International Conference on 'Rare Earth & Critical Elements for Energy Security' (REES 2025)

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Bhubaneswar, Odisha

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RARE EARTHS ASSOCIATION OF INDIA

MESSAGE

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सत्यमेव जयते

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MESSAGE

I am pleased to learn that the Rare Earths Association of India (REAI) is organizing an International Conference on "Rare Earth & Critical Elements for Energy Security" (REES-2025). This conference is aimed at developing indigenous capability, inspire R&D institutes and aspiring industrial conglomerate to work on Rare Earth & Critical Element based technologies for the benefit of the Country.

Rare Earth & Critical Elements are the foundation of modern technology making it backbone of emerging clean technologies. Energy has become the foremost requirement in present time to accelerate economic growth for poverty alleviation and sustainable development. India has been poised to leverage its resource for unleashing the niche values, for achieving self-reliance in energy security of the country and this has placed India in the global map having the capabilities to produce clean energy based materials through advancement in Rare Earth & Critical Elements.

REAI is a premier association uniting Scientists, Technologists and Academicians formed with the objectives of promoting research, development and application of Science and Technology of rare earths and critical materials by exchanging, promoting, communicating and disseminating information in this field.

This endeavour on part of REAI is relevant to the present requirement of the Country and the targets set by the Government of India. I am sure this conference will offer a perfect platform to all the stakeholders in strategizing long term and sustainable growth of the sector and help achieve the goals set by Government of India for achieving self-reliance.

I would like to appreciate the efforts of the Rare Earth Association of India (REAI) in organizing the international conference and wishing the event resounding success.

New Delhi
29.07.2025

स्वच्छ भारत
एक कदम स्वच्छता की ओर

(Dr. V. K. Saraswat)


RARE EARTHS ASSOCIATION OF INDIA

Rare Earths Association of India

Dr. Deependra Singh
President
Rare Earths Association of India (REAI)

MESSAGE

As the world accelerates toward a cleaner, smarter, and more interconnected future, rare earth elements (REEs) have emerged as the silent backbone of the 21st-century industrial revolution. From electric vehicles and wind turbines to semiconductors, defense systems, and advanced electronics, rare earths power the technologies that define modern innovation.

In 2025, the rare earth sector stands at a critical inflection point. Geopolitical shifts, rising demand for energy transition materials, and increasing concerns over supply chain dependencies—particularly on single-source nations—are driving countries and corporations to rethink sourcing strategies and invest in diversified, resilient value chains.

The rare earth sector is no longer just about minerals—it's about geopolitics, green energy, and the next wave of industrial competitiveness. Governments across the Globe are enacting policies to secure rare earth supply, offering incentives for domestic industry and opening doors to more sustainable and economically viable production methods. For emerging economies, this presents a unique opportunity: to position themselves not just as suppliers of raw materials, but as strategic players in the global clean tech and digital supply chains.

Incidentally, in India the upstream sector was established way back with independence and rejuvenated with great energy and strength in last decade. Recent embargo of magnet supply by China has provided further impetus and the draft policy initiated few years back is likely to see light of the day in near future. It is anticipated that such forward looking initiatives would be helpful in establishing RE ecosystem in the country.

The conference is expected to reveal new trends of technological development in rare-earth. The discussion in the sessions will also highlight the need for Collaboration, innovation, and responsible mining practices, which will be key in building a rare earth ecosystem that balances economic growth with environmental stewardship.

(Dr. Deependra Singh)


RARE EARTHS ASSOCIATION OF INDIA

SPEAKER ABSTRACTS

Supply and Demand Dynamics of Rare Earth Minerals

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Abstract

Rare earth minerals are critical for the global energy transition, particularly in the production of electric vehicles (EVs) and wind turbines. These minerals, such as Neodymium (Nd), Praseodymium (Pr), and Dysprosium (Dy), are essential for manufacturing high-performance permanent magnets used in EV motors and wind turbines. These magnets are preferred due to their ability to operate efficiently at high temperatures and their superior magnetic strength, which enhances the performance and energy efficiency of these technologies.

China dominates the rare earth supply chain, controlling ~80% of mining and more than 90% of processing capacity. The processing of rare earth minerals is particularly challenging. Rare earth elements are not found as single entities in nature but occur as combinations of multiple elements, making their separation and refinement complex and resource-intensive. This creates significant geopolitical and supply chain risks for industries dependent on these minerals. This concentration has led to a global supply-demand mismatch, with shortages of key minerals like neodymium and praseodymium projected to reach 23%-34% and 7%-15%, respectively, by 2035.

The demand for rare earth minerals is surging due to the rapid growth of green mobility and renewable energy technologies. EVs are expected to drive over 70% of neodymium and praseodymium demand by 2035, followed by wind turbines. Despite their critical importance, the supply chain for rare earth minerals faces challenges such as geopolitical tensions, environmental concerns, and limited recycling capabilities. These issues, coupled with China's strategic focus on retaining resources for domestic industries, underscore the urgent need for diversified sourcing and the development of resilient supply chains to ensure long-term availability.

Critical Metals and Critical Choices: Between Demand, Dependency and Sustainability

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Abstract

The global race for technological leadership amid intensifying geopolitical competition and structural shifts in the world economy is paralleled by accelerating industrialization in developing countries, large-scale implementation of low-carbon technologies, and rapid digital transformation. In this environment, the sustainable and secure supply of critical metals and their derivatives is essential for maintaining national security and technological independence across strategic domains such as defence, nuclear energy, aerospace, renewable energy, electromobility, photonics, electronics, and robotics. The continued rise in rare metal consumption is accompanied by long-term systemic risks making the sustainability of this trajectory vulnerable. Foremost are the environmental issues related to intensive rare metal mining and processing, which entail massive land disruption, heavy chemical use, and hazardous waste generation. All these factors degrade ecosystems and pose serious health risks to nearby communities. In parallel, rare metal supply chains remain mostly concentrated in just a few countries, creating geopolitical vulnerabilities and supply insecurity. The prevailing linear “take-make-dispose” consumption model for critical metals is inherently unsustainable given finite resources and surging demand (projected to require several-fold higher output by 2040), while scaling up circular economy solutions is still difficult due to persistent technological and (mostly) economic barriers.

To mitigate risks associated with import dependency, countries such as Russia and India have adopted comprehensive strategies aimed at stimulating domestic value chains for critical materials. We believe that these strategies increasingly incorporate not only the development of primary mineral resources but also the active utilization of secondary raw materials. These include industrial by-products and wastes such as electronic scrap, spent lithium-ion batteries, Nd-Fe-B grinding sludge, red mud from alumina production, leachates containing uranium, rare earth and refractory metals, fly ash, slags, and spent oil refining catalysts, etc. As the transition to low-carbon energy systems accelerates, the volume of such secondary resource streams is expected to grow substantially. The development and industrial adoption of efficient, selective, and environmentally sound recycling technologies is therefore a technological priority. Current methods, while promising, often suffer from insufficient scalability, low recovery efficiency, or poor economic performance. This highlights the need for intensified R&D efforts focused on advanced hydrometallurgical processes, low-temperature chemical separations, direct recovery of functional

hydrometallurgical processes, low-temperature chemical separations, direct recovery of functional materials, and integrated modular recycling platforms.

This talk will outline most significant risks and challenges that we face while relaying on permanently rising consumption of rare metals in many technological areas. Several technological developments at GIREDMET that address these challenges will be outlined, including methods for mineral enrichment and selective chemical processing, production of high-purity critical metals and compounds, as well as innovative recycling routes for complex industrial residues. Emphasis will be placed on technological solutions that enable the recovery of critical elements from secondary sources while minimizing environmental impact and contributing to the sustainability of future supply chains.

Keywords: critical metals, circular economy, secondary raw materials, recycling technologies, sustainable development.

Strengthening Initiatives for a Robust Rare Earth Industry Ecosystem in India: Significance and Way Forward

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Abstract

A detailed analysis conducted by the National Institute of Advanced Studies (NIAS), Bengaluru in 2020-21, focusing on seven green energy product value chains of commercial interest (six NdFeB magnet-based value chains and one cerium oxide-based value chain), estimated that the cumulative demand for Neodymium, Dysprosium, and Praseodymium (magnet-grade powder) is about 75,510 tonnes for the period 2021-30. This RE demand translates to a total magnet requirement (NdFeB) of about 2,36,596 tonnes for the ten years. Additionally, the conservative estimate for Cerium Oxide demand for automotive catalytic converters turns out to be 11,922 tonnes. Considering the continuously growing aspirational growth trajectories, the total RE demand for the decade 2021-30 was estimated at 87,432 tonnes. This necessitates a significant expansion of the resource base.

In India, monazite is the principal source of rare earths and thorium (Th), and IREL (India) Limited is the nodal agency actively engaged in mining and processing Beach Sand Minerals (BSM) from placer deposits. It is noteworthy that India's ores are lean sources (grade ~ 0.06%), and those are mostly radioactive. The low concentration of RE in Indian ore and the radioactivity associated with it render the ore processing long, complex, and expensive. Also, the beach sand mining (even surface scraping) is constrained by the Coastal Regulation Zone (CRZ) rules, and the presence of fragile ecosystems (e.g., mangroves), forests, and community inhabitation. Therefore, continuous and progressive exploration of inland reserves is important.

Extractable quantities of high-value REEs, dysprosium (Dy) and terbium (Tb), are not available in India. Therefore, the acquisition of foreign reserves would be a crucial step toward ensuring the uninterrupted availability of raw material inputs for building a resilient RE Industrial ecosystem, largely around the RE permanent magnets.

The reports published by the IEA and other international organizations have highlighted that the supply shortage of critical minerals is expected in the coming decades, since their natural deposits are geographically concentrated in a few locations. For example, the deposits for the rare earth materials used in the manufacture of permanent magnets are predominantly located in countries like China, the United States, and Myanmar, with the share in rare earth oxide-equivalent (REO)

production being 60.63%, 15.52%, and 9.38%, respectively. India came in seventh position with a 1.05% share in the REO production in 2021. However, China plays a much significant role when it comes to NdFeB permanent magnet manufacturing, contributing to more than 80% of the magnet value chain. The supply chains are going to face bottlenecks and possible disruptions owing to the volatile geopolitical environment in some of the critical and nodal countries and regions.

Therefore, it is important to render resilience to the global rare earth supply chain network by augmenting an alternate supply source, primarily through the end-of-life (EoL) product recycling. Establishing a comprehensive manufacturing ecosystem capable of sourcing raw materials uninterruptedly would help manufacture the finished products at globally competitive prices. This could unveil India's potential to build a well-planned white goods production ecosystem while creating strategic capability through partnerships and building capacity by generating large-scale job opportunities.

The sensitivity analysis carried out by NIAS on material recovery, considering two predominant magnet recycling techniques and the associated recovery rates, shows that in the case of a 100% collection scenario for end-of-life (EoL) room air conditioners, about 12% of the annual magnet demand for the fresh sectoral manufacture could be met through recycling by 2030, which can even grow to 25% in the coming decade.

Another assessment by NIAS on the sustainable strategy around energy-efficient laundry washing machines discusses a multi-pronged approach encompassing the recovery of end-of-life LWMs, critical components, and materials; refurbishing discarded products for possible life extension; and recycling for material recovery and reuse in fresh manufacturing. The magnets recovered from the motors of discarded LWMs can either be used to make smaller NdFeB magnets for different applications that require miniaturized energy-efficient ones, or the RE materials (Nd, Pr, Dy) can be recycled to manufacture fresh magnets.

Such case studies emphasize the need for strategy-focused and demand-driven bottom-up assessments to firm up the national requirements so that a holistic national plan can be formulated around the core philosophy of resource adequacy and resource security.

Global Rare Earth Market Outlook

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Topics covered

Price updates

Fundamentals

US-China conflicts

Development of a supply chain outside of China

From Waste to Wealth: Approaches for Recovery of Critical Minerals associated with Atomic Minerals

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Abstract

India's twin pursuits of energy security and strategic self-sufficiency are highlighted by its commitment to the recently launched Nuclear Energy Mission and the National Critical Mineral Mission, 2025. A robust supply chain for critical minerals becomes indispensable as the country advances toward its climate goals of Net-Zero emission by 2070 and 50% of its energy requirements from renewable energy by 2030.

Atomic Minerals Directorate for Exploration and Research (AMD), the oldest unit of Department of Atomic Energy (DAE), is uniquely positioned to support both missions. AMD has delineated uranium and thorium bearing provinces that are geochemically enriched with associated critical elements like Rare Earth Elements (REE), yttrium, zirconium, niobium, copper, vanadium, cobalt and molybdenum. These critical minerals are associated with uranium, REE and Beach Sand Minerals (BSM) deposits established by AMD and possess strategic value for both clean energy systems and nuclear reactor technologies.

The growing imperative to secure a sustainable and self-reliant supply chain for critical minerals has renewed the national focus on the strategic re-evaluation of secondary mineral resources which have traditionally been considered industrial waste. During mining operations, critical elements are frequently unrecovered and accumulate in tailings. With the advent of advanced extraction technologies, India holds significant potential to recover these elements from existing mill tailings, which require no additional mining or comminution costs.

The recovery of critical minerals from secondary resources not only mitigates the risks associated with raw material import dependency but also enhances the sustainability of India's mineral economy. It is essential to transform India's vast mineral "waste" into strategic wealth and promote environmentally sustainable mining practice with Net Zero discharge to realize the vision of critical mineral self-reliance.

The UK-India Critical Minerals Supply Chain Observatory: A Collaborative Framework for Enhanced Energy Security and Resilient Supply Chains

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Abstract

As the world moves to cleaner energy and uses more high-tech devices, there is a strain on the supply of rare earths and other essential minerals. To face this common challenge, the United Kingdom and India have launched a special partnership: the UK-India Critical Minerals Supply Chain Observatory. This project aims to build a resilient and sustainable supply chain for these vital materials, which directly helps secure the long-term energy needs and high-tech industry growth of both countries.

This presentation will provide an overview of the Observatory's structure, goals, and current work. It will highlight the teamwork between top universities, government groups, and business partners in the UK and India who are creating a powerful data system and advanced analytics to enhance the viability, traceability, and transparency of the flow of minerals. The talk will explore new methods being used, like artificial intelligence and satellite imagery, which make the supply chain more open and help prevent shortages.

Furthermore, this talk will look at why international teamwork is essential for dealing with the complex geopolitics surrounding critical minerals. It will show how the UK-India partnership is a great model for cooperation between two nations, supporting shared learning and joint research in key areas. By sharing knowledge and successful methods, the Observatory hopes to open up new avenues for investment, new ideas, and the responsible growth of mineral supplies, making all of us more energy-secure in this time of fast-changing technology.

Building a Non-China Rare earth Supply Chain: A Global Perspective

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Abstract

The presentation explores how countries and industries worldwide are working to reduce reliance on China for critical rare earth materials essential in clean energy, electronics, and defense. It examines new mining projects, advanced processing technologies, recycling initiatives, and international collaborations aimed at securing sustainable and diversified rare earth supply chains. The discussion highlights economic, geopolitical, and environmental challenges, as well as emerging opportunities for nations to establish resilient and competitive alternatives in the global market.

Introduction to Evolution Metals & Technology's Future Strategy for Establishing an Alternative Rare Earth Value Chain

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Abstract

(1) Evolution Metals & Technology (EMAT) is a NASDAQ listed company having 6 existing entities in the USA and Republic of Korea in the battery recycling field, E-scrap recycling as well as in RE magnet manufacturing spaces.

(2) Brief introduction to each of EMAT entity's business activities.

(3) EMAT's future business strategy at identifying and collaborating with potential partners globally, and in India.

Trends in Automotive Electrification and Critical Resources

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Abstract

This presentation will provide a comprehensive overview of Toyota Tsusho Corporation, emphasizing its significant role within the resource sector.

The speaker will outline the strategic initiatives undertaken by the company to secure and manage critical resources that are essential for the automotive industry.

Additionally, the presentation will address the current status of automotive electrification.

As the automotive industry transitions towards electric vehicles (EVs), there has been a substantial increase in the demand for critical resources such as lithium, nickel, and rare earth elements.

The speaker will also explore the trends within the supply chain for these vital resources.

By examining these dynamics, participants will gain valuable insights into the complexities associated with supporting electrification and the critical importance of responsible resource management.

Establishing a Sintered Neodymium Iron Boron Magnet Facility in India

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Abstract

High strength, high energy product and excellent resistance to demagnetization have resulted in neodymium iron boron magnets becoming widely used in a variety of technologies. Virtually all market analysts predict significant growth in key applications such as robotics, transport and wind turbines. However, geopolitical factors, in particular the dominance of China in the supply chain, have resulted in a huge market imbalance and strategic vulnerability for global magnet users.

This paper discusses the key technologies required to manufacture sintered neodymium iron boron magnets, and how these technologies are impacted by geopolitical factors. The relevance to India is discussed and consideration is given as to how India may develop a domestic magnet manufacturing industry to support the growing domestic market.

Working with highly experienced international experts, Trafalgar Rare Earth Alloys Pvt. Ltd. Is working to establish a vertically integrated facility to produce neodymium iron boron sintered magnets in India, both to serve the domestic market and for export. The challenges for such a venture will be described, together with the approach taken to overcome these challenges.

Advances in High-Temperature NdFeB Magnet Manufacturing for Electric Vehicles

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Abstract

The growing demand for high-performance electric vehicles (EVs) necessitates the development of permanent magnets capable of operating efficiently at elevated temperatures while maintaining high energy density and corrosion resistance. NdFeB magnets are critical components in EV traction motors, but their performance degrades at temperatures above 150°C due to thermal demagnetization.

This talk explores innovative manufacturing techniques—such as grain boundary diffusion (GBD) with heavy rare-earth elements (HREEs), dual-alloy sintering, and nanostructuring—that enhance the thermal stability of NdFeB magnets without sacrificing coercivity or remanence.

Key topics include:

- **Material Design:** Optimizing composition (e.g., Dy, Tb doping) and microstructure to improve high-temperature performance.
- **Process Innovations:** Scalable methods like New Press less Process (NPLP), spark plasma sintering (SPS) and additive manufacturing for near-net-shape magnet production.
- **Sustainability:** Reducing reliance on critical rare-earth materials through recycling and lean-HREE solutions.
- **Applications:** Case studies on high-temperature NdFeB magnets in next-gen EV motors, demonstrating efficiency gains under real-world operating conditions.

This presentation will highlight recent breakthroughs and future directions in magnet manufacturing, addressing both technical challenges and economic viability for mass adoption in the automotive industry.

Glimpses of
REES Series

Glimpses of REES 2021

Glimpses of REES 2023

Glimpses of REES 2024

SPEAKER ABSTRACTS

CSIR-CECRI at the Helm of Indigenous Electrometallurgical Processes for Rare Earths & Critical Metals

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Abstract

The increasing demands for rare earth and critical metals in energy and other sectors, and supply-chain issues related to geopolitical situations necessitate the indigenization of processing in making the country self-reliant and self-sustained. CSIR-CECRI, known for its vast experience in electrochemical technologies, has been developing indigenous processes to secure critical metal supply chains in alignment with the national missions and goals of Atmanirbhar Bharat and Viksit Bharat @ 2047. CSIR-CECRI has developed several Molten Salt Electrowinning protocols for the rare earth metals such as La, Ce, and Nd, alloys (NdPr, NdFe, NdPrFe), and hexaborides, REB6 (La, Sm, Nd, Ce) using primary and secondary resources. CSIR-CECRI is currently augmenting its capabilities in molten salt electrowinning of rare earths for scale-up production and modernization required for commercial translation of technologies to interested stakeholders. CSIR-CECRI has developed a comprehensive approach for the extraction of metal values from spent lithium-ion batteries (LIBs), with a focus on efficient recovery of critical metals including lithium, cobalt, nickel, and manganese in the form of salts and metals. Additionally, a tailored hydrometallurgical process is explored for the selective extraction of gallium (from Bayer liquor) and magnesium (from primary and secondary sources), enabling resource recovery from secondary sources and supporting circular economy objectives in critical mineral supply chains. The perspective of CSIR-CECRI's capabilities in this niche area will be presented.

NdFeB – Magnetrecycling: Market Potential & Technologies

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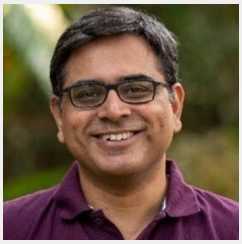
Abstract

The global market for rare earth magnet recycling is poised for substantial growth, driven by the accelerating demand for electric vehicles (EVs), renewable energy systems, and advanced electronics. Rare earth magnets—primarily neodymium-iron-boron (NdFeB) and samarium-cobalt (SmCo)—are critical components in these sectors. The recycling efficency of rare earth magnets is estimated to be below 1%. Innovations in collection, separation and refining technologies are the enablers for higher recovery rates.

A core strategic objective is to deliver a one-stop solution for the sustainable and transparent recovery of critical raw materials from electric vehicle (EV) drivetrains. The presentation details the recycling potential of various material streams—pre-consumer (magnet manufacturing scrap), post-consumer (wind turbine magnets, hard drive disks, and electric motors)—highlighting their characteristics, legal classifications, available volumes, and estimated REE recycling rates. Pre-consumer waste offers the highest recycling rates (>95%), while post-consumer streams present greater challenges due to lower volumes, complexity, and contamination.

Technologically, hydrometallurgical recycling—specifically solvent extraction—remains the dominant process, enabling efficient recovery and purification of rare earth elements with compensation on output quality comparable to primary materials. However, the sector is witnessing innovation in direct magnet-to-magnet recycling, reverse logistics, and automated separation techniques. These advancements are essential for improving the economic and environmental performance of recycling, especially as scrap volumes from end-of-life products are projected to rise sharply in the next decade. Overall, rare earth magnet recycling represents a dynamic market with increasing technological diversity and strategic importance for sustainable supply chains that can support supply chain resilience for the Indian economy.

Building Circularity in Rare-Earth Magnets: Lohum's Roadmap and Key Levers



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Abstract

Lohum is India's largest sustainable refiner of critical minerals, with a proven track record in battery material recycling and refining for lithium, cobalt, and other key elements. Building on this expertise, we are now expanding into rare-earth processing and permanent magnet manufacturing to help establish a domestic, resilient supply chain for these strategic materials.

This talk shares our learnings from large-scale material processing, building collection networks, and working alongside government initiatives that have enabled circularity in adjacent sectors. We outline Lohum's vision for rare-earth refining and magnet production in India, and the key levers—standards, traceability, targeted policy support, and financing mechanisms—needed to scale rare-earth magnet circularity and reduce long-term import dependence.

Building India's Rare Earth Future: The Role of the Rare Earth & Titanium Theme Park

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Abstract

The significance of rare earth elements in nation-building needs no introduction. As one of the world's fastest-growing economies, India cannot afford to fall behind in this critical sector. With ambitious targets in electronics manufacturing, electric mobility, and clean energy, the country may face serious challenges unless domestic production of rare earth-based products is urgently initiated and scaled.

IREL (India) Ltd, operating under the aegis of the Department of Atomic Energy (DAE) for over eight decades, has been at the forefront of exploring and processing the country's primary rare earth mineral resources. The company has consistently produced rare earth oxides, carbonates, and oxalates that are vital for a range of strategic and industrial applications.

However, India has lagged in the value addition of rare earths, particularly in the production of metals, alloys, and finished products, primarily due to the absence of indigenous technologies for mass-scale manufacturing. This gap has been exacerbated by China's strategic policy dominance and the global availability of these materials at highly competitive prices.

To address this challenge and promote self-reliance, the visionary leadership of the DAE conceptualized the establishment of a dedicated "theme park" where BARC-developed laboratory-scale technologies could be demonstrated and scaled up to bench scale. The objective is not only to build a trained and skilled workforce in cutting-edge rare earth technologies but also to nurture entrepreneurship for industrial production based on these indigenously developed processes. In line with this vision, the Rare Earth and Titanium Theme Park (RETTP) has been established in Bhopal.

This talk will highlight the technologies already in place, explore emerging advancements, and discuss the challenges and opportunities ahead, laying out a strategic roadmap for India's growth in this vital sector.

Recovery of Critical Minerals from Mine Tailings & Overburden

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Abstract

Critical minerals are essential for economic development and national security, have a key role in driving growth of sunrise sectors during the Amrit Kaal journey to help build a Viksit Bharat by 2047

Some of the key sectors to drive growth through Amrit Kaal journey.

Mine tailings, OB & waste have untapped critical minerals potential of significant economic value.

Some of the key themes to address challenges & unlock the potential of critical mineral recovery- Challenges & Themes

Strategies to establish a sustainable critical mineral recovery ecosystem such as Policies and incentives, Extraction and processing technologies, Supply chain development and integration & Capacity building.

Unlocking Hidden Resources: Recovery of Rare Earth Elements from Coal Fly Ash for Sustainable Technological Advancement

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Abstract

Rare earth elements (REEs) are indispensable to a wide range of modern technologies, from smartphones, electric vehicles, and wind turbines to advanced defense systems and high-performance electronics. However, the global supply of REEs is limited and geopolitically concentrated, posing significant risks to resource security and sustainability. In this context, coal fly ash (CFA) —an abundant by-product of thermal power plants contains trace amounts of these critical elements and has emerged as a promising secondary source of REEs. This talk will present recent advancements in the recovery of REEs from CFA, focusing on both the scientific challenges and the technological innovations that are driving progress in this field. The talk will discuss the chemistry behind REE occurrence in ash, efficient leaching strategies, selective separation techniques, and environmentally benign recovery processes. Emphasis will be placed on sustainable processes development that minimize environmental impact and support circular economy goals. By recovering valuable REEs from what is conventionally regarded as industrial waste, this approach not only contributes to reducing environmental burdens associated with CFA disposal but also supports the diversification and sustainability of REE supply chains. This talk aims to highlight how the intersection of waste management and resource recovery can pave the way for more resilient and sustainable technological infrastructure.

Processing of Primary and Secondary Resources to recover Critical Metals at CSIR-NML, India

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Abstract

The increasing over-all demand of Critical Metals (CMs) in various application, depletion of natural reserves, and associated supply risks resulting from geopolitical, environmental, or technological factors compels the researchers to make fruitful R&D efforts for the development of feasible technology to recover CMs from different primary and secondary resources. Sincere R & D efforts has been made at CSIR-NML, India, to explore possibility for the processing of various resources to recover CMs using physical beneficiation/ pyro-/ hydro-/ hybrid processes to selectively separate and recover CMs as value added product. Present paper is focused on the status, prospects and CSIR-NML's contribution in recovery of CMs from different resources. Technological Know-how's were developed to process primary (Korean monazite/ beach sand) and secondary resources (permanent magnets, fluorescent tubes, EV batteries, etc.). The developed processes require less energy to deliver high purity product, which is one-step towards green environment. Therefore, the established processes are indigenous, energy-saving and comply with stringent environmental regulations.

Keywords: Critical Metals; Primary Resources; Secondary Resources; Hydrometallurgy; Sustainable Development

Role of critical minerals & REE towards ESG goals

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Abstract

India has committed to achieving net-zero carbon emissions by 2070. Meeting this goal requires deep decarbonization across key sectors — energy, transport, and industry — all of which depend heavily on critical minerals and rare earth elements (REEs) since they enable green technologies like Li-ion batteries, REPM-based motors that are used in EVs, wind turbines, and Green hydrogen electrolysers & fuel cells, etc

•Demand for batteries for EVs and storage is expected to quadruple from 1,100 GWh to 4,500 GWh by 2030. This will also push the demand for Lithium, cobalt, nickel, and graphite between 2x & 9X, which are indispensable for these.

•Demand for Rare earths like neodymium, praseodymium, and dysprosium, which are vital for permanent magnets used in high-efficiency motors and wind turbine generators, is also expected to double by 2030

•Green hydrogen technologies rely on platinum group metals, such as platinum and iridium, for electrolyzers. By 2050, H2 production is expected to increase 6x to 500-550 MTPA.

• Even solar PV modules require minerals such as silicon, tellurium, and indium.

Without these raw materials, the clean energy transition would stall, making the availability of these minerals a key environmental challenge. India faces several constraints in procuring these critical minerals.

Even though India holds large rare earth reserves of 6-7 million tonnes, it lacks midstream capabilities like refining, separation, and processing that produce the bulk of the value addition. This area is dominantly held by China, which undertakes 90% of the global REE processing.

However, China has highly restricted the export of these minerals and REEs, with volumes falling by 80%, which has affected various sectors including electronics, green energy & renewables, automotive, aerospace, etc.

As ESG disclosures become more mainstream and institutionalized, a key question arises - are companies only disclosing ESG data to comply, or are they using it to drive meaningful operational change? This paper explores how ESG ratings and disclosure frameworks such as CDP, EcoVadis, and India's BRSR influence corporate transformation in the context of Industry 5.0. While Industry 4.0 emphasized automation and digitalization, Industry 5.0 emphasizes human-centricity, resilience, and sustainability. ESG frameworks are beginning to shape how companies integrate environmental and social concerns into decision-making, design future-ready operations, and communicate stakeholder value. However, ratings often reward disclosure maturity more than action. This paper proposes a practical model to map ESG maturity to Industry 5.0 readiness. Using data from FY 2023 - 24 sustainability reports of three Indian companies (Mahindra & Mahindra, Tata Steel, and Hindustan Zinc Ltd.), we evaluate real-world practices that go beyond compliance. The paper concludes with actionable insights on how ESG can become a lever for transformation, not just a metric for evaluation.

Keywords
ESG ratings; CDP; EcoVadis; BRSR; Industry 5.0; ESG maturity; sustainability reporting; corporate transformation.

TECHNICAL ABSTRACTS

Mixed Hydroxide Fusion: Key to Refractory Sample Decomposition and Silica Separation for Rare Earth Elements Determination in Peralkaline Granites of Siwana Ring Complex, Rajasthan

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Abstract

Peralkaline granites of Siwana Ring Complex (SRC) host more than 1 lakh tonne of Rare Earth Elements (REE). The REE minerals present in peralkaline granites are monazite, xenotime, eudialyte, zircon, gittinsite, allanite, which are all refractory. Their complete dissolution is crucial for accurate analysis of REE. But they resist HF-HNO3 acid treatment and require additional step of fusion of residue with flux like Na2O2. This multistep sequence is tedious, prone to analyte loss, and is high chemical and power consuming. A single step fusion of SRC samples using fluxes like Na2O2 and mixed phosphate (Na2HPO4+ NaH2PO4) results in hydrolysis of Silica (Si) and Zirconium (Zr), and solution instability issues due to the high amount of Si in these samples (SiO2: 60-70 %), leading to inaccurate analysis of REE.

Therefore, the objective was to develop an accurate, quicker, user friendly and cost-effective method for decomposing refractory REE minerals and simultaneous Si separation, thus allowing routine analysis of a large number of samples to support the exploration program.

Burner fusion of SRC samples was attempted with mixed hydroxide flux (NaOH+KOH) in nickel crucible, which produced REE bearing precipitates and water soluble silicates on dissolution of the fused mass in distilled water. Addition of KOH is crucial as it is reported to have slightly better decomposition effect on the refractory zircon. Optimum conditions for maximum recoveries of REE, maximum separation of Si and sufficient solution st ability were found to be - NaOH and KOH mixed in ratio 3:1, sample to flux ratio 1:7, 6 hours of contact time of fused mass with distilled water and 10% HCl concentration in final solution. REE and Si in respective acidic solutions, having dilution factors 1000 and 125000 respectively, were analysed with ICP-OES at interference free wavelengths using matrix matched calibration standards. More than 98.9±1.2% recoveries were obtained for REE and more than 87.3±2.1% Si separation was achieved. The tolerance limit of Si on REE analysis was studied and found to be 1000 ppm.

Results obtained for Certified Reference Material ‘REE-1’ (CCRMP) and ten pre-analysed SRC samples using developed method were in close agreement with the certified and reported values, confirming the reliability and repeatability of the method. Relative Standard Deviation values were found to be less than 5% and 2% for REEs and Si respectively. Limit of Quantification for the

developed method was 5 ppm for La, Ce, Pr, Nd, Sm, Gd; 2 ppm for Tb, Dy, Ho, Er, Tm, Yb, Sc, Y and 1 ppm for Eu and Lu.

The developed method is quicker and saves 18-20 hours over conventional method of decomposing SRC samples i.e. HF-HNO3 treatment followed by ashing and fusion of residue. Moreover, for accurate analysis of REE, this method uses mixed hydroxide flux as a single reagent for decomposition of refractory minerals in the sample and Si separation, instead of using a number of toxic and oxidising chemicals, and avoids costly platinum ware and sophisticated furnaces.

Keywords: Siwana Ring Complex, refractory, mixed hydroxide flux, REE, ICP-OES

Integrating Industry 5.0 into ESG Disclosure

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Abstract

As ESG disclosures become more mainstream and institutionalized, a key question arises - are companies only disclosing ESG data to comply, or are they using it to drive meaningful operational change? This paper explores how ESG ratings and disclosure frameworks such as CDP, EcoVadis, and India's BRSR influence corporate transformation in the context of Industry 5.0. While Industry 4.0 emphasized automation and digitalization, Industry 5.0 emphasizes human-centricity, resilience, and sustainability. ESG frameworks are beginning to shape how companies integrate environmental and social concerns into decision-making, design future-ready operations, and communicate stakeholder value. However, ratings often reward disclosure maturity more than action. This paper proposes a practical model to map ESG maturity to Industry 5.0 readiness. Using data from FY 2023 - 24 sustainability reports of three Indian companies (Mahindra & Mahindra, Tata Steel, and Hindustan Zinc Ltd.), we evaluate real-world practices that go beyond compliance. The paper concludes with actionable insights on how ESG can become a lever for transformation, not just a metric for evaluation.

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