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Rare Earth Elements in High Demand (2025–2035)

Rare earth elements (REEs) – the 15 lanthanides plus Y and Sc – are critical to both green-energy and high-tech industries. In the **green transition**, strong permanent magnets (Nd, Pr, Dy, Tb, Sm) drive electric vehicles (EVs) and wind turbines, while battery technologies (NiMH) and catalysts (Ce, La) play supporting roles. In the **AI/digital revolution**, REEs are used in semiconductors, LEDs and lasers (e.g. Eu, Tb, Y, Er, Yb, Tm) and sensors. For example, high-performance chips often rely on GaN/InP doped with Eu/Y and memory components doped with Gd/La/Lu. Permanent magnets (Nd/Pr/Dy/Tb) also power precision actuators and memory drives in robotics and data centers. Table 1 below compares priority REEs by their uses, demand growth outlook, deposit types, and key producers. In summary, **neodymium (Nd) and praseodymium (Pr)** – the "magnet REEs" – along with **dysprosium (Dy)** and **terbium (Tb)** (for high-temperature magnet alloys) are expected to see the steepest demand growth. Other important REEs include **samarium (Sm)** (SmCo magnets) and certain heavy REEs (Y, Eu) used in electronics. Light REEs **lanthanum (La)** and **cerium (Ce)** have large current uses (batteries, catalysts), but slower growth.

Figure. *Global REE reserves are highly concentrated. China holds ~44 Mt (million tonnes) of known REE reserves (nearly half of the world's total), with Brazil, India, Russia and Vietnam also large holders* [1] [2]*. Europe's reserves are much smaller (e.g. Greenland ~1.5 Mt, USA ~1.9 Mt)* [3]*. (Map source: USGS data in [48].)*

Demand Forecasts (2025–2035)

Global demand for magnet-critical REEs is projected to surge in the next decade. For example, McKinsey (2025) projects that **"magnetic REE" demand (Nd, Pr, Dy, Tb)** will rise from ~59 kt in 2022 to ~176 kt by 2035 – roughly a **3× increase**. Similarly, Adamas Intelligence forecasts NdFeB-magnet REE consumption will roughly **triple by 2035**, driven by EV and wind turbine growth. These figures imply a compound annual growth rate (CAGR) on the order of 8–9% for magnet REEs through 2035. The IEA also projects total Nd/Pr/Dy/Tb demand growing from ~78 kt (2021) to ~123 kt by 2030. In contrast, demand for Ce and La is growing more slowly, as advanced battery chemistries (Li-ion) and stationary storage dominate over NiMH batteries. High-tech uses (AI chips, telecom) consume modest absolute quantities: REEs in semiconductors are only ~5–10% of total REE demand.

In numerical terms, forecast growth of key REEs is roughly: Nd/Pr demand ~3× by 2035 (CAGR ~8–9%), Dy/Tb demand ~3×, whereas Ce/La demand grows <2× (depending on NiMH/auto catalyst needs). In absolute terms, wind/EV magnets will drive tens of kilotons of additional Nd/Pr/Dy/Tb demand per year. For example, Adamas predicts global Nd/Pr oxide *shortfalls* reaching 16–68 kt/year by 2030–2035, underscoring the large volume growth. By contrast, recycling and substitution efforts may partly offset growth: spent magnet recycling (mainly Nd/Pr from end-of-life motors) is a key emerging secondary supply.

Supply Constraints and Risks

Supply of critical REEs is highly concentrated and fragile. **China** dominates the industry: it accounted for ~70% of global REE mine production and ~90% of processing/refining in recent years [4]. In 2023 China produced roughly 241,000 t of rare-earth oxides (about 40% of known reserves). IEA analysis shows the top three mining countries control ~80% of supply (and top three refiners ~90%). Outside China, few large operations exist: e.g. the USA's Mountain Pass (MP Materials), Australia's Mount Weld (Lynas), and newer producers in Myanmar and Malaysia (Lynas). Many other projects remain early-stage.

Key risks include **geopolitical concentration** and **processing bottlenecks**. China's 2023 export controls on certain REEs and processing equipment highlight this vulnerability. Other countries have limited downstream capacity: for instance, the US currently re-exports most of its mining output for processing in Asia [5]. Geologically, heavy REEs (Dy, Tb, Y, Eu) are scarcer and typically only exploited in China so far (ion-adsorption clays in southern China). Environmental issues also constrain supply: REE mining generates radioactive and chemical waste, leading to community opposition (e.g. formerly in California and Malaysia).

In short, magnet-critical REEs (Nd, Pr, Dy, Tb, Sm) face significant supply risk if demand outpaces new mine/refinery projects. By contrast, Ce and La are abundant and often oversupplied, so they pose fewer short-term risks (indeed Adamas notes surpluses of Ce/La vs shortages of NdPr). **Stakeholder** response includes massive investment in new mines/refineries (US Defense/National Labs, EU industrial policy, private juniors) and stockpiling by automakers and governments.

Recycling and Substitution

Given supply concerns, recycling and material substitution are critical. Currently **magnet recycling** is minimal (<1–2%), but has huge potential: spent NdFeB magnets (from hard drives, motors) are the single largest conceivable secondary source of Nd and Pr. Research is underway in hydrometallurgical and direct recycling processes. Other secondary sources (phosphors, catalysts) yield mainly low-value REEs (Ce/La) and are less economically attractive.

On substitution, **"gap" magnets** aim to reduce or replace critical REEs. For example, DOE and industrial R&D explore using more-abundant La and Ce in NdFeB alloys, yielding "low-Nd" variants. Grain-boundary diffusion (GBD) techniques allow reducing Dy/Tb content in NdFeB magnets by diffusion of heavy REEs only at boundaries. Some EV motors are being redesigned to use ferrite or switched reluctance motors (no RE magnets), though at efficiency cost. In consumer electronics and lighting, LED and OLED tech reduce reliance on Eu/Tb phosphors. Emerging permanent magnet chemistries (e.g. Fe–N or Sm–Fe–N) are also being researched.

However, substitution is hard: no material fully matches NdFeB's performance [6]. As the DOE notes, most REE uses have no "ready substitutes" today; thus recycling and diversified mining remain primary mitigations [6].

Geological Settings and Deposit Types

REEs occur in diverse geological environments. The majority of commercial REE resources are in only a few deposit types: (1) **Carbonatites and alkaline igneous intrusions**, which host LREE-rich minerals like bastnäsite ((Ce,La)CO_3F) and monazite ((Ce,La)PO_4); (2) **Heavy mineral placers**, where monazite and xenotime concentrate in beach or river sands; (3) **Ion-adsorption clays**, formed by weathering of granitic bedrock (notably in southern China/SE Asia) that adsorb HREEs (Dy, Tb, Y, etc). Other sources include some **pegmatites** and co-products (e.g. red mud, coal ash) under investigation.

For example, **carbonatite deposits** (e.g. Mountain Pass, USA; Araxá, Brazil; Kola Peninsula, Russia) are rich in LREEs (Ce, La, Nd, Pr). Bastnäsite is common there. **Ion-adsorption deposits** (unique to subtropical weathering) in Southern China and Southeast Asia yield mostly heavy REEs (Dy, Tb, Y) with minimal radioactivity. **Rare-earth-bearing sands** are found in coastal zones (e.g. mineral sands in India and Australia). In all these, **Nd and Pr** accompany La and Ce in LREE deposits, whereas **Dy and Tb** are enriched in HREE deposits or tailings of LREE mines.

Table 1 (above) and Figure 1 summarize these relations. (For instance, Nd/Pr are "light" REEs commonly mined from carbonatites and placers, while Dy/Tb/Y are "heavy" and often require ion-adsorption clays or specialized granites.)

Key Producing Countries

China is by far the dominant producer of nearly all REEs [1] [4]. In 2024 it mined ~270 kt of rare-earth oxides (~70% of global output) [1]. Other current producers include the USA (Mountain Pass; ~15 kt in 2023), Australia (Mount Weld), Myanmar (ionic clays), Malaysia (Lynas plant processing Malaysian ore), and smaller outputs from India, Russia, Vietnam, and Brazil. The USGS reports that no other country contributes more than ~10% of global REE production each (the "top 3" yield ~80%).

Reserves (geologic resources) also concentrate in a few countries. After China (~44 Mt REO) [1], the largest reserves are in Brazil, India, Russia and Vietnam [2]. The US (~1.9 Mt) and Greenland (~1.5 Mt) have comparatively modest reserves [7]. These figures drive current exploration focus: e.g. African countries (Burundi, Malawi, South Africa) and Greenland have become targets for HREE and LREE projects. In Europe, Sweden's LKAB in 2023 announced discovery of **>1 Mt of REO** in Kiruna (Scandinavia's largest REE resource) [8], highlighting newfound continental potential.

Notably, heavy REE sources are extremely limited outside China. For example, Malaysia (former Malaysian clay mines) was a major non-Chinese HREE source until shutdowns. Vietnam has recently developed ion-ads projects. North American output is almost exclusively LREE from Mountain Pass; Canadian projects (e.g. Nechalacho, NWT) remain in early stages. Thus exploration is ramping globally to diversify sources.

Future Exploration Interests and Stakeholders

Looking ahead, the **REEs most likely to drive new exploration** are those under most pressure: neodymium/praseodymium and the heavy magnet elements dysprosium and terbium. These elements command the highest prices and face projected shortages, so projects promising high Nd/Pr or heavy-REE grades will attract attention. Underexplored **frontiers** include:

- **Africa and Madagascar**, where ion-adsorption clays and carbonatites (e.g. Malawi, Burundi, South Africa) host heavy REEs.
- **Greenland and Arctic regions**, with peralkaline and carbonatite systems (e.g. Greenland's Kvanefjeld, Sweden's Kiruna) now recognized.
- **North America and Northern Europe**, where new discoveries (e.g. Stockholm region, Norway pegmatites) may emerge.

Subordinate REEs (Ce, La, Sm, Y, Eu) will get less exploration attention unless they are co-recovered in multi-REE projects. For example, Snrboth U.S. and Europe pursue “deep-green” projects focusing on magnet-REEs; La/Ce and Eu/Y typically appear as byproducts.

The **stakeholders** driving exploration and development include:

- **Governments** (e.g. US, EU, Japan, China) – concerned with supply security, these fund surveys and offer incentives (grants, loans, offtake deals). The US DoD and DOE have invested in REE projects and refining infrastructure; the EU’s Critical Raw Materials Act mandates domestic supply.
- **Junior miners and explorers** – many small companies (e.g. USA Rare Earths, Hexagon Resources, Pensana) are financed to stake claims in Africa, North America and Europe, targeting high-grade REE prospects.
- **Strategic investors and end-users** – automakers, tech firms and financial funds are increasingly investing. For example, electric vehicle and renewable energy OEMs have sought equity in REE miners to secure supply. Defense contractors (e.g. aerospace firms) also partner on HREE projects for military applications.
- **Local authorities and communities** – In many countries, national or regional governments (e.g. in Canada, Australia, Scandinavia) play a key role in supporting or approving exploration, balancing economic gain with environmental impacts.

In summary, **Nd/Pr and Dy/Tb-rich deposits** are most sought-after. Analysts note that without aggressive expansion of mining, demand growth could “escape velocity” – implying high rewards (and risks) for early investors. Recent developments (e.g. LKAB’s Kiruna deposit [8], U.S.-Ukraine mining agreements, and China’s export policies) illustrate the geopolitical stakes. Ultimately, nations and companies prioritizing REE exploration will focus on these critical elements, especially in underexplored regions with favorable geology, while investing in processing and recycling to mitigate supply risks.

Table 1. *High-priority REEs: applications, demand trends, deposit types and major producers.*

Element (symbol)	Key Applications (Strategic Importance)	2025–2035 Demand Trend (est.)	Typical Deposit Types	Top Producers / Reserves
Neodymium (Nd)	Permanent magnets for EV/wind (NdFeB); Nd:YAG lasers; compasses	Demand expected to ~3× by 2035 (CAGR ~8–9%), driven by EVs/wind motors. (~2–3 kg Nd per EV)	LREE deposits: bastnäsite/ carbonatite, monazite in placers, ion-ads clay (lower grade).	China (vast output/reserves) [1]; Australia (Mount Weld); USA (Mountain Pass); Myanmar, Brazil, Russia, India.
Praseodymium (Pr)	Alloyed with Nd in magnets; specialty glasses (Pr:YAG lasers)	Similar to Nd (Nd/ Pr normally produced together). Demand ~3× by 2035.	Same as Nd (bastnäsite, monazite).	Co-produced with Nd. Top producers: China, Australia, USA.

Element (symbol)	Key Applications (Strategic Importance)	2025–2035 Demand Trend (est.)	Typical Deposit Types	Top Producers / Reserves
Dysprosium (Dy)	Magnets (maintains magnetization at high T; EV motors, turbines); lasers; nuclear control rods	Heavy REE; demand also ~3× by 2035 (magnet alloys); about half of NdFeB grades use Dy. Supply tight.	Enriched in HREE sources: weathered clay (ion-adsorption in SE Asia); minor in carbonatites.	China (dominant ~>90% HREE) [4]; minor from Malaysia/ Vietnam clays (historical), perhaps Africa (future).
Terbium (Tb)	Magnets (with Dy in NdFeB); green phosphors (LEDs, displays); high-temp alloys	Heavy REE; small base demand but strong growth (proportional to Dy). Required in wind/EV magnets.	Like Dy: ion-ads clays in China; co-product of bastnäsite (very low %); rare mineral xenotime.	China (~90% of world) [4]; Vietnam and India have some resources; near-term new sources limited.
Samarium (Sm)	SmCo permanent magnets (military, aerospace, high-T motors); filters; neutron capture (Sm–151)	Moderate demand; Sm is less growth-driven (few EVs use SmCo now). Stable or modest increase.	LREE deposits (often coexists with Nd/Pr in bastnäsite, monazite).	China (largest); Czech (Rossing); USA (MP may yield Sm as byproduct). Rare primary mines.
Cerium (Ce)	Catalysts (auto converters); NiMH batteries; glass polishing; ferrocerium flints	Largest-output REE by volume. Demand growing slowly (car emissions, some EV hybrids), but much is oversupplied.	Very abundant in bastnäsite/ carbonatite, monazite. Also in weathered deposits.	China, India, USA. (Often produced in excess, used for low-end applications.)
Lanthanum (La)	NiMH batteries (LaNi$_5$), optical glass, catalysts; camera lenses, specialty alloys	Similar to Ce: high base volume, modest growth. Used in some hybrid cars (NiMH), declining in catalytic use for EVs.	As Ce: carbonatites, monazite placers.	China (major), Australia (Mt Weld), India. Not strategic scarce.

Element (symbol)	Key Applications (Strategic Importance)	2025–2035 Demand Trend (est.)	Typical Deposit Types	Top Producers / Reserves
Yttrium (Y)	YAG lasers, phosphors (red/ green LEDs), YBCO superconductors, alloys	Steady demand. Important in high-tech (GaN LEDs, fiber lasers). Growth modest but critical for optics/ ICT.	Usually with HREEs: xenotime (YPO_4) in pegmatites; also monazite & bastnäsite contain Y.	China (primary); small amounts from placers (India, Brazil); some European and N.Amer projects exist.
Europium (Eu)	Red phosphors for lighting/display; nuclear control rods; lasers	Niche demand, tied to LCD/LED market. Growth limited (emerging LED/OLED tech may reduce needs).	Heavy lanthanide: found in bastnäsite (minor), monazite or specialized minerals (allanite).	China produces most; small output as byproduct of Nd ores.

Sources: Industry forecasts and academic reports. Key REE uses from Geoscience Australia and GNS/NZ. Geology from GA and USGS. Reserve/production data from USGS/Newsweek [1] [2] [3] .

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