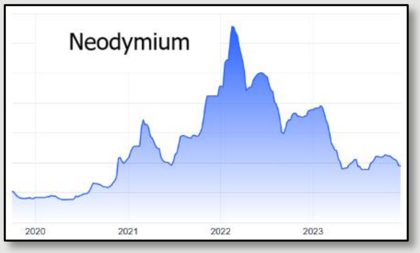


*Sources: S&P Capital IQ*

| IAC REE Public Companies | Price ($) | Mkt Cap ($M) |
|---|---|---|
| Aclara | $0.50 | $81.6 |
| Alvo | A$0.17 | A$15.4 |
| Appia | $0.23 | $30.2 |
| Australian RE | A$0.15 | A$22.4 |
| BBX | A$0.02 | A$15.5 |
| Ionic RE | A$0.02 | A$88.6 |
| Meteoric | A$0.23 | A$453.3 |
| Resouro SM | $0.41 | $28.7 |
| SI6 Metals | A$0.01 | A$10.0 |
| Viridis | A$1.28 | A$62.8 |
| VHM | A$0.71 | A$144.4 |

*Sources: S&P Capital IQ*

**Christopher P. Thompson, CFA, MBA, P.Eng.**
**Director of Equity Research**
**eResearch Corp.**

*Note: All figures are in Canadian dollars unless otherwise noted.*

# Ionic Adsorption Clay Deposits Potential to Supply REE for the EV Industry

**Your Guide to Understanding and Investing in IAC REE Companies with a Focus on Brazil**

**REPORT HIGHLIGHTS:**

- **Rare Earths Industry Crucial for a Green Future**
  - Rare Earth Elements (REE) play a crucial role in the ongoing energy and environmental transition, serving as critical raw materials in low-carbon technologies, such as permanent magnets in Electric Vehicles (EVs).
  - The transition to clean energy to address climate change requires an increased supply of specific minerals to meet the technology demands. Low-carbon technologies often depend on REE, which are recognized as "critical minerals" in Australia, Canada, the EU, and the US.
  - With a forecasted REE supply shortfall, new REE projects have emerged globally to help meet the growing demand.
  - Ionic Adsorption Clay (IAC) deposits are a prominent source of REE, with Asia leading REE production. New projects in Brazil, Africa, and Australia offer substantial resource potential.
- **Ionic Adsorption Clay Deposits**
  - IAC-hosted REE deposits refer to a specific type of mineral deposit where REE are associated with clay minerals, particularly those with ionic adsorption characteristics.
  - The REE are adsorbed onto the surface of the clay minerals as hydrated ions and can be easily extracted by common leaching processes.
  - IAC deposits are shallow free digging material and are some of the most sustainable rare earth deposits, known for low CAPEX and OPEX, and are mined in bulk at lower grades.
  - IAC-hosted REE deposits are a significant source of current REE production and a focus of various mineral exploration companies.
- **IAC-Focused Companies in this Report**
  - IAC companies and projects mentioned in this report include **Aclara** (Carina), **Alvo** (Bluebush), **Appia** (Cachoeirinha), **BBX** (Ema and Apui), **Meteoric** (Caldeira), **MSV** (Serra Verde), **Resouro Strategic Metals** (Tiros), **Si6** (Caldera) and **Viridis** (Colossus) in Brazil; **Australian Rare Earths** (Koppamurra) in Australia; **Aclara** (Penco) in Chile; and **Ionic** (Makuutu) in Uganda.


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# 1.0 Rare Earths Industry Crucial for a Green Future

Rare earth elements (REE) are crucial for the ongoing energy and environmental transition, serving as critical raw materials in low-carbon technologies, such as permanent magnets in electric vehicles.

The transition to clean energy to address climate change requires an increased supply of specific minerals to meet the technology demands. Low-carbon technologies often depend on REE, which are recognized as “critical minerals” in Australia, Canada, the EU, and the US.

With the forecasted REE supply shortfall, new REE projects have emerged globally to help meet the demand.

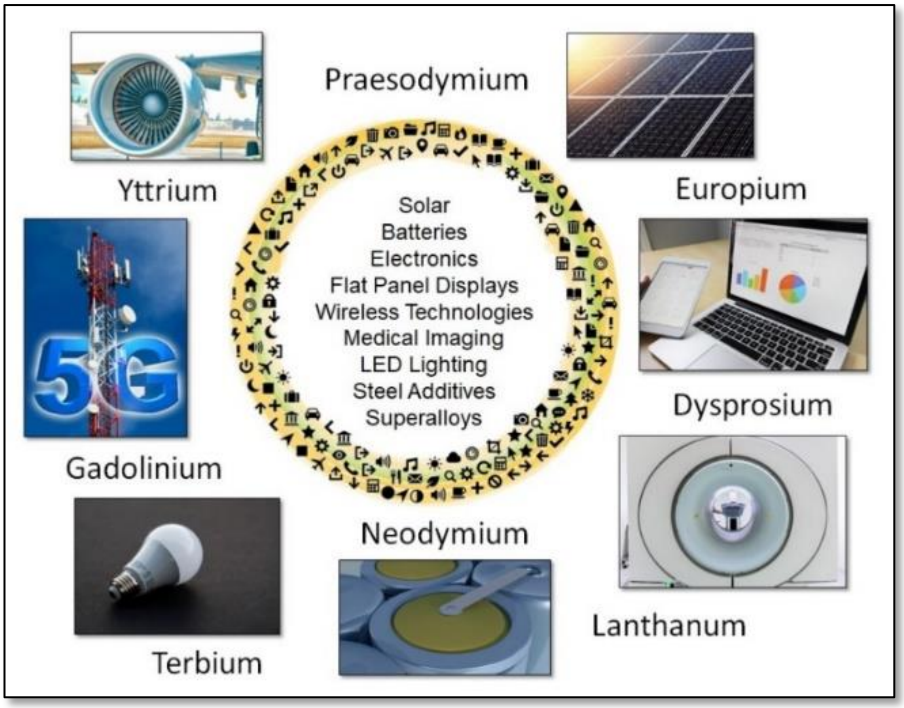
Carbonatite, alkaline igneous rock, and ionic clay deposit types are prominent sources of REE, with Asia leading in REE production. Africa, Australia, Brazil, Greenland, the US, and recent discoveries in Europe offer substantial resource potential.

## 1.1 REE Overview

Rare earth elements (REE) are a group of 17 elements that are essential for modern technologies, such as magnets, batteries, lasers, and are used in electronics (cellular phones, computer hard drives, displays), defense systems (guidance and radar systems), EVs, and renewable energy products (solar, wind), due to their unique properties (see Figure 1).

These elements exhibit unique magnetic, luminescent, and catalytic properties, making them essential components of many products and, while substitutes are available for many applications, the substitutes are generally less effective.

***Figure 1: REE Minerals and Applications***




*Sources: Pixabay (image files); eResearch Corp. (compilation)*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The amount of REE required in a product may not be significant, REE are fundamental for the device to work. For example, rare earth magnets are recognized as the most efficient way to power EVs and are mostly made from iron (Fe) and the rare earth metals neodymium (Nd), praseodymium (Pr), and dysprosium (Dy).

Ironically, REE are not rare. The most common REE is cerium (Ce), the 25th most common element in the earth's crust which makes it more common than copper. What makes these elements rare is that they never occur naturally as base metals and the ores that contain them in commercially extractable quantities are rare.

The growing global demand for these minerals is driven by emerging economies and the push for clean energy technologies.

With China currently dominating REE mining and refining, and the spectre of trade wars looming, western governments are attempting to diversify the REE supply chain.

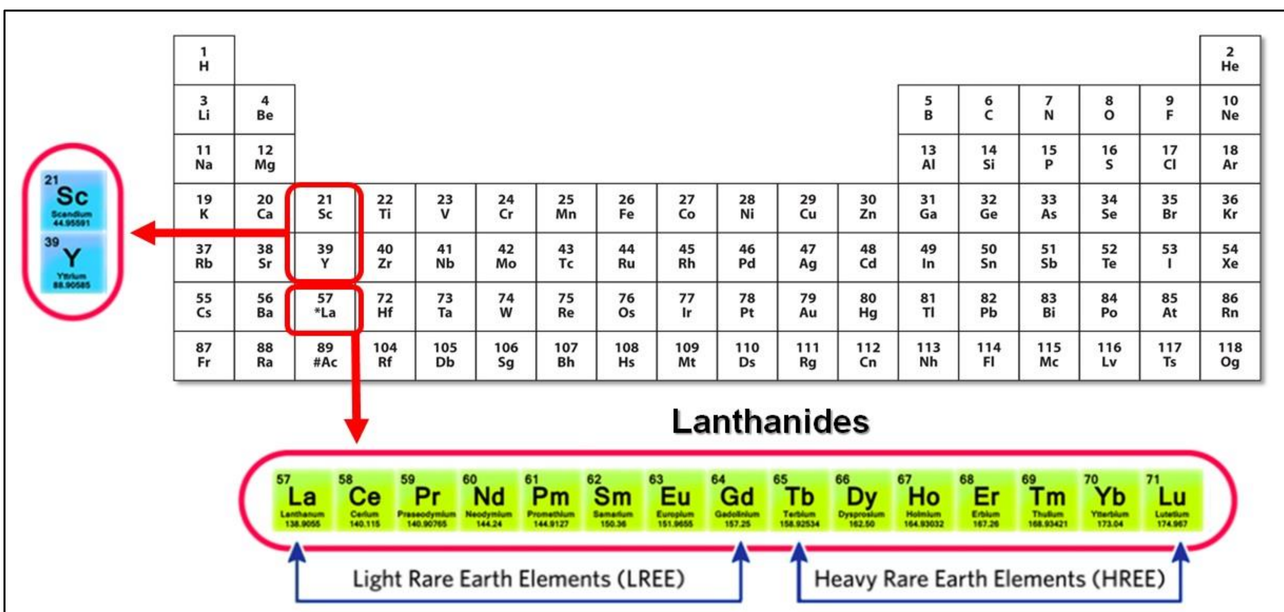
## 1.2 Rare Earth Elements (REE) vs Rare Earth Oxides (REO)

They are also called rare earths, rare earth metals, rare earth minerals, and sometimes lanthanides because of their place on the periodic table (see Figure 2). Although yttrium and scandium, which do not belong to the lanthanides series, are usually included as REE as they exhibit similar chemical properties.

Mineral resource estimates (MRE) often report REE in terms of Rare Earth Oxides (REO), the oxide form of these REE. The oxide form happens when these elements react with oxygen. The result of this reaction is a new compound that includes both the original element and oxygen. For example, neodymium (Nd) would be reported as neodymium oxide (Nd2O3) and terbium (Tb) would be reported as terbium oxide (Tb2O3).

In addition, when reporting REE/REO resources, rather than listing all of the 17 elements individually, companies often report the Total Rare Earth Oxides (TREO), and TREO refers to the total sum of the REO.

***Figure 2: The Periodic Table and the Rare Earth Elements***




*Source: eResearch Corp.*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## 1.3 Light REE versus Heavy REE

The REE group contains 17 elements, including 15 lanthanides, scandium (Sc), and yttrium (Y).

The REE are often divided into Light Rare Earth Elements (LREE) and Heavy Rare Earth Elements (HREE) based on their atomic number (mass) in the periodic table (see Figure 3).

LREE have lower atomic numbers, typically ranging from 57 to 64, and HREE have higher atomic numbers, generally ranging from 65 to 71 but includes Y with the atomic number 39.

- The LREE group includes lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), and gadolinium (Gd).
- The HREE group includes terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), lutetium (Lu), yttrium (Y).
- Although Sc (atomic number 21) is classified as a REE, it forms its own group as its properties cannot be classified as either a LREE or HREE.

The abundance of LREE is generally several times higher than that of HREE, which makes them more easily accessible for mining and extraction.

Due to their scarcity and specific uses, HREE are considered more valuable and sought after in certain industries (see Figure 3).

LREE are often used in technologies that require a high degree of magnetic strength, such as in permanent magnets for wind turbines, electric motors, and speakers. They are also utilized in catalytic converters, glass polishing, and phosphors for lighting and display applications.

LREE, specifically neodymium, and praseodymium, are critical components in the permanent magnets used in electric motors for EVs and wind turbines.

HREE, on the other hand, are essential for specific advanced technologies and high-performance applications. For example, they are used in the manufacturing of powerful magnets for high-temperature environments, lasers, X-ray imaging, and nuclear reactors.

HREE, specifically dysprosium and terbium, are used in some specialized applications, particularly in certain high-temperature magnets and advanced electronic devices.

Both LREE and HREE play important roles in driving the electric revolution.

The demand for REE is forecasted to grow exponentially to meet the needs of green power and electric mobility solutions.


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## 1.4 REE Commodity Prices

A summary of REE oxide commodity prices is listed in Figure 3. The oxide prices typically trade at a lower price than the metal prices.

Figure 4 shows the five-year commodity (metal) price movement charts for dysprosium, neodymium, praseodymium, and terbium.

As of December 12, 2023:

- Dysprosium (metal) is trading at $578.40/kg, down 11.5% this year, but still 40.7% higher than its price of $411.10/kg on January 1, 2021.
- Neodymium (metal) is trading at $123.00/kg, down 41.2% this year, but still 12.1% higher than its price of $109.70/kg on January 1, 2021.
- Praseodymium (metal) is trading at $122.40/kg, down 38.3% this year, but still 46.8% higher than its price of $83.40/kg on January 1, 2021.
- Terbium (metal) is trading at $2,230.40/kg, down 44.6% this year, but still 68.7% higher than its price of $1,322.10/kg on January 1, 2021.

***Figure 3: REE Commodity Prices***

| REE ELEMENT NAME | SYMBOL | COMMODITY | PRICE (2016) (US$/kg) | PRICE (2022) (US$/kg) | PRICE (Dec. 2023) (US$/kg) |
|---|---|---|---|---|---|
| **LREE** | | | | | |
| Cerium | Ce | $CeO_2$ | 3 | 1 | 5 |
| Europium | Eu | $Eu_2O_3$ | 650 | 38 | 26 |
| Gadolinium | Gd | $Gd_2O_3$ | 30 | 77 | 40 |
| Lanthanum | La | $La_2O_3$ | 6 | 3 | 1 |
| Neodymium | Nd | $Nd_2O_3$ | 80 | 171 | 81 |
| Praseodymium | Pr | $Pr_6O_{11}$ | 105 | 165 | 111 |
| Promethium | Pm | $Pm_2O_3$ | *n/a* | *n/a* | *n/a* |
| Samarium | Sm | $Sm_2O_3$ | 5 | 4 | 2 |
| **HREE** | | | | | |
| Dysprosium | Dy | $Dy_2O_3$ | 500 | 559 | 378 |
| Erbium | Er | $Er_2O_3$ | 40 | 63 | 42 |
| Holmium | Ho | $Ho_2O_3$ | 0 | 210 | 76 |
| Lutetium | Lu | $Lu_2O_3$ | 1,200 | 846 | 774 |
| Terbium | Tb | $Tb_4O_7$ | 800 | 1,813 | 2,117 |
| Thulium | Tm | $Tm_2O_3$ | *n/a* | *n/a* | *n/a* |
| Ytterbium | Yb | $Yb_2O_3$ | 30 | 18 | 14 |
| Yttrium | Y | $Y_2O_3$ | 20 | 12 | 6 |
| **Other** | | | | | |
| Scandium | Sc | $Sc_2O_3$ | 1,349 | 1,000 | 685 |

*Sources: Argus Media; Kitco; Metal.com; Trading Economics; eResearch Corp. (compilation)*


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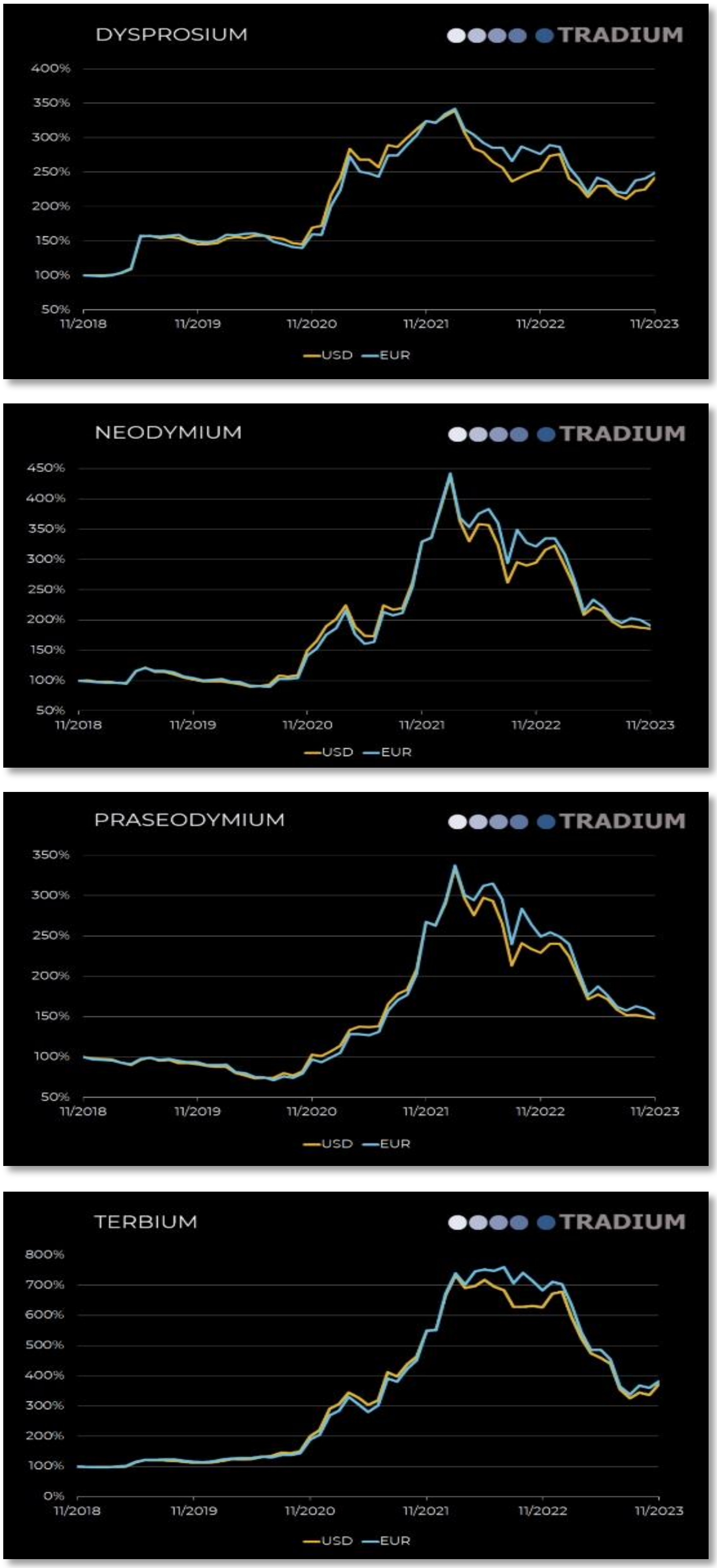
***Figure 4: Sample REE Five-Year Price Movement Charts***




*Source: Strategic Metals Invest (December 2023)*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## 1.5 Demand/Supply Ratio – A Market Facing Deficits

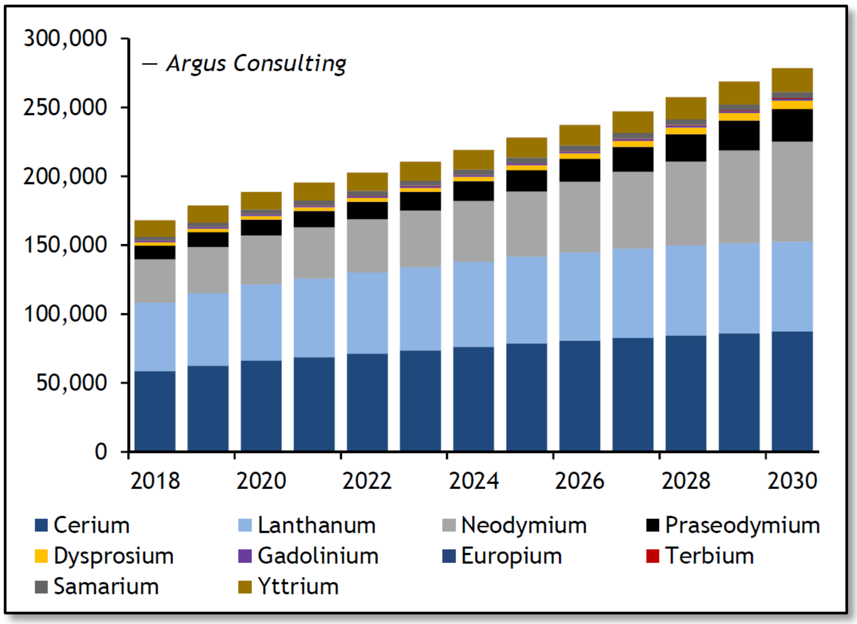
There is very significant variability in anticipated demands for REE over the next 10 years, primarily related to the rate of adoption of clean energy technologies.

Further complicating demand projections is the reality that REE are not mined individually. While the percentage of light rare earth minerals and heavy rare earth minerals vary with the deposit, all rare earth deposits contain REE in varying percentages. Furthermore, the most common REE, lanthanum and cerium, are both the most common and lowest value REE and represent a cost for both refining and disposal.

Figure 5 estimates REE consumption by various elements from 2018 through 2029.

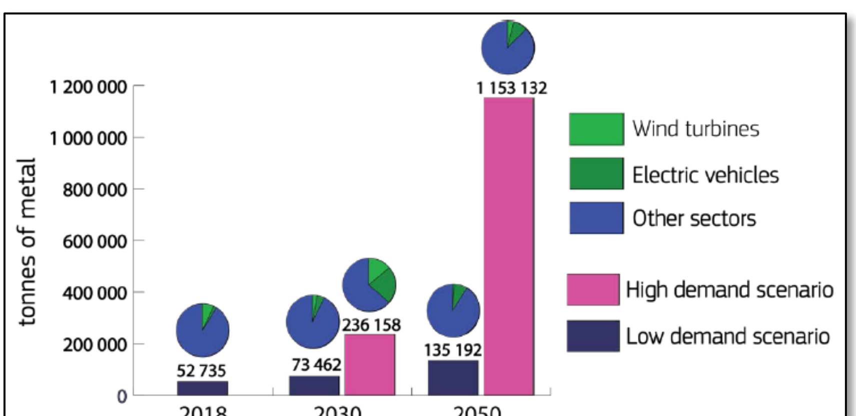
Figure 6 estimates the global demand for neodymium, praseodymium, dysprosium, and terbium for wind turbine generators, EV motors, and other sectors, according to low- and high-demand scenarios.

***Figure 5: Rare Earth Consumption by Element in Tonnes – 2018-2029***




*Source: Argus Media (2020)*

***Figure 6: Estimated Global Demand for Neodymium, Praseodymium, Dysprosium, and Terbium for Wind Turbine Generators, EV Motors, and Other Sectors***




*Source: Joint Research Centre, EU Science Hub*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## 1.6 The Geopolitics of REE

The United States and Australia were pioneers of REE production but by the late 1980s, they had relinquished leadership to China. By the early 2000s, both the U.S. and Australia had disappeared from the list of REE-producing nations and have only recently re-emerged as REE producers (see Figure 7).

According to the U.S. Geological Survey (USGS), Mineral Commodity Summaries (2023), China's mines were estimated to produce approximately 70.0% of the REE market supply in 2022, followed by the U.S. with 14.3%, then Australia with 6.0%, and Burma was in fourth place with 4.0% (see Figure 14).

Although China mines 70% of the world's REE, it is responsible for 85-90% of the refined REE, as a majority of the REE refineries are located in China.

### What are the Risks?

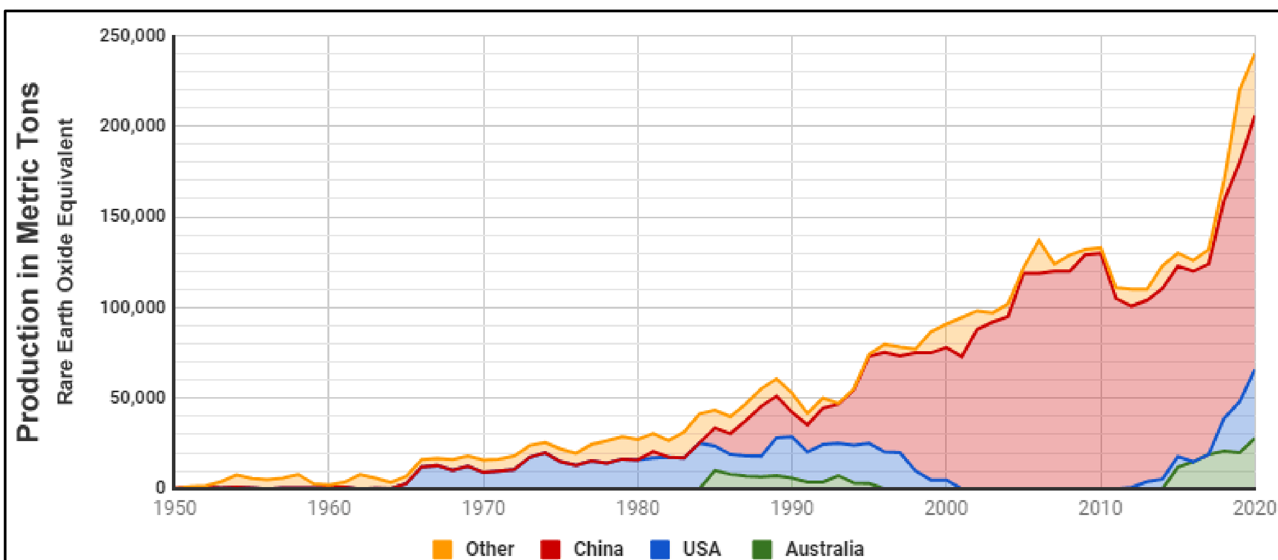
In 2010, during a political spat with Japan, China cut REE exports to Japan. This event had a significant impact on the downstream market as Japan was a key manufacturer of products requiring REE. As a result, the shockwave was felt worldwide. The world recognized the critical nature of REE in an ever-expanding list of products and the political risk of China's dominance of that resource. This recognition sparked a dramatic increase in new sources of REE-bearing ores and ecologically sustainable refining technologies.

As the demand from renewable energy systems and EVs for permanent magnets increases, the demand for REE required to make these magnets also increases and highlights the strategic importance of securing domestic and politically-friendly sources.

Western countries are actively working on securing the supply chain for REE. Since the current REE supply chain is centralized and dominated by a few countries, it poses a risk to energy transition plans and the national security of many countries.

Therefore, diversifying the REE supply chains is a priority for Western nations. These efforts involve the formation of domestic and international partnerships across the entire supply chain, encompassing mining, extraction, processing, and refining.

***Figure 7: Historical REE Production by Country (1950 to 2020)***




*Source: Geoscience News and Information*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## 1.7 Major REE Deposit Types

Rare earth elements are common and reside in a variety of geological environments, most commonly in alkaline igneous rocks (carbonatites/pegmatites), as well as residual, undersea, and placer deposits.

REE appear in both primary and secondary mineral ores in nature. Primary ores form deep within the Earth through magmatic-hydrothermal processes, such as carbonatites and alkaline igneous deposits, while secondary ores develop on the surface through weathering and sedimentary processes, such as ionic adsorption clay deposits.

REE are usually found in association with specific types of geology, where they are concentrated by magmatic, hydrothermal, or weathering processes. These types of deposits or occurrences include alkaline igneous rock, carbonatite, hydrothermal, ion-adsorption clay, iron-REE, placer (alluvial, ash-fall, marine, or palaeo-placer), or the by-product of tin mining (see Figure 8). Three main types of geology where REE are found include:

1. **Ionic Adsorption Clay (IAC) Deposits:**
    - Ionic adsorption clays are residual soils that are formed from the intense weathering of REE-rich rocks, such as granites, syenites, or carbonatites, in tropical or subtropical climates.
    - The weathering process leaches out most of the elements from the rocks and leaves behind a clay-rich layer that is enriched in REE.
    - The REE are adsorbed onto the surface of the clay minerals as hydrated ions and can be easily extracted by leaching with dilute acids or ammonium sulfate solutions.
    - IAC deposits are shallow free digging material and are some of the most sustainable rare earth deposits, known for low CAPEX and OPEX, and are mined in bulk at low grades.
    - IAC deposits are mainly found in southern China, southeastern Asia, the southern coast of Australia, and the eastern coast of South America. China accounts for most of the global production of REE but IAC projects are also found in Australia, Brazil, Chile, and Uganda.
    - Examples of IAC projects include Tiros (**Resouro**), Cachoeirinha (**Appia**), and Serra Verde (**MSV**) in Brazil, Koppamurra (**Australian Rare Earths**) in Australia, Penco (**Aclara Resources**) in Chile, and Makuutu (**Ionic Rare Earths**) in Uganda.
2. **Carbonatites and Carbonatite-related Deposits:**
    - Carbonatites are igneous rocks that are composed of more than 50% carbonate minerals, such as calcite, dolomite, or ankerite. They are rare and often associated with alkaline igneous rocks, which are also enriched in REEs.
    - Carbonatites can form intrusive bodies, such as dikes, sills, or plugs, or extrusive bodies, such as volcanic cones or lava flows.
    - Carbonatites can host REE-bearing minerals, such as bastnasite, monazite, apatite, or synchysite, in their primary magmatic phases or their secondary alteration zones.
    - Examples of carbonatite-related deposits include Mountain Pass (**MP Materials**) in California, Bayan Obo (**Baotou**) in China, and Mount Weld (**Lynas**) in Australia.
3. **Alkaline Igneous Deposits:**
    - Alkaline igneous rocks are formed from magmas that have high concentrations of alkali metals (sodium and potassium) and low concentrations of silica.


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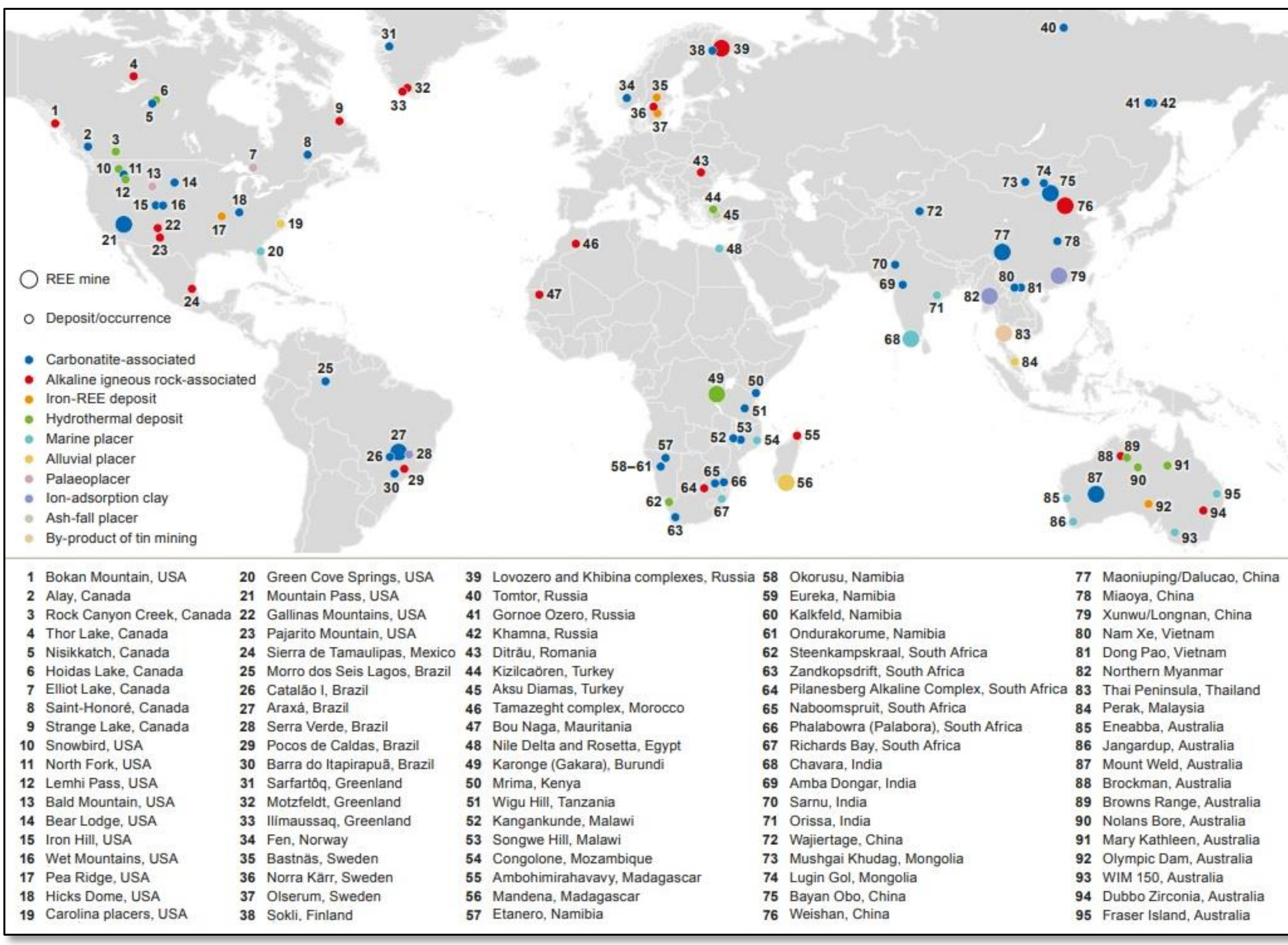
- They are usually associated with continental rift zones or mantle plumes and can form large intrusive complexes or volcanic fields.
- Alkaline igneous rocks can contain REE-bearing minerals, such as perovskite, zircon, eudialyte, or loparite, in their primary magmatic phases or their pegmatitic or hydrothermal veins.
- Examples of alkaline igneous deposits include Kvanefjeld (**Energy Transition Minerals**) in Greenland, Strange Lake (**Torngat Metals**) and Nechalacho (**Vital Metals**) in Canada, and Norra Kärr (**Leading Edge Materials**) in Sweden.

In general, processing is complex and is not standard as it depends on the deposit type, different rare earth elements, and separation technology. Companies that develop new REE-focused mines have to develop far more research on processing than the usual mining project with conventional metals, such as gold or base metal concentrations.

The most common REE are found in hard rocks such as bastnaesite and monazite, but other types of deposits, namely ionic clay deposits, have a more sustainable impact, and projects are faster to develop and with lower CAPEX requirements.

***Figure 8: Global REE Mines, Deposits, and Occurrences (2021)***




*Source: Deady, E. (2021) Global rare earth element (REE) mines, deposits and occurrences (May 2021); BGS.*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## 1.8 IAC-hosted REE Deposits

IAC-hosted REE deposits refer to a specific type of mineral deposit where REE are associated with clay minerals, particularly those with ionic adsorption characteristics.

The world's supply of the Heavy Rare Earth Elements (HREE) primarily originate from IAC deposits found in China. IAC-hosted REE deposits are an important source of current REE production and a focus of various mineral exploration companies

IAC deposits are typically found near the Earth's surface and are commonly located in tropical or subtropical regions where weathering processes have occurred over long periods (see Figure 9). The high rainfall and warm conditions in these areas contribute to the leaching and redistribution of REE ions.

At its Tiros Project in Brazil, **Resouro** estimates the "REEs Enrichment Zone" of between 20m to 40m with a thin overburden that results in a low estimated strip ratio.

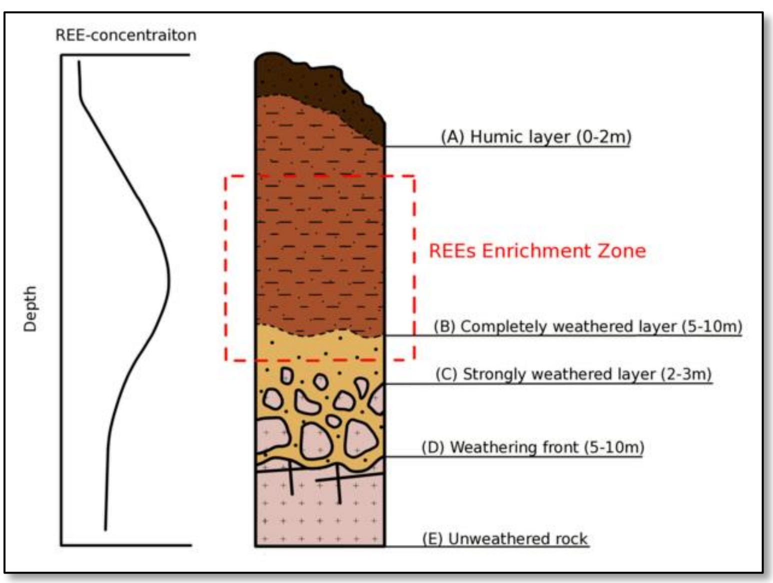
In these deposits, REE ions are adsorbed into the clay, making them relatively easy to extract using simple, less energy-intensive, and environmentally friendly leaching and flotation methods, compared to the extraction methods used for other types of REE deposits, such as hard rock or placer deposits.

Economically viable ionic clay deposits have garnered significant interest due to their high content of HREE, which are essential for various modern technologies, including EVs, wind turbines, and advanced electronics.

Environmental factors, the leachability of REE, and the overall tonnage, rather than just the grade, influence the economic exploitation of these deposits. However, secondary ores, such as ionic clay deposits, can host other minerals with the REE recovered as a by-product during the processing of other mineral resources, which helps improve the overall economics of the project.

The relatively straightforward extraction process and high HREE content make these deposits economically attractive and environmentally friendly sources of rare earth elements.

***Figure 9: Weathering Profile with Indicative High REE-Concentrations in the "REEs Enrichment Zone"***




*Source: WikiCommons*



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## 1.9 Advantages of IAC-hosted REE Deposits Over Hard Rock-Hosted REE Deposits

IAC-hosted REE (IAC-REE) deposits offer several advantages over (HR-REE) deposits, including (see Figure 10):

**1. Accessibility and Mining Ease:**

- IAC-REE deposits are typically near-surface and easily accessible compared to HR-REE deposits, which are often located at greater depths.
- The shallow nature of clay deposits simplifies the mining process, with minimal stripping of waste material, and reduces the need for extensive and costly underground operations.

**2. Lower Extraction Costs:**

- The mining and extraction processes for IAC-REE deposits are generally less expensive than for HR-REE deposits.
- Since clay-hosted deposits are closer to the surface in a soft material (clay) and require minimal blasting, crushing, or milling, the overall operational costs are significantly reduced.
- In addition, minerals from IAC-REE deposits can be extracted by simple methods, such as floatation and leaching with water or acid solutions.
- HR-REE deposits, on the other hand, require more complex and expensive methods, such as blasting, crushing, grinding, and flotation.

**3. Lower Environmental Impact:**

- IAC-REE deposits usually have a lower environmental impact compared to HR-REE deposits.
- Hard Rock mining can involve substantial land disturbance and generate large amounts of waste rock or tailings that need to be disposed of or treated.
- In contrast, clay-hosted deposits often involve less invasive mining techniques and fewer harmful chemicals, making them more environmentally friendly.
- In addition, some HR-REE deposits can produce radioactive waste, due to the presence of thorium and uranium in some REE minerals, such as monazite and bastnaesite.

**4. Quicker Production:**

- Production from IAC-REE deposits can start relatively quickly compared to HR-REE deposits, which often require extensive exploration and development before commercial production can begin.
- This quicker production timeline allows for a faster response to market demands and earlier cash flows.

**5. Higher Heavy REE Grades:**

- IAC-REE deposits tend to have higher grades of the Heavy REE (HREE), which are more valuable and in higher demand than the Light REE (LREE).
- This higher grade can result in extraction and processing that is more efficient, leading to a higher yield of valuable REE per unit of ore processed.

**6. Greater Potential for By-product Recovery:**

- Some IAC-REE deposits contain other valuable metals, such as aluminum, niobium, tantalum, and titanium. During the extraction process, recovering these valuable by-products can add further economic value to the deposit.


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It is important to note that while IAC-REE deposits offer these advantages, they also have their own set of challenges and considerations. For example, managing clay tailings during the processing phase can be challenging, requiring careful attention to environmental and water management practices.

As with any mineral deposit, the overall economic viability and environmental impact will depend on various factors, including capital requirement, geology, market conditions, technology, and regulatory requirements.

***Figure 10: Comparison of Ionic Clay versus Hard Rock REE Projects***

| | Ionic Clay REE Projects | Hard Rock REE Projects |
|---|---|---|
| **Accessibility and Mining Ease** | Easier: Near-surface; low strip ratio | Harder: Often at greater depths; higher strip ratio |
| **Extraction Costs** | Lower: Requires minimal blasting, crushing, or milling; extraction can be by simple methods, such as flotation and leaching with water or acid solutions | Higher: Often requires blasting, crushing, grinding, and flotation |
| **Grades / Value** | Lower grade but often more of the (higher valuable) HREE so higher value per kg extracted | Higher grade but often more of the (lower valuable) LREE so lower value per kg extracted |
| **Environmental Impact** | Lower: Clay-hosted deposits often involve less invasive mining techniques and fewer harmful chemicals, making them more environmentally friendly | Higher: Hard rock mining can involve substantial land disturbance and generate large amounts of waste rock or tailings |
| **Radioactivity** | Usually low or no radioactivity | Common: Some HR-REE deposits can produce radioactive waste, due to the presence of thorium and uranium |
| **Production Timelines** | Faster: Production from IAC-REE deposits can start relatively quickly compared to the "gravel pit" type nature of the deposit. | Slower: HR-REE deposits often require extensive exploration and development before commercial production can begin |
| **By-product Recovery** | Higher: Some IAC-REE deposits contain other valuable metals, such as aluminum, niobium, tantalum, and titanium | Lower |

*Source: eResearch Corp.*


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## 2.0 REE Demand

REE have unusual conductive, fluorescent, and magnetic properties that make them very useful when alloyed with more common metals such as iron. REE are seen as transformational because even when used in small quantities, these elements can have an enormous impact on the properties of the other materials they are combined with.

REE have found uses in various ways (see Figure 11):

- REE can make magnets up to 40 times stronger;
- REE are known to drastically enhance the strength, heat resistance, as well as heat dissipation capabilities of both metals and glass;
- REE can change the colour brightness of computer monitors or televisions;
- In EV motors and wind turbines, neodymium and dysprosium have a natural magnetic force and are part of permanent magnet motors, powering the rotor of the drivetrain;
- In semiconductors, REE are being added to improve the electrical or magnetic properties. This includes the addition of gadolinium, erbium, or europium to improve the magneto-optical characteristics of gallium-nitride semiconductors used to produce high-power transistors;
- When REE are used in catalytic converters, greenhouse gas emissions can be reduced;
- When used in glass, REE can filter harmful light frequencies.

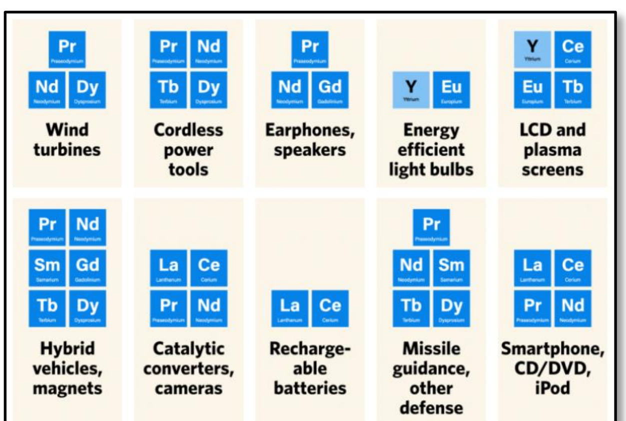
Given that REE are essential components of permanent magnets used in EV and wind turbine motors, the shift towards clean and sustainable energy solutions is poised to trigger a substantial surge in the demand for these minerals.

At least 15 countries committed to net-zero carbon emissions by 2050. To meet the Paris Agreement climate goals, the IEA estimates that REE demand could increase three to seven times from 2021 to 2040.

Demand growth for REE should come from:

- The growth in EVs as they currently represent only 1-2% of the global automotive fleet.
- Offshore wind turbines are estimated to grow at 12% annually until 2030.
- The emergence of electric mobility vehicles in cities, including e-bikes and e-scooters.
- Military-grade magnets for guided weapons, drones, and jet aircraft.

*Figure 11: Uses of Rare Earth Elements*




*Source: Rane Network, April 2019*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## 2.1 EV Motor Metals versus EV Battery Metals

EVs rely on the use of permanent magnets, with REE playing a crucial role in their efficient operation. It is essential to note that rare earths are distinct from battery metals, as they are not used directly in the battery technology itself. Instead, rare earths are utilized in the electric motor, which is a key component in EVs.

The electric motor functions through magnetic induction, where a copper coil is energized by the lithium battery, creating a magnetic field that propels the motor's movement. When the electric motor incorporates permanent magnets, it requires less energy input to generate the same magnetic field, resulting in several advantages for EVs.

One of the main benefits is increased range autonomy, as the motor's efficiency allows for longer distances to be covered on a single charge. Moreover, EVs equipped with permanent magnet motors make better use of space within the vehicle, contributing to a more compact and lightweight design. This optimization not only enhances the overall performance of the EV but also allows for greater cargo capacity and passenger comfort.

Furthermore, the use of permanent magnets in the electric motor results in higher power density, meaning that the motor can deliver more power with less weight and size. This higher power density translates into improved acceleration and performance, contributing to a more enjoyable driving experience for EV owners.

From an economic perspective, employing permanent magnets in electric motors can lead to lower battery costs. By achieving higher efficiency, EVs with permanent magnet motors reduce the demand for certain battery materials, such as lithium, cobalt, and nickel. This, in turn, helps to mitigate the environmental impact of battery production and makes EVs more cost-competitive in the market.

***Figure 12: EV Motor***

*Source: WikiCommons*



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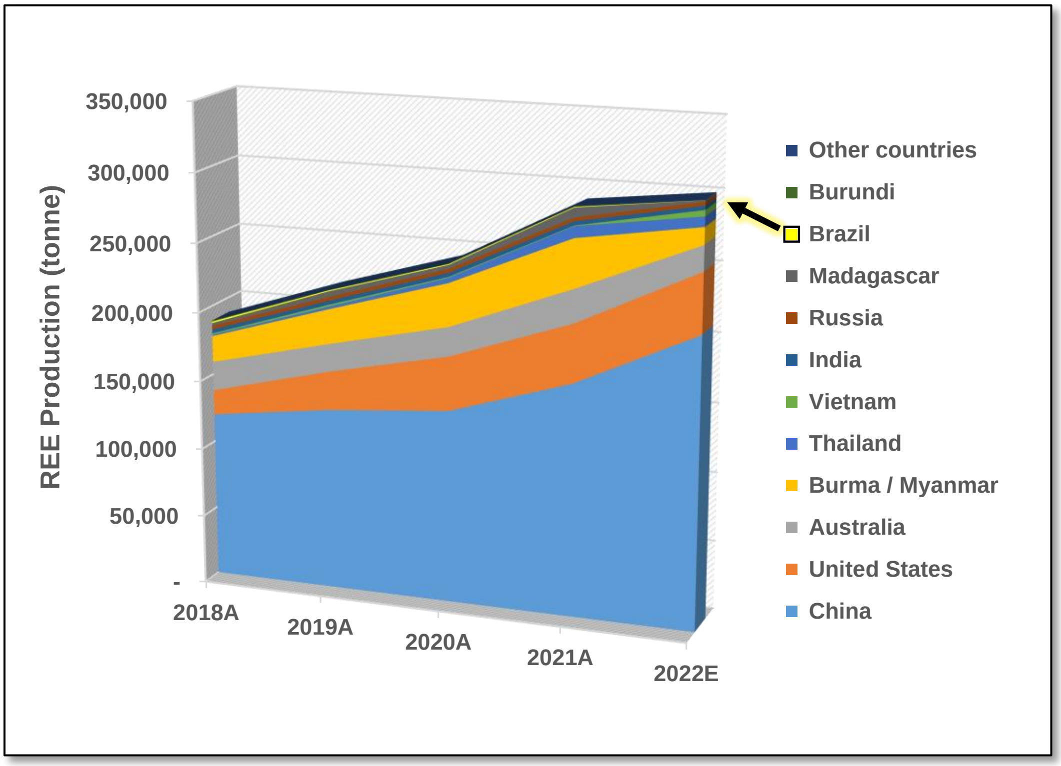
# 3.0 REE Supply

## 3.1 REE Supply

According to the USGS, global mine production of REE was 300,000 metric tons (tonnes) in 2022, with China producing 210,000 tonnes (70%), followed by the U.S. at 14%, and then Australia at 4% (see Figure 13).

In addition, according to the IEA, China also dominates the global share of REE processing at 90% with other REE processing located in Estonia, Malaysia, and Japan.

***Figure 13: Global REE Mine Production (Tonne/Year); Brazil Accounts for Only 0.03% of Production***




*Sources: USGS (data); eResearch Corp. (graph)*


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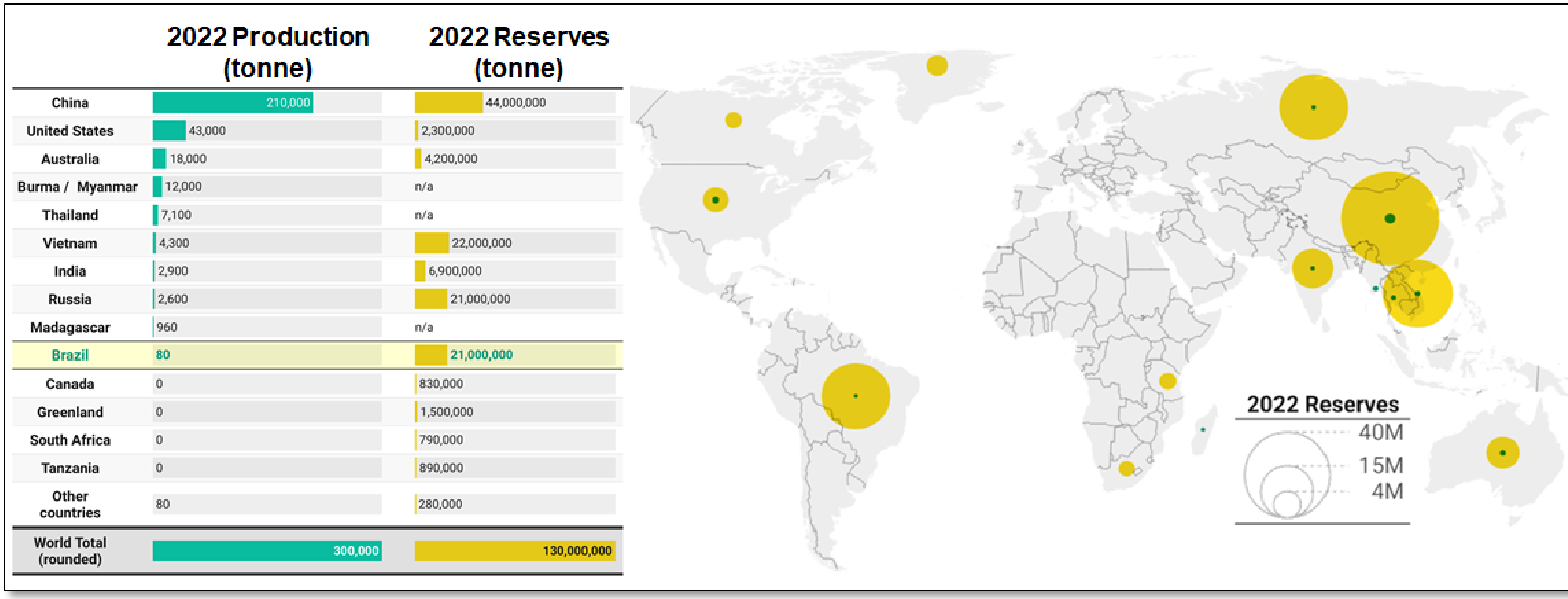
***Figure 14: Global REE Mine Production and Reserves; Geographic Concerns as Current Production Centred Around S/E Asia***



| | 2022 Production (tonne) | 2022 Reserves (tonne) |
|---|---|---|
| China | 210,000 | 44,000,000 |
| United States | 43,000 | 2,300,000 |
| Australia | 18,000 | 4,200,000 |
| Burma / Myanmar | 12,000 | n/a |
| Thailand | 7,100 | n/a |
| Vietnam | 4,300 | 22,000,000 |
| India | 2,900 | 6,900,000 |
| Russia | 2,600 | 21,000,000 |
| Madagascar | 960 | n/a |
| Brazil | 80 | 21,000,000 |
| Canada | 0 | 830,000 |
| Greenland | 0 | 1,500,000 |
| South Africa | 0 | 790,000 |
| Tanzania | 0 | 890,000 |
| Other countries | 80 | 280,000 |
| World Total (rounded) | 300,000 | 130,000,000 |



*Sources: USGS (data); eResearch Corp. (graph)*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## 3.2 Brazil's Rare Earths Industry

Renowned for its abundant natural resources and extensive mining heritage, Brazil is resurging as an enticing investment destination for the REE industry.

Factors like a diverse mineral portfolio, including critical minerals and REE, an 85% renewable energy-supplied power grid, and strong global relationships, particularly with China and the West, amplify the country's investment appeal.

Brazil boasts some of the world's largest REE reserves, making it a potential major supplier globally. Brazil's proximity to key markets and domestic demand growth present opportunities for local companies to capitalize on the industry's potential.

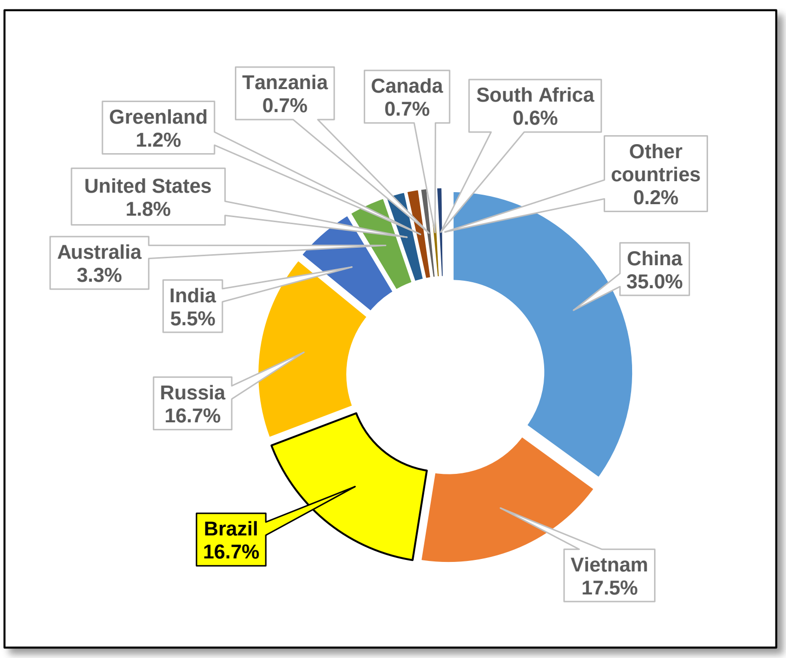
Brazil holds the world's third-largest reserve of REE, totaling 21 million tonnes (Mt), see Figures 14 and 15. However, despite this substantial reserve, Brazil's global contribution to REE production remains relatively modest (Figures 13 and 14). In 2021, the country produced only 500 tonnes, representing less than 0.2% of global production, and USGS estimated a decline in production to only 80 tonnes in 2022.

Most of the REE reserves in Brazil are located in alkaline-carbonatitic rocks, granites, and sedimentary deposits.

Despite its potential, the country's REE industry faces various challenges, including environmental concerns, regulatory issues, and infrastructure limitations.

By addressing challenges through strategic investments, regulatory updates, and international collaborations, Brazil can optimize its rare earths industry and position itself as a key player in the global rare earths market.

***Figure 15: Global REE Reserves (2022E); Brazil Accounts for 17% of Reserves but Less Than 0.2% of Production***




*Sources: USGS (data); eResearch Corp. (graph)*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## 3.3 REE Comps

Since REE are not publicly traded on commodity exchanges, it is difficult to invest in physical REE commodities. Instead, investors interested in the REE industry can gain exposure to the market through mining companies focusing on REE exploration, development, or mining.

We provide a list of publicly traded companies that mine or are exploring for REE in Figure 16, which is divided into groups by project stage. It is evident that as most companies move toward production, the Enterprise Value increases.

One of the largest cap REE miners is **Lynas Rare Earths (ASE: LYC)**, which operates a REE mine in Australia and also processes REE minerals. In North America, the only company mining and processing REE is **MP Materials (NYSE: MP)**, which operates the Mountain Pass mine in California.

In the various stages, average Enterprise Value ranges are:

| Stage | Enterprise Value Average | Enterprise Value Median |
|---|---|---|
| **Production** | $2.106 billion | $1.858 billion |
| **Near-term Production** | $129.5 million | $129.5 million |
| **Feasibility/Pre-Feasibility** | $84.3 million | $66.7 million |
| **PEA/Scoping Study** | $51.4 million | $24.7 million |
| **NI 43-101 / JORC Resource** | $75.7 million | $28.6 million |
| **Near-Term Resource** | $25.9 million | $25.9 million |
| **Resource Definition** | $20.7 million | $18.9 million |
| **Early-Stage Exploration** | $22.1 million | $12.4 million |



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### *Figure 16: Select Companies Producing, Developing, and Exploring for REE*

| COMPANY NAME | TICKER | PRICE 2023-12-18 | MKT CAP (M) | CASH (M) | DEBT (M) | EV (M) | REVENUE (M) | EBITDA (M) | EV/ EBITDA | PROJECT/LOCATION |
|---|---|---|---|---|---|---|---|---|---|---|
| **PRODUCTION COMPANIES** | | | | | | | | | | |
| Energy Fuels | TSX:EFR | $9.46 | $1,585.1 | $125.2 | $1.4 | $1,422.9 | $37.64 | -$28.44 | | Purchasing monazite from Chemours (NYSE:CC) and processing at its White Mesa Mill in Utah. |
| Iluka Resources | ASX:ILU | A$6.74 | A$2,870.9 | A$432.1 | A$114.8 | A$2,553.6 | A$1,520.9 | A$746.8 | 3.4 | Iluka is an international mineral sands company with REE operations at its Eneabba and Wimmera projects in Australia. |
| Lynas Rare Earths | ASX:LYC | A$6.75 | A$6,309.2 | A$1,011.2 | A$190.4 | A$5,488.3 | A$739.3 | A$288.9 | 19.0 | REE processing plant in Malaysia; constructing the Kalgoorlie REE processing facility in Australia and a REE processing facility in Texas. |
| MP Materials | NYSE:MP | US$18.46 | US$3,188.2 | US$1,084.7 | US$694.8 | US$2,798.4 | US$305.5 | US$114.7 | 24.4 | Mountain Pass Rare Earth Mine and Processing Facility, California. |
| Neo Performance Materials | TSX:NEO | $7.47 | $317.3 | $113.4 | $30.0 | $208.4 | $602.05 | $39.85 | 5.2 | REE production facilities in the U.S, Canada, Germany, South Korea, Estonia, and China. |
| Vital Metals | ASX:VML | A$0.01 | A$29.5 | A$3.6 | A$7.0 | A$32.9 | A$0.0 | -A$8.2 | | Nechalacho REE Property (North T Zone), Thor Lake, NWT, Canada. |
| ***Average (<100x)*** | | | | | | ***$2,106.0*** | | | ***13.0*** | |
| ***Median*** | | | | | | ***$1,858.4*** | | | ***12.1*** | |
| **NEAR-TERM PRODUCTION** | | | | | | | | | | |
| Australian Strategic Materials | ASX:ASM | A$1.21 | A$201.8 | A$56.7 | A$17.7 | A$162.9 | A$4.4 | -A$25.7 | | REE ore from the planned Dubbo Mining Project in Australia; Optimisation Study completed in December 2021. A metals processing plant in South Korea commenced production in November 2021 with REE ore from Myanmar. |
| Pensana | LSE:PRE | £0.24 | £74.00 | £9.70 | £0.00 | £66.4 | £0.00 | -£5.63 | | Building a REE processing hub in the UK with feedstock from Longonjo Mine & Concentrator in Angola. |
| ***Average*** | | | | | | ***$129.5*** | | | | |
| ***Median*** | | | | | | ***$129.5*** | | | | |
| **PRE FEASIBILITY / FEASIBILITY** | | | | | | | | | | |
| Arafura Rare Earths | ASX:ARU | A$0.16 | A$351.8 | A$128.8 | A$1.6 | A$224.6 | A$0.0 | -A$99.5 | | The Nolans Project will encompass a mine and processing plant, north of Alice Springs in Australia's Northern Territory. |
| Astron Corporation | ASX:ATR | A$0.47 | A$73.7 | A$7.2 | A$21.6 | A$88.0 | A$14.5 | -A$4.8 | | Developing the Donald Mineral Sands and Rare Earth Project in Australia. |
| Avalon Advanced Materials | TSX:AVL | $0.11 | $58.8 | $2.6 | $3.3 | $59.6 | $0.0 | -$3.9 | | Nechalacho REE Property (Basal Zone), Thor Lake, NWT, Canada. |
| Energy Transition | ASX:ETM | A$0.04 | A$57.4 | A$21.6 | A$0.9 | A$36.7 | A$0.0 | -A$5.8 | | Developing the Kvanefjeld REE project in Greenland. |
| Hastings Technology Metals | ASX:HAS | A$0.67 | A$91.0 | A$98.6 | A$134.8 | A$127.2 | A$0.0 | -A$29.9 | | PFS on the Yangibana REE project in Western Australia. Also owns the Brockman heavy REE project in Australia. |
| Mkango Resources | TSXV:MKA | $0.18 | $48.2 | $2.3 | $0.0 | $50.5 | $0.0 | -$4.3 | | Developing the Songwe Hill rare earths project in Malawi, with a Pre-Feasibility Study completed in 2015 and a Feasibility Study completed in July 2022. |
| Northern Minerals | ASX:NTU | A$0.03 | A$177.5 | A$11.7 | A$13.4 | A$179.1 | A$0.0 | -A$21.6 | | Earning up to a 60% interest in the Makuutu REE project in Uganda. |
| Peak Rare Earths | ASX:PEK | A$0.31 | A$82.0 | A$25.9 | A$0.3 | A$74.2 | A$0.0 | -A$32.8 | | Ngualla-Teesside REE project in Tanzania and a REE refinery in the Tees Valley, United Kingdom. |
| Quebec Precious Metals | TSXV:QPM | $0.09 | $8.5 | $1.5 | $0.0 | $7.0 | $0.0 | -$1.8 | | Kipawa (68%) and Zeus (100%) REE projects in Quebec, Canada. |
| Rare Element Resources | OTCPK:REEM.F | US$0.18 | US$38.3 | US$6.6 | US$0.2 | US$32.0 | US$0.0 | -US$11.2 | | Developing the Bear Lodge REE Project in Wyoming, USA. |
| VHM Limited | ASX:VHM | A$0.71 | A$144.4 | A$20.6 | A$1.0 | A$124.7 | A$0.0 | -A$13.6 | | Flagship project is the Goschen REE and mineral sands project in Australia. |
| ***Average*** | | | | | | ***$84.3*** | | | | |
| ***Median*** | | | | | | ***$66.7*** | | | | |


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| COMPANY NAME | TICKER | PRICE 2023-12-18 | MKT CAP (M) | CASH (M) | DEBT (M) | EV (M) | REVENUE (M) | EBITDA (M) | EV/ EBITDA | PROJECT/LOCATION |
|---|---|---|---|---|---|---|---|---|---|---|
| **PEA / SCOPING STUDY STAGE** | | | | | | | | | | |
| Aclara Resources | TSX: ARA | $0.50 | $86.5 | $45.7 | $0.0 | $24.7 | $0.0 | -$10.0 | | Penco Module project in Chile and the Carina Module in Brazil. The company has developed an extraction process called Circular Mineral Harvesting, it uses no explosives, no crushing, no milling and it does not produce any liquid residues. |
| Commerce Resources | TSXV: CCE | $0.16 | $23.5 | $0.1 | $0.1 | $23.5 | $0.0 | -$1.2 | | Ashram Deposit in Quebec, Canada. |
| Defense Metals | TSXV: DEFN | $0.17 | $43.5 | $7.6 | $0.0 | $35.9 | $0.0 | $0.0 | | Wicheeda REE Property, British Columbia, Canada. |
| Enova Mining | ASX: ENV | A$0.01 | A$6.4 | A$0.0 | A$0.0 | A$6.4 | A$0.0 | -A$0.2 | | Enova primarily focuses on the Charley Creek REE project, which covers 110 kilometers located in the Northern Territory, Australia. |
| Imperial Mining | TSXV: IPG | $0.06 | $11.3 | $1.7 | $0.0 | $9.6 | $0.0 | -$1.6 | | Crater Lake Scandium-REE project in north-eastern Québec, Canada. |
| Ionic Rare Earths | ASX: IXR | A$0.02 | A$88.6 | A$11.1 | A$0.0 | A$77.5 | A$0.0 | -A$8.2 | | Its flagship project is the Makuutu REE project in Uganda. Browns Range Heavy REE pilot plant and JORC resource at the Dazzler deposit with Banshee, Cyclops, Rockslider, and Wolverine prospects. |
| IperionX | ASX: IPX | A$1.30 | A$284.3 | A$11.9 | A$1.0 | A$267.9 | A$0.0 | -A$17.5 | | Monazite sands from its Titan Project in Tennessee sold to Energy Fuels. |
| Leading Edge Materials | TSXV: LEM | $0.15 | $25.3 | $0.8 | $0.0 | $24.4 | $0.0 | -$2.0 | | The Norra Kärr HREE project in Sweden. |
| Namibia Critical Metals | TSXV: NMI | $0.06 | $10.8 | $1.4 | $0.0 | $9.3 | $0.0 | -$0.2 | | JOGMEC can earn up to 50% in NMI's Lofdal Heavy Rare Earths Project in Namibia. |
| Rainbow Rare Earths | LSE: RBW | £0.14 | £88.24 | £8.11 | £0.53 | £80.8 | £0.00 | -£3.13 | | The Phalaborwa Project in South Africa and the Gakara Project in Burundi, East Africa. |
| Search Minerals | TSXV:SMY | $0.03 | $10.4 | $0.0 | $0.1 | $10.5 | $0.0 | -$1.5 | | Developing the Foxtrot and Deep Fox projects, along with regional prospects, including Fox Meadow, Silver Fox, Awesome Fox, and the Red Wine District, in Labrador, Canada. |
| Texas Mineral Resources | OTC: TMRC | US$0.27 | US$19.7 | US$1.1 | US$0.0 | US$18.6 | US$0.0 | -US$2.6 | | USA Rare Earth (*private*) (80%) and Texas Mineral Resources (20%) own the Round Top Project in Texas. |
| Ucore Rare Metals | TSXV: UCU | $0.78 | $48.2 | $1.0 | $5.3 | $52.5 | $0.0 | -$5.0 | | Bokan Mountain Project, Alaska, USA. Working on the commercial deployment of the RapidSX™ separation technology platform. |
| ***Average*** | | | | | | ***$51.4*** | | | | |
| ***Median*** | | | | | | ***$24.7*** | | | | |
| **NI 43-101 / JORC RESOURCE** | | | | | | | | | | |
| Appia Rare Earths | CSE: API | $0.24 | $30.9 | $5.4 | $0.0 | $25.5 | $0.0 | $0.0 | | Uranium and REE resource near Elliot Lake, Ontario, Canada and the Alces Lake property in Saskatchewan. It is also exploring the PCH ionic clay REE project in Brazil. |
| American Rare Earths | ASX: ARR | A$0.16 | A$69.2 | A$12.5 | A$0.1 | A$56.8 | A$0.0 | -A$3.5 | | La Paz Project, AZ, the Halleck Creek Project in Wyoming, and Searchlight Project in Nevada, USA. |
| Australian Rare Earths | ASX: AR3 | A$0.15 | A$22.4 | A$15.0 | A$0.2 | A$7.6 | A$0.0 | -A$2.6 | | Australian RE is exploring the Koppamurra ionic clay REE project, located in South Australia and Victoria. |
| Geomega Resources | TSXV: GMA | $0.23 | $32.8 | $3.5 | $2.5 | $31.8 | $0.6 | -$2.0 | | Montviel Carbonatite Deposit in Quebec, Canada. |
| Meteoric Resources | ASX: MEI | A$0.23 | A$453.3 | A$17.3 | A$1.8 | A$437.8 | A$0.0 | -A$37.7 | | Exploring the Caldeira ionic clay REE project in Brazil. |
| Radio Fuels Energy | CSE: CAKE | $0.16 | $22.2 | $20.0 | $0.0 | $2.2 | $0.0 | $0.0 | | Eco Ridge Project, Elliot Lake, Ontario, Canada. |
| RareX | ASX: REE | A$0.03 | A$19.1 | A$4.3 | A$0.2 | A$15.1 | A$0.0 | -A$9.0 | | The Cummins Range REE Project in the Kimberly region of Western Australia. |
| Skyharbour Resource | TSXV: SYH | $0.47 | $85.1 | $4.0 | $0.0 | $81.2 | $0.0 | $0.0 | | South Falcon Point project with uranium, thorium and REE mineralization in Saskatchewan, Canada. |
| ***Average*** | | | | | | ***$75.7*** | | | | |
| ***Median*** | | | | | | ***$28.6*** | | | | |



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| COMPANY NAME | TICKER | PRICE 2023-12-18 | MKT CAP (M) | CASH (M) | DEBT (M) | EV (M) | REVENUE (M) | EBITDA (M) | EV/ EBITDA | PROJECT/LOCATION |
|---|---|---|---|---|---|---|---|---|---|---|
| **NEAR-TERM RESOURCE** | | | | | | | | | | |
| Resouro | TSXV: RSM | $0.41 | $28.74 | $4.99 | $0.26 | $25.9 | $0.0 | -$1.70 | | Advancing the Tiros Rare Earths and Titanium Project in Brazil. |
| ***Average*** | | | | | | ***$25.9*** | | | | |
| ***Median*** | | | | | | ***$25.9*** | | | | |
| **RESOURCE DEFINITION STAGE** | | | | | | | | | | |
| Auxico Resources | CSE: AUAG | $0.12 | $11.75 | $0.07 | $7.20 | $18.9 | $0.0 | -$4.74 | | Developing a REE project in Colombia and distribution agent for a REE project in the Congo. |
| Medallion Resources | TSXV: MDL | $0.01 | $0.70 | $0.03 | $1.61 | $2.3 | $0.0 | -$1.48 | | Pursuing partnerships and licensing for its Monazite Process to extract REE from mineral sand monazite. |
| Meeka Metal | ASX: MEK | A$0.04 | A$48.2 | A$2.8 | A$0.1 | A$45.5 | A$0.0 | -A$0.9 | | Heavy REE Cascade project within Western Australia's Albany Fraser Mobile Belt. |
| ***Average*** | | | | | | ***$20.7*** | | | | |
| ***Median*** | | | | | | ***$18.9*** | | | | |
| **EARLY-STAGE EXPLORATION** | | | | | | | | | | |
| Alvo Minerals | ASX: ALV | A$0.17 | A$15.4 | A$2.5 | A$0.1 | A$12.9 | A$0.0 | -A$6.0 | | Alvo is focused on the Bluebush ionic clay REE project in Brazil. |
| BBX Minerals | ASX: BBX | A$0.02 | A$15.5 | A$1.7 | A$0.8 | A$14.7 | A$0.0 | -A$4.3 | | BBX's key assets are the Três Estados and Ema precious metal projects and the Ema and Apui REE projects |
| SI6 Metals | ASX: SI6 | A$0.01 | A$10.0 | A$0.7 | A$0.0 | A$9.3 | A$0.0 | -A$2.0 | | Si6 is exploring the Limbopo nickel belt in eastern Botswana, the Laverton gold district in Western Australia, and recently optioned some gold, lithium, and REE projects in Brazil. |
| Viridis Mining | ASX: VMM | A$1.28 | A$62.8 | A$1.2 | A$0.1 | A$61.7 | A$0.0 | -A$0.7 | | Viridis is an exploration focused on gold, nickel, copper and PGM projects in Australia and Canada, and recently acquired the Colossus ionic clay REE project in Brazil. |
| ***Average*** | | | | | | ***$22.1*** | | | | |
| ***Median*** | | | | | | ***$12.4*** | | | | |
| **OTHER** | | | | | | | | | | |
| Canada Rare Earth | TSXV: LL | $0.03 | $6.35 | $0.02 | $0.80 | $7.1 | $3.5 | -$0.42 | | Developing a vertically and horizontally integrated business within the REE industry. |
| Globex Mining | TSX: GMX | $0.91 | $50.88 | $21.27 | $0.00 | $29.6 | $1.4 | -$1.68 | | A Project Generator company that focuses on acquiring and developing mineral properties through exploration, partnerships, and strategic sales or advancements to production. It has various REE projects including Crater Lake SE and Lac Brennan. |
| Itafos Inc. | TSXV: IFOS | $1.38 | $263.04 | $36.35 | $109.79 | $363.4 | $481.7 | $150.27 | | Operates as a phosphate and specialty fertilizer company but holds the Araxa proejct, a REE and niobium mine and extraction plant project located in Minas Gerais, Brazil. |

*Sources: S&P Capital IQ; eResearch Corp.*


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# 4.0 IAC REE Projects

In the section below is a list of companies that have been associated with REE ionic adsorption (IAC) clay projects around the world.

## 4.1 Brazil – IAC REE Projects

### 4.1.1 Pre-Production Stage – Brazil

- **Serra Verde Pesquisa e Mineração Ltd** or **Mineracao Serra Verde (MSV)**
  - www.serraverde.com
  - **MSV** is a private company exploring and developing the Serra Verde REE project in Brazil.
  - **MSV** is a portfolio company of **Denim Capital** (www.denhamcapital.com). Denham started investing in **MSV** in 2010.
  - The Serra Verde Project is, reportedly, one of the largest ionic clay deposits outside of China to produce a combination of heavy and light magnetic rare earths.
  - All required permits have been received. **MSV** is currently in the construction phase and commissioning has started with production expected in late 2023. The project aims to produce 5,000 tpa of rare earth oxide (REO) over a 25-year mine life.
  - The project is fully funded until production after raising US$150 million from investors, including **Energy and Minerals Group** (*private*) and **Vision Blue Resources** (*private*).
  - The Serra Verde Project is expected to produce the four key REE: Nd, Pr, Tb, and Dy, comprising 85% of the concentrate value.

### 4.1.2 Resource Stage – Brazil

- **Aclara Resources Inc.** (TSX: ARA)
  - www.aclara-re.com
  - **Aclara** is a REE developer advancing the Penco Module project in Chile, and the Carina Module in Brazil with other exploration projects in China, Peru, and Brazil.
  - On December 12, 2023, **Aclara** released a maiden mineral resource from the Carina Module project in the State of Goias, Brazil. The mineral resource estimate is based on data from 201 auger drill holes, totalling 1,630 meters.
  - The initial Inferred mineral resource was estimated to contain 168 Mt, with a grade of 1,510 (0.15%) parts per million (ppm) TREO and 477 ppm (0.05%) of desorbable rare earth oxide (DREO). DREO represents the fraction of TREO that can be effectively recovered using the Penco Module's ammonium sulfate-based metallurgical process.
  - The project's rare earth recovery process aligns with the patented technology developed by **Aclara**, which has been successfully demonstrated at a pilot plant in Chile.
  - For additional information about the Penco Module project in Chile, see Section 4.3.1 below.
  - **Aclara** has a strong balance sheet with no debt – as of September 30, 2023, it had US$45.7 million in cash. Notably, it raised US$100 million in an equity financing in December 2021.
- **Meteoric Resources NL** (ASX: MEI)
  - www.meteoric.com.au
  - **Meteoric** is an Australian company that explores mineral properties in Brazil and Western Australia. Its current focus in the Caldeira REE Project with a recently released, JORC mineral


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resource of 409Mt at 2,626 ppm (0.26%) TREO at a 1,000 ppm cut-off, based on historical drilling to an average depth of less than 10m. In total, 85% of all holes finished in grades greater than 1,000 ppm, and it remains open at depth.

- A 60,000m drill program is ongoing to define M&I resources with scoping/prefeasibility studies expected to begin in Q4/2023.
- Recent drill results released (July 24, 2023) extended the clay zone high-grade REE mineralization up to 56m at Figueira and another 36m at Capao do Mel, highlighted by 32.2m grading 3,769 ppm (0.38%) TREO.
- The initial program was to test the base of the clay below the current Inferred resource and 41 holes (1,313m) have been drilled to date in the six known deposits.
- **Meteoric** plans to infill drill at the Capao do Mel, Sorberbo, and Figueira zones to delineate M&I resources in anticipation of future economic studies and drill another 17 regional targets outside the existing REE resource areas.

***Figure 17: IAC REE Comps***

| Company | Main Ticker | Project | Size | Country | Grade | Size (Mt) |
|---|---|---|---|---|---|---|
| **Near-Term Production** | | | | | | |
| Serra Verde Pesquisa e Mineração Ltda. | *Private* | Serra Verde | 65,303 hectares | Brazil | 0.12% | 911.0 |
| **PEA** | | | | | | |
| Aclara Resources Inc. | TSX: ARA | Penco | 600 hectares | Chile | 0.19% | 29.2 |
| Ionic Rare Earths Limited | ASX: IXR | Makuutu | 24,200 hectares | Uganda | 0.06% | 532 |
| **Resource (NI 43-101 / JORC)** | | | | | | |
| Aclara Resources Inc. | TSX: ARA | Carina Module | 1,400 hectares | Brazil | 0.15% | 168 |
| Australian Rare Earths Limited | ASX: AR3 | Koppamurra | 400,000 hectares | Australia | 0.07% | 186.0 |
| Brazilian Rare Earths | *listing* | | 46,100 hectares | Brazil | 0.15% | 169.0 |
| Meteoric Resources NL | ASX: MEI | Caldeira | 80,000 Hectares | Brazil | 0.26% | 409.0 |
| **Near-term Resource** | | | | | | |
| Resouro Strategic Metals | TSXV: RSM | Tiros | 47,700 hectares | Brazil | | |
| **Early-Stage Exploration** | | | | | | |
| Alvo Minerals Limited | ASX: ALV | Bluebush REE | 12,000 hectares | Brazil | | |
| Appia Rare Earths & Uranium Corp. | CSE: API | PCH | 17,551 hectares | Brazil | | |
| BBX Minerals | ASX: BBX | Ema and Apui | 18,874 hectares | Brazil | | |
| SI6 Metals Limited | ASX: SI6 | Caldera | 17,800 hectares | Brazil | | |
| Viridis Mining and Minerals Limited | ASX: VMM | Colossus | 5,616 hectares | Brazil | | |

*Sources: Company data; eResearch Corp.*


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### 4.1.3 Pre-Resource Stage – Brazil

- **Resouro Strategic Metals Inc.** (TSXV: RSM | OTC: RSGOF | FSE: 8TX)
  - www.resouro.com
  - **Resouro** is a Canadian mineral exploration and development company operating in Brazil with a primary focus on the Tiros Titanium-REE Project in the Brazilian state of Minas Gerais. It is also developing the Novo Mundo Gold Project in the Brazilian state of Mato Grosso.
  - The Tiros Titanium-REE project comprises 25 mineral concessions totalling 47,700 hectares (477 $km^2$ / 117,869 acres).
  - Previous drilling from 21 holes, totaled 1,033m, in 10 concessions and targeted the titanium.
  - In March 2023, **Resouro** started a work program, which includes a maiden auger and air core (AC) drilling campaign. To date, 25 auger holes and 4 AC holes have been completed.
  - The initial drilling results released returned near surface, intercepts of 11m of 20.56% $TiO_2$ and 7,197 ppm (0.72%) TREO, including 1,444 ppm (0.14%) neodymium and praseodymium (NdPr), and 10.5m of 10.47% $TiO_2$ and 7,181 ppm (0.72%) TREO, including 2,222 ppm (0.22%) NdPr.
  - The remaining samples from 12 auger drill holes are currently being analyzed and their results are pending.
  - In November 2023, **Resouro** announced metallurgical test results from a 207 kg composite sample of 19 historic drill holes that returned over 41% recovery of Nd, over 60% recovery of Dy, over 31% recovery of Pr.
  - The short-term catalysts for **Resouro** include the continuation of the AC drill program, delivering a maiden NI 43-101 compliant resource, further metallurgical testing, and working on baseline environmental studies.

### 4.1.4 Early Exploration Stage - Brazil

- **Alvo Minerals Ltd** (ASX:ALV)
  - www.alvo.com.au
  - **Alvo** Minerals is a copper-zinc-lead-gold developer focused on the Palma VMS Project in the Palmeiropolis region of Central Brazil. **Alvo** is also advancing the exploration-stage Bluebush REE project that is 10km to the west of its Palma project and to the north of **MSV**'s Serra Verde ionic clay REE project,
  - Both projects have the same geological setting, and Serra Verde is one of the only ionic clay projects in construction outside of China.
  - Serra Verda is majority owned by US-based private equity, **Denham Capital**, and has a mineral resource of 911Mt grading 1,200 ppm (0.12%) TREO and a mine life of 20 years, starting production in late 2023.
  - A maiden drill program has been ongoing with 264 holes completed at Bluebush since January 2023. Early-stage work confirmed high-grade REE at shallow levels, up to 4,500 ppm (0.45%) TREO in alluvial and 2,350 ppm (0.24%) TREO in saprolite (clay).
  - In October 2023, a diamond drill rig was mobilized at Bluebush to test the depth profile and the first drill hole returned 34m at 1,090 ppm (0.11%) TREO from the surface (0.5m).


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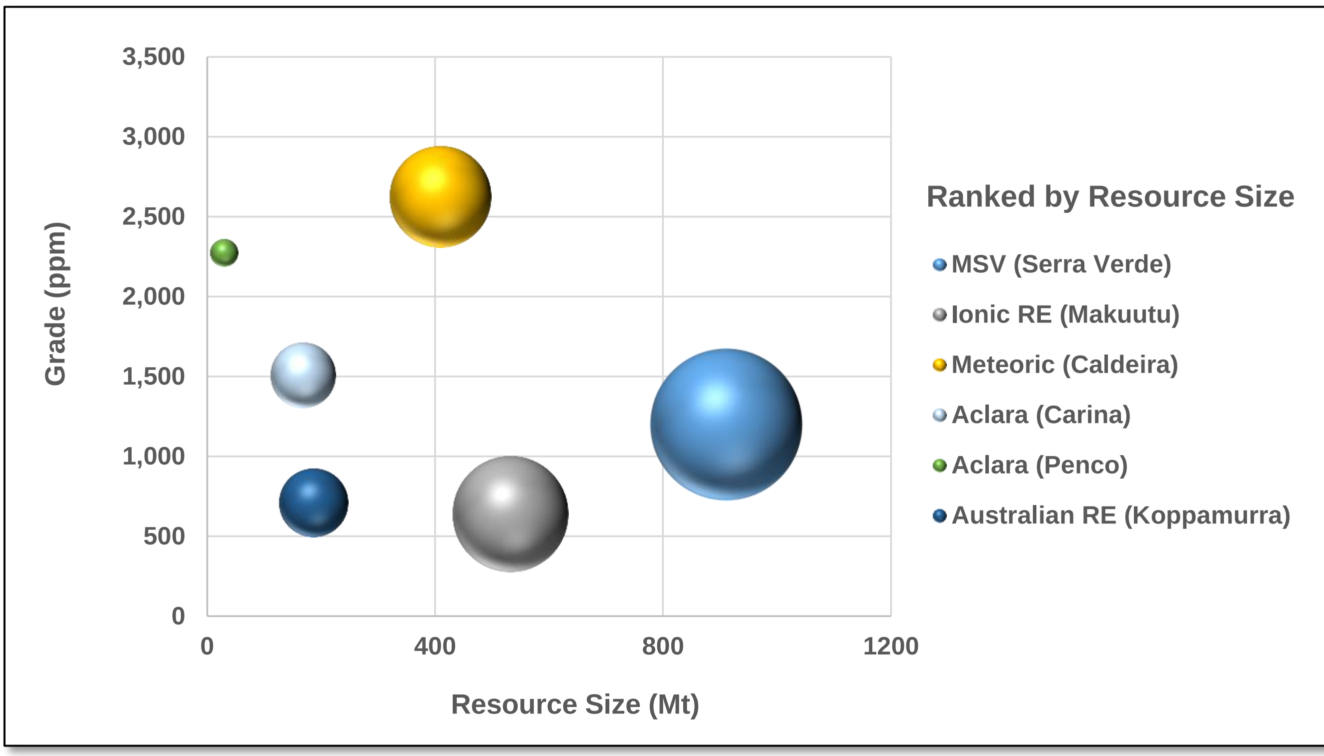
- **Appia Rare Earths & Uranium Corp.** (CSE: API)
    - www.appiareu.com
    - **Appia** is a REE and uranium explorer and is currently focused on REE at its Alces Lake property in Saskatchewan. **Appia** is also advancing the Cachoeirinha Project (PCH Project), a 175.51 square km (over 43,369 acres) ionic clay project located in Goias State, Brazil.
    - At PCH, **Appia** is conducting a Lidar topographic survey over approximately 17 square km and a 300-drill hole, 4500m program, to an average depth of 15m per hole. The bulk of drilling will be on Target IV with approximately 2,500m planned there.
    - As of the end of September 2023, **Appia** has completed 232 holes for a total of 2,847.5m and 2,255 samples have been sent for assaying. Drilling at Target IV has hit a total of 147 holes.
    - **Appia** signed a definitive agreement in June 2023 to acquire up to 70% of the project and closed the acquisition in December. This agreement includes payment in shares and a US$10 million five-year tiered earn-in spend.
    - Previous partners have been active on the property for two years and have delineated nine targets. Only 50% of the project area has been explored thus far.
    - In November 2023, **Appia** released drill results with highlight holes that included 11m at 24,309 ppm (2.43%) TREO and 24m at 27,188 ppm (2.72%) TREO.

***Figure 18: IAC REE Deposits – Resource (Mt) versus Grade (ppm)***




*Sources: Company data; eResearch Corp.*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- **BBX Minerals Ltd.** (ASX: BBX)
  - www.bbxminerals.com
  - **BBX** Minerals is a gold-PGM- base metal and ionic absorbed clay and REE explorer focused in the state of Amazonas in Brazil. It is advancing two 100%-owned projects, the Três Estados and Ema precious metal projects and the Ema and Apui REE projects.
  - At its ionic REE Ema project, on December 7, 2023, **BBX** released an update from its 2017 to 2021 drill programs, highlighted by several results in the range of 6m to 16m in width and grading 739 ppm (0.07%) TREO to 1352 ppm (0.14%) TREO.
  - Based on drilling to date, **BBX** believes there is potential for an approximately 200 Mt deposit, grading 800 ppm to 1,200 ppm TREO, and expects a Mineral Resource at Ema to be released in Q1/2024.
- **Si6 Metals Ltd** (ASX: SI6)
  - www.si6metals.com
  - **Si6** Metals is an exploration company with assets in eastern Botswana (Ni), Eastern Australia (Au), and Brazil (Au, REE, Li).
  - On July 11, 2023, **Si6** acquired a 50% interest in a portfolio of Brazilian REE and lithium assets over 17,000 Ha. Three of the four projects acquired have REE components and are called Apui (Gold, REE) located in Amazonas, and Lithium Valley (Li, REE) and Caldera projects (REE) located in Minas Gerais.
  - Caldera is SE to **Meteoric Resources**' Poços De Caldas Alkaline Complex, host to a mineral resource 409 Mt grading 2,626 ppm (0.26%) TREO.
  - In June 2023, the previous operator **Foxfire Metals**, announced REE mineralization from the surface to 88m (end of the hole). As well, in March 2023, **Foxfire** also discovered the first known REE in Lithium Valley, returning up to 3050 ppm (0.31%) REE.
  - Starting in January 2024, **Si6** plans to start geochemical work at the South Minas Gerais REE project and targets drilling at the Lithium Valley REE project.
- **Viridis Mining and Minerals Limited** (ASX: VMM)
  - www.viridismining.com.au
  - **Viridis** is a Ni-Ci-Pd-Au-REE explorer with assets in Canada, Australia, and Brazil.
  - In August 2023, **Viridis** acquired the Colossus project, a 5,616 Ha ionic clay REE project located in Minas Gerais, Brazil for US$2 million.
  - Previous work on the project includes 34 augur holes to a max depth of 3m, with highlights of 3m grading 2,003 ppm (0.20%) TREO.
  - **Viridis** plans to conduct an initial exploration program that will include geochemical sampling, mapping, and exploration drilling to quickly release a maiden compliant mineral resource.
  - In November and December 2023, **Viridis** released the first set of assays from the Colossus project with highlight holes that returned 46.0m of 3,285 ppm (0.33%) TREO at Cupid South, 21.5m of 3,195 ppm (0.32%) TREO at Carijo, 40.0m of 2,352 ppm (0.24%) TREO at Central, and 40.0m of 2,162 ppm (0.22%) TREO and 15.0m of 3,559 ppm (0.35%) TREO at Fazenda.


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## 4.2 Australia – IAC REE Project

### 4.2.1 Resource Stage - Australia

- **Australian Rare Earths** (ASX: AR3)
    - www.ar3.com.au
    - **Australian Rare Earths** is an REE developer focused on its 100%-owned Koppamurra clay project, which hosts a Mineral Resource of 186Mt at 712 ppm (0.07%) TREO located 300km SE of Adelaide in southern Australia.
    - At Koppamurra, REE mineralization is hosted in a clay layer less than 10m from the surface. **Australian Rare Earths**'s recent upgrade drill program added 13,400m to the existing resource and drilling has been ongoing since February 2023. The program was directed at resource expansion and regional exploration. A resource update was released in September 2023.
    - In October 2023, **Australian Rare Earths** announced that it started a new 30,000 AC drilling program at Koppamurra that is focused on the northern 10km strike extension that has not been tested yet.

## 4.3 Chile - IAC REE Project

### 4.3.1 Feasibility / Scoping Study Stage - Chile

- **Aclara Resources Inc.** (TSX: ARA)
    - www.aclara-re.com
    - **Aclara** is a REE developer advancing the Penco Module project in Chile and the Carina Module in Brazil with other exploration projects in China, Peru, and Brazil.
    - For additional information about **Aclara** or the Carina Module in Brazil, see Section 4.1.2.
    - The Penco Module project is a PEA-stage ionic clay deposit located in southern Chile and it is targeting first production in 2026. The project is 600 Ha and is located 15km from the city of Concepción in Chile.
    - On July 4, 2023, Aclara received termination from its EIA application. It now has to submit a new EIA which has caused a delay in Feasibility Study efforts.
    - An updated mineral resource was released in December 2022 with M&I resource of 27.5 Mt at 2,292 ppm (0.23%) TREO. The resource included 5,298m from 175 new holes conducted in 2021 and 2022 and the definition of a new resource called Alexandra Poniente.
    - A pilot plant is currently in operation and the first concentrate samples of heavy rare earth elements were produced in June 2023. Penco has a project CAPEX of US$130 million.


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## 4.4 Uganda - IAC REE Project

### 4.4.1 Feasibility / Scoping Study Stage - Uganda

- **Ionic Rare Earths (ASX:IXR)**
    - www.ionicre.com.au
    - **Ionic Rare Earths** is a REE-focused developer advancing the Makuutu project in Uganda. It has also developed a separation and refining technology for recycling REE from used permanent magnets.
    - The 51%-owned Makuutu project (earning up to 60%) is located in eastern Uganda and is host to 532Mt grading 640 ppm (0.06%) TREO. **Ionic Rare Earths** estimates there is exploration potential for another 216Mt to 535Mt grading 400 ppm to 600 ppm TREO along an approximately 37 km trend.
    - The base case from its Stage 1 DFS shows a post-tax IRR of 32.7% over a mine life of 35 years (5 Mt/year) with pre-production CAPEX of US$121 million.
    - Moving forward, **Ionic** plans to operate the Makuutu demonstration plant and continue construction and installation efforts moving into Q4/2023. In addition, drilling is ongoing from a 4,380m program to drive further growth in resource
    - Permitting efforts are ongoing and efforts have taken longer than anticipated.


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# Appendix A: Abbreviations and Element Information

The following abbreviations have been used:

- CAPEX: Capital Expenditures
- Critical Rare Earth Element (CREE)
- EV: Electric Vehicle
- HEV: Hybrid Electric Vehicle
- Net Present Value (NPV)
- OPEX: Operating Expenditures
- REO: Rare Earth Oxides
- SGS: SGS Canada Inc.

**Rare Earth Elements (REE)**

- Rare Earth Elements (REE)
    - Scandium (Sc)
    - Yttrium (Y)
    - 15 lanthanide elements (cerium, dysprosium, erbium, europium, gadolinium, holmium, lanthanum, lutetium, neodymium, praseodymium, promethium, samarium, terbium, thulium, and ytterbium)
- Light Rare Earth Elements (LREE) Grouping
    - Ce – Cerium
    - La – Lanthanum
    - Nd – Neodymium
    - Pr – Praseodymium
    - Pm – Promethium
    - Sm – Samarium
- Heavy Rare Earth Elements (HREE)
    - Dy – Dysprosium
    - Er – Erbium
    - Eu – Europium
    - Gd – Gadolinium
    - Ho – Holmium
    - Lu – Lutetium
    - Tb – Terbium
    - Tm – Thulium
    - Yb – Ytterbium
    - Y – Yttrium
- Total Rare Earth Elements (TREE) = LREE + HREE + Scandium (Sc)
- Parts per million (ppm): 10,000 ppm = 1% = 10 kg/tonne


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