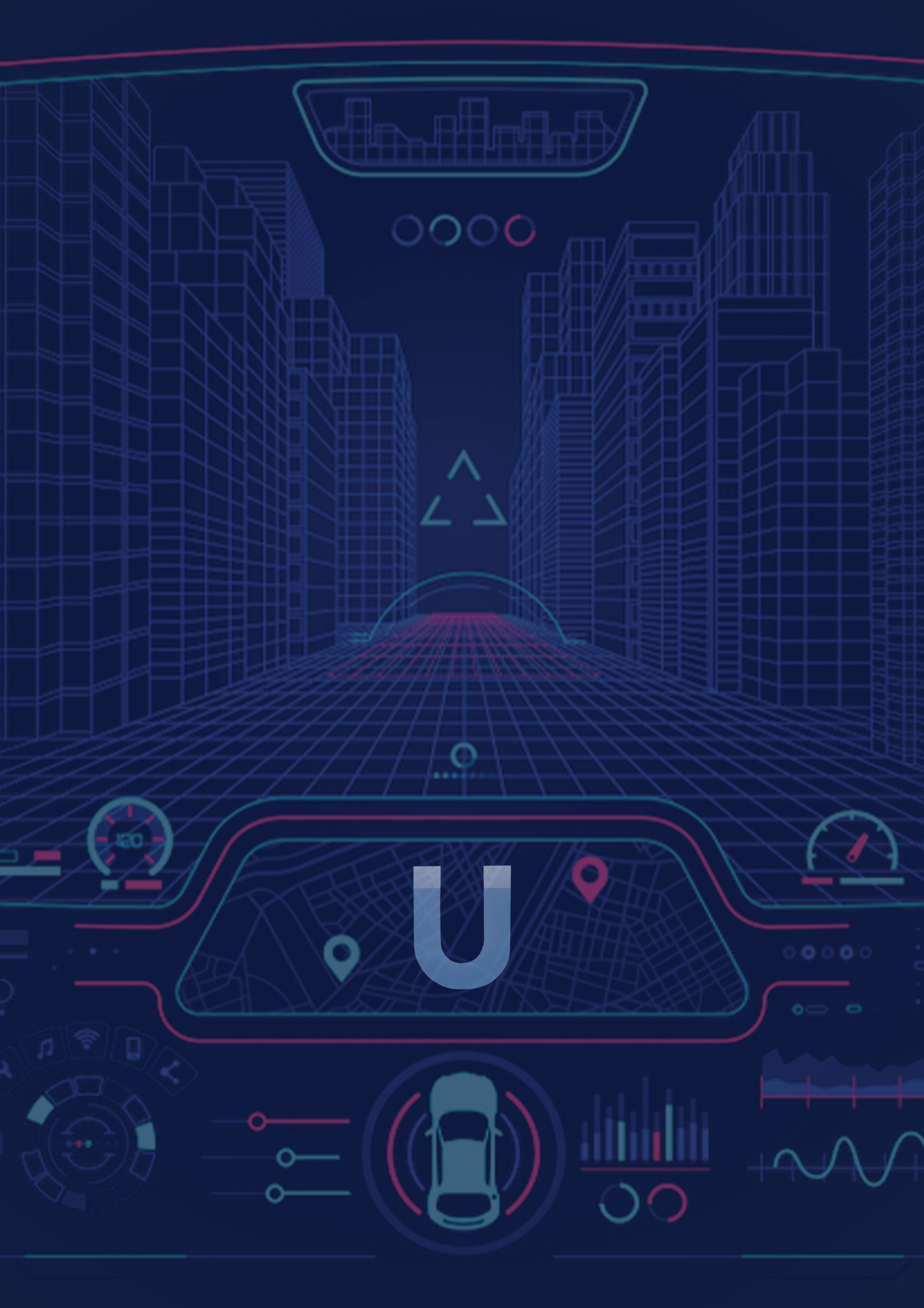
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