GLOBAL CRITICAL MINERAL REVIEW AND CHALLENGES ON ITS EXPLORATION IN INDONESIA

REVIEW MINERAL KRITIS GLOBAL DAN TANTANGAN EKSPLORASINYA DI INDONESIA

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ABSTRACT

Global critical minerals will highlight critical minerals such as lithium, cobalt, rare earth elements (REEs) and nickel that are critical in the clean energy transition. The analysis also covers the distribution of critical minerals in different regions of the world, including Europe, Africa, the Middle East, and Asia. It also discusses challenges in the extraction and processing of critical minerals and implications for sustainable exploration practices. The method used was a literature review of journals. The results show that countries such as Australia, the Democratic Republic of Congo, and China have significant critical mineral reserves. However, the African continent also has great potential in providing critical minerals needed for the clean energy transition. Therefore, emphasizing the importance of securing a reliable supply of critical minerals to support industrial and technological ambitions. In conclusion, then, with Australia, China, and Africa as major providers of clean energy, the provision of critical minerals such as nickel, lithium, cobalt, and REEs is essential for the clean energy transition and to control processes and reduce production costs, improve geological data and laboratory facilities for analysis are required. Indonesia has significant reserves for the global transition to clean energy and technological advancement. Hence, it is strategically positioned in the global mineral market as it becomes a focal point for geopolitical competition, especially between major powers. The regulatory framework in Indonesia can be complex and can pose challenges for foreign investment to enter, so addressing these challenges through increased research and regulatory alignment will be critical to unlocking Indonesia's abundant REE resources and meeting global demand.

Keywords: potential, critical minerals, global REE, geology, exploration, minerals.

ABSTRAK

Mineral kritis global akan menyoroti mineral-mineral kritis seperti litium, kobalt, logam tanah jarang (LTJ), dan nikel yang sangat penting dalam transisi energi bersih. Analisis ini juga mencakup distribusi mineral kritis di berbagai wilayah dunia termasuk Eropa, Afrika, Timur Tengah, dan Asia. Selain itu juga membahas tantangan dalam ekstraksi dan pengolahan mineral kritis serta implikasi untuk praktek eksplorasi yang berkelanjutan. Metode yang digunakan yaitu literatur review dari jurnal. Hasil penelitian menunjukkan bahwa negara-negara seperti Australia, Republik Demokratik Kongo, dan Cina memiliki cadangan mineral kritis yang signifikan. Namun, benua Afrika juga memiliki potensi besar dalam menyediakan mineral kritis yang diperlukan untuk transisi energi bersih. Oleh karena itu, menekankan pentingnya mengamankan pasokan mineral kritis yang dapat diandalkan untuk mendukung ambisi industri dan teknologi. Maka, kesimpulannya dengan Australia, Cina, dan Afrika sebagai penyedia utama energi bersih, penyediaan mineral kritis seperti nikel, litium, kobalt, dan LTJ sangat penting untuk transisi energi bersih dan untuk mengontrol proses dan mengurangi biaya produksi, diperlukan peningkatan data geologi dan fasilitas laboratorium untuk analisis. Indonesia memiliki cadangan yang signifikan untuk transisi global menuju energi bersih dan kemajuan teknologi, maka Indonesia berada pada posisi strategis dalam pasar mineral global karena menjadikannya titik fokus persaingan geopolitik, terutama antara negara-negara besar.

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Kerangka peraturan di Indonesia bisa jadi rumit dan dapat menimbulkan tantangan bagi investasi asing untuk masuk, maka mengatasi tantangan-tantangan ini melalui peningkatan penelitian dan penyelarasan regulasi akan sangat penting untuk membuka sumber daya LTJ Indonesia yang melimpah dan memenuhi permintaan global.

Kata kunci: potensi, mineral kritis, LTJ global, geologi, eksplorasi, mineral.

INTRODUCTION

As the world strives to reduce dependence on fossil fuels, the supply and availability of these critical minerals have become a strategic concern for many countries. Countries around the world are increasingly recognizing the importance of securing reliable supplies of critical minerals to support their industrial and technological ambitions. Critical minerals have emerged as an important component in the global transition to clean energy technologies (Gielen, 2021).

Renewable energy systems, electric vehicles, and advanced electronics use critical minerals. According to the International Energy Agency (IEA), these minerals, which include lithium, cobalt, rare earth elements (REEs), and nickel, are critical to the energy transition, resulting in increasing demand in many countries coupled with volatile price movements (International Energy Agency, 2021), but have supply risks due to high production and processing concentrations, limited reserves and geopolitical concerns (Gielen, 2021).

Countries around the world are increasingly recognizing the importance of securing critical mineral supplies that can support their strategic industries and technologies (Nassar *et al.*, 2020). Efforts are being made to conduct exploration activities aimed at finding and developing new mineral deposits (Gonzalez-Alvarez, Goncalves and Carranza, 2020).

This paper aims to provide an overview of the current state of critical minerals, the potential of critical minerals that exist globally, such as in Europe, Africa, the Middle East, and Asia, and the challenges for exploration in the Indonesian region.

METHODOLOGY

To obtain data relevant to the research problem, a literature study was conducted for this research using comparative studies or relevant studies. After collecting a wide range of literature related to the topic, such as journals on recognizing critical minerals and research seminars on critical minerals, a literature review was conducted.

RESULTS AND DISCUSSION

Global Critical Mineral Distribution

Critical minerals are not evenly distributed around the world and their availability varies greatly by region. In 2016, 126,000 metric tons (of Rare Earth Oxides (REO)) were produced worldwide with the majority produced in China (85%) and Australia (10%), with the remainder produced in Malaysia, Brazil, India, Russia, and Vietnam. In addition, especially in South China, illegal production is estimated to account for 20% of legal production in China, although there is no consistent pattern. Currently, more than 200 REE-bearing minerals have been identified; however, most of the REE production worldwide comes from four minerals: bastnäsite, monazite, xenotime, and loparite (alkali rock and carbonatite). In addition, other economically viable REE minerals are also found in placer deposits, pegmatites, copper-gold iron-oxide, marine phosphates, and deep igneous weathering residue deposits (Zhou, Li and Chen, 2017).

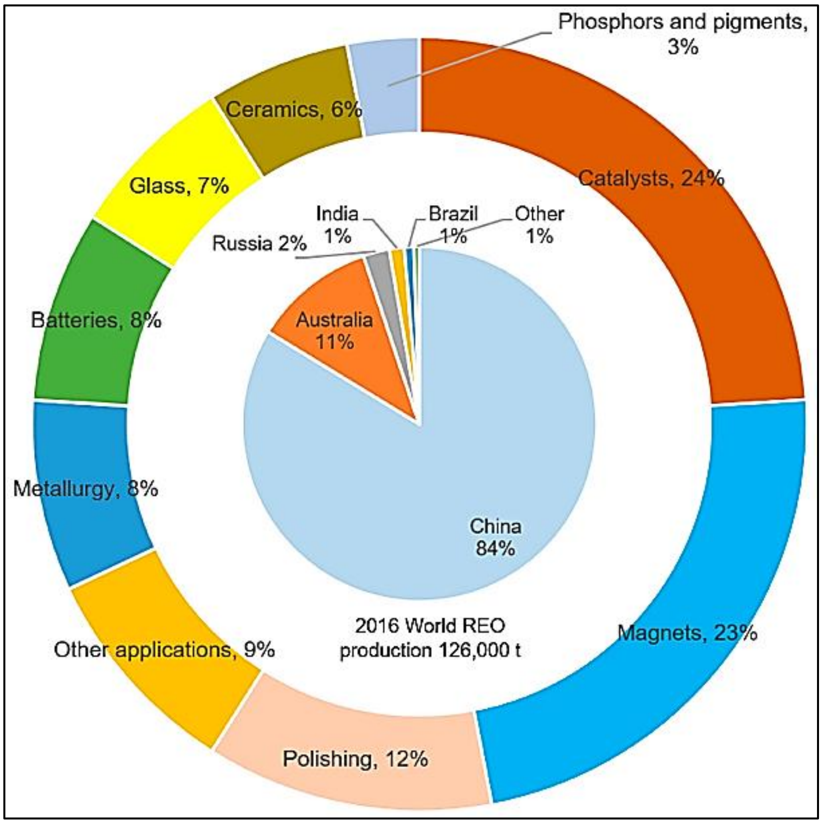
There are 478 million tons (Mt) of Rare Earth Elements (REE) worldwide, with the last 119 million tons (Mt) distributed in Canada, Sweden, the US, Vietnam, and other countries. These include China (164 million tons (Mt)), Brazil (55 million tons (Mt)), Australia (49 million tons (Mt)), Russia (48 million tons (Mt)), and Greenland (43 million tons (Mt)). REE resources worldwide are mainly composed of carbonatite, which contains 297.6 million tons of REO in 66 deposits, accounting for 62% of the resources. These resources are mainly concentrated in a few large-sized REE deposits or regions, such as Bayan Obo in China, Morro dos Seis Lagos in Brazil, Tanbreez in Greenland, and

Lovozero in Russia. In addition, alkaline igneous, copper-oxide copper-gold, placer, and ion adsorption rock types hold 77.9, 74.1, 22.9, and 2.9 million tons of REO, along with an additional 3.7 million tons of REO held by other types. As most of the deposit consists of more than one REE mineral and exploitation has not yet begun. In addition, it should be kept in mind that REE resources have not yet demonstrated economic value; in contrast to REE reserves, the amount of REE resources worldwide is much larger than those declared by the USGS. Therefore, reserves may be economically produced or extracted at the time of determination (Zhou, Li and Chen, 2017).

According to the IEA, the combined market value of major energy transition minerals will increase by 55% in the Alternative Policy Scenario (APS) and by 80% in the Net Zero Emissions Scenario (NZE) by 2030. Demand for REEs, nickel, cobalt, and graphite is expected to double by 2040, while copper demand is expected to increase by half. Keeping in mind the importance of batteries, lithium demand is expected to increase eightfold through 2040 (International Energy Agency, 2024a).

Australia

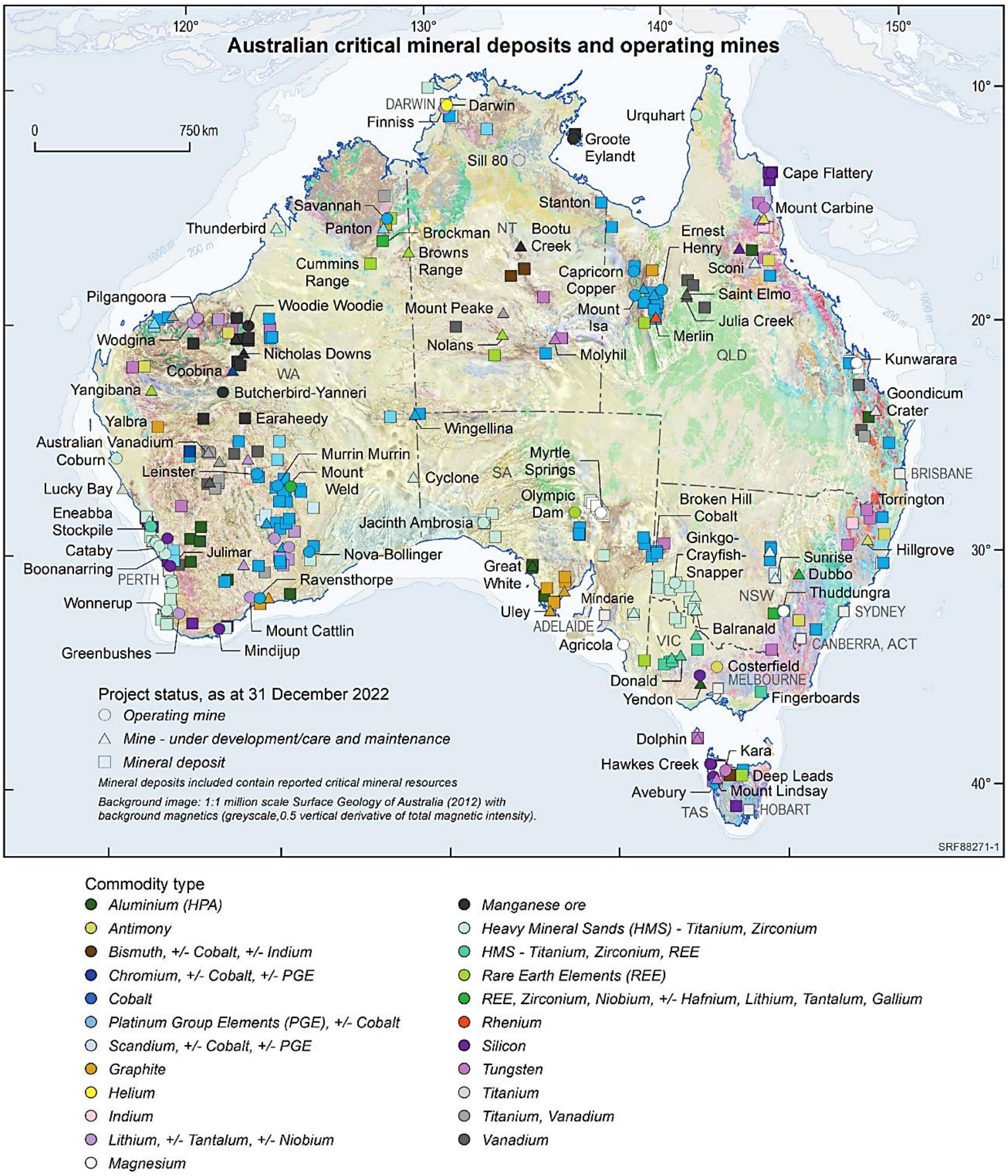
Australia is a major supplier of rare earth elements, nickel, and lithium worldwide. The country is now an important part of the worldwide critical minerals supply chain thanks to its stable politics, thriving mining industry, and strategic location. Australia has developed into a worldwide critical minerals market leader thanks to its large reserves of lithium, nickel, and rare earth elements. The country has attracted large investments in exploration activities due to its stable politics and established mining industry. The definition of critical minerals according to (Australian Government, 2023) is the commercial value of critical minerals, which is constantly changing depending on the latest technological requirements, resource availability, and commodity prices in the global market.



source: Zhou, Li and Chen (2017)

Figure 1. Global resource distribution by major deposit type and country.

Australia's critical minerals sector continues to grow in response to the growing need for supplies of these critical and strategic minerals around the world. Australia's Identified Mineral Resources 2023 shows that Australia continues to be the world's largest lithium producer in 2022 with 52%. The country is also a top five producer of rare earth metals, such as rutile (27%), tantalum (4%), zircon (25%), and cobalt (3%) (Australian Government, 2023). The map below in Figure 2 shows that, in addition to being a world leader in the supply of important minerals, many more deposits have been discovered or are in the process of being discovered. To respond to the increasing demand for critical minerals, the Australian resources industry has undertaken exploration and additional resources are available. Australia's 13 economically viable critical minerals increased by 2021-2022, including manganese (79%), platinum group elements (45%), rare earths (34%), nickel (11%), cobalt (10%), rutile (15%), zircon (12%), ilmenite (11%), vanadium (5%), graphite (6%), lithium (5%), molybdenum (5%), and tantalum (5%) (Australian Government, 2023).



Source: Australian Government (2023)

Figure 2. Australia's key mineral deposits and mines in 2023.

As the 2022 Fraser Institute Annual Survey of Mining Companies shows, Australia's heavy investment in mineral exploration in Southeast Asia has discovered $220 billion worth of mineral reserves and invested $2.6 billion in mining capital. In 2022, mineral production reached $4.86 billion and exploration expenditure reached $198.6 million (Mejía and Aliakbari, 2023).

Australia has large nickel reserves, especially in the Northern Territory and Western Australia, which are estimated to account for 22% of global nickel reserves. In addition, tin reserves, mainly in Queensland, are estimated at 16% of global tin reserves. Australia has potential REE reserves, especially in the Northern Territory and Western Australia. Australia has the potential to become one of the major REE producers, although its reserves are not as large as those of China. Australia has large cobalt reserves mainly in the Northern Territory, but lithium production is still under development. There are an estimated 1.7 million tons of reserves. Australia has sizable graphite reserves, mainly in the Northern Territory and South Australia (Australian Government, 2023).

Africa

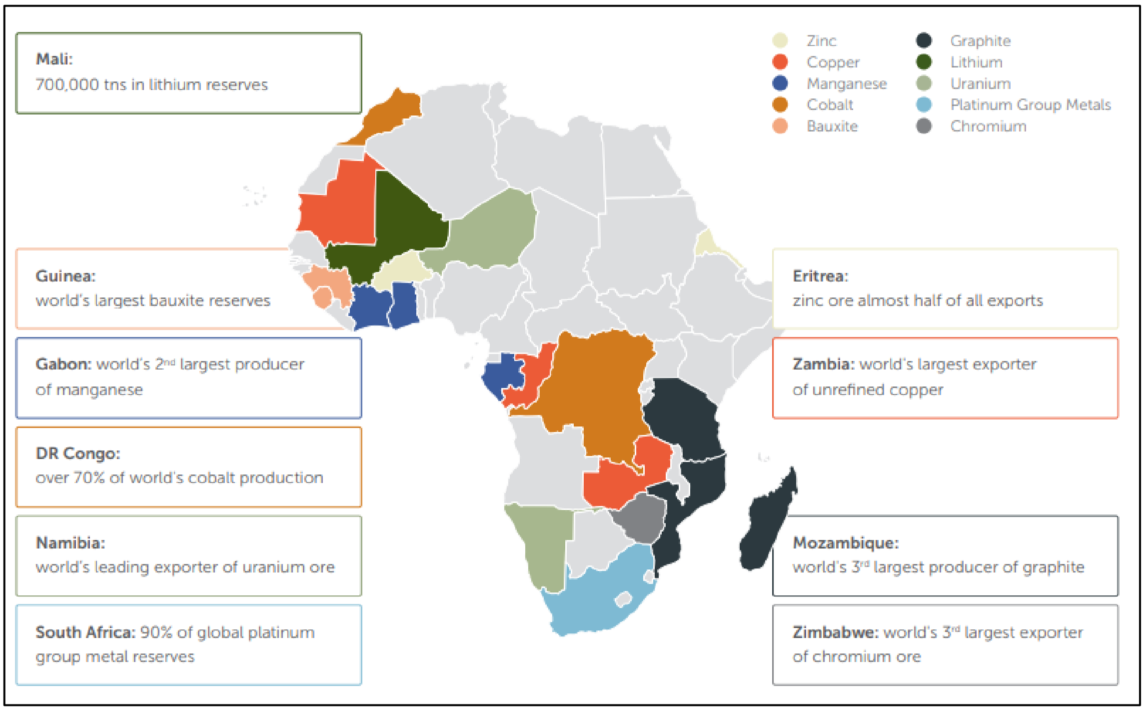
Africa has significant critical mineral reserves, making it an important player in the global critical minerals market. Countries such as the Democratic Republic of Congo (DRC), South Africa, Gabon, and Ghana contribute significantly to global production and the continent has around 30% of the world's critical mineral reserves. In addition to huge reserves of critical minerals such as lithium, platinum, and cobalt-concentrated in the Democratic Republic of Congo (DRC)-Africa has huge reserves of cobalt. However, political instability, infrastructure, and environmental and social governance issues plague the region (Boafo *et al.*, 2024).

Africa has many critical mineral resources and is poised to play an important role in the global transition to clean energy. However, the continent faces challenges related to resource governance, socio-ecological effects, and the need for sustainable development. By implementing strong governance structures and strategic planning, Africa can maximize its economic benefits while ensuring comprehensive management of its critical mineral resources.

Africa accounts for 30% of the world's mineral reserves. Many of these are critical for renewable and low-carbon technologies, such as solar power, electric vehicles, battery storage, green hydrogen, and geothermal. Production of minerals and metals such as lithium, graphite, and cobalt will need to increase almost half-fold by 2050 to meet anticipated global demand. Africa's resources are critical to achieving this. Many such critical minerals are also becoming more of a concern in global geopolitics, especially in the growing competition between the United States and China, especially China's strategic control over global critical mineral supply chains.

Africa will be at the center of the future of green energy from an environmental and geopolitical perspective, with increasing competition for critical mineral resources on the continent. African countries (Figure 3) must seize this opportunity in political, economic and environmental terms. Focusing on Africa's role in the green transition will strengthen Africa's voice in global forums as the continent has long been marginalized from the climate debate (Chandler, 2022).

However, rather than being consumers of essential minerals, African nations are significant suppliers in the global critical mineral value chain. Because they are necessary to meet global climate and decarbonization goals, these minerals (Table 1) may thus be regarded as crucial in Africa. Many African nations are stepping up their efforts by developing and investing in mining operations for important minerals due to the significant untapped potential for these minerals in Africa and the rising demand for these materials worldwide. Demand for lithium, in particular, has been rising steadily in recent years, despite the fact that demand for other essential minerals is rising globally. This growth has been fueled by the shift to renewable energy sources and the growing popularity of electric cars.



Source: Chandler (2022)

Figure 3. African countries: Selected low-carbon minerals.

Table 1 Critical mineral deposits in Africa

Mineral	Africa's share	Major Producers	Use
Lithium	Africa accounts for 5% of the world's lithium reserves	Democratic Republic of Congo, Zimbabwe, Namibia, Ghana	Lithium is used in lithium-ion batteries, making it crucial for electric vehicles and energy storage
Cobalt	Africa accounts for 47% of the world's cobalt reserves	Democratic Republic of Congo	Cobalt is a vital component in lithium-ion batteries used in electric vehicles and renewable energy storage systems.
Copper	Africa accounts for 6% of the world's copper reserves	Zambia	Copper is used in the wiring and other components of electrical equipment
Graphite	Africa accounts for over 21% of the world's reserves	Madagascar, Mozambique, Tanzania	Graphite is used in lithium-ion batteries and is essential for electric vehicles and energy storage systems.
Chromium	Africa is home to about 80% of the world's chromium reserves	South Africa	Chromium is used in a variety of applications, including stainless steel, pigments, and refractory materials
Rare Earth Elements	Africa accounts for 15% of the world's rare earth reserves	Democratic Republic of Congo	Rare Earth Elements are used in green technologies, i.e., wind turbines, solar panels, and electric vehicle components.
Manganese	Africa accounts for about 85% of the world's manganese reserves	South Africa, Gabon	Manganese is essential for several industrial applications, including the production of steel, batteries, and fertilizers.
Platinum Group Metals	Africa accounts for about 80% of the world's Platinum Group Metals reserves	South Africa, Zimbabwe	Platinum, palladium, and rhodium are used as catalysts in fuel cells for hydrogen-based energy systems

Source: Boafo *et al.* (2024).

United States

In 2016, the National Science and Technology Council (NSTC) assessed the “criticality potential” of minerals based on three key metrics: supply risk, production growth, and market dynamics. Minerals “that have supply chains that are vulnerable to disruption, and that have essential functions in the manufacture of products, the absence of which would cause significant economic or security consequences”. Strategic minerals as part of critical minerals and important for national security applications (U.S. Geological Survey, 2023).

Lithium is essential for battery technology, especially in renewable energy storage systems and electric vehicles (EVs). China controls the processing of key minerals and rare earth elements, making the United States dependent on lithium imports. Cobalt is another important mineral used in clean energy technologies such as EV batteries. If cobalt mining poses hazards to the environment and health at home and abroad, the United States must safeguard its supply chain (Barbanell, 2023). Advanced electronics, defense, and renewable energy depend on REEs. The United States has designated REEs as critical minerals that are vital to national security and the economy. This is because nickel is used in stainless steel manufacturing and battery technology (Runde and Hardman, 2023). Although the United States is not currently a major copper producer, it has large copper reserves, especially in Arizona and is an important part of renewable energy systems such as wind turbines and solar panels.

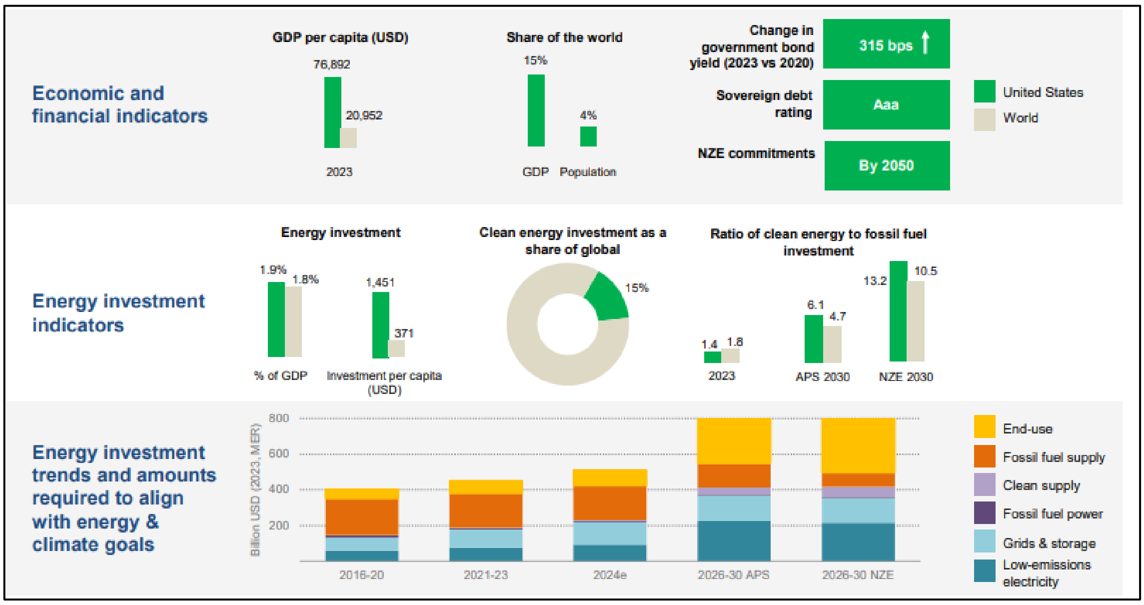
The United States has great potential to produce critical minerals such as lithium, rare earth elements, cobalt, and nickel. Although the United States has many sources of critical minerals, obtaining these minerals poses major problems due to supply chain risks, environmental effects, and regulatory systems. These minerals are critical to technological advancement, energy transition, and national security.

However, to capitalize on this potential, it must overcome a number of issues, such as environmental concerns, legal constraints, and competition from global producers. The United States should implement targeted policies to prioritize the domestic procurement and processing of critical minerals to address these issues effectively.

Through policy, funding, and public-private partnerships, the United States government has taken action to support the exploration and development of significant mineral resources. Ensuring that the United States can meet its critical mineral needs in the coming decades will require advances in mining and processing technologies and efforts to build sustainable supply chains.

The United States has taken major steps to increase investment in clean energy. These investments overtook the expenditures used for fossil fuels in 2020, when investments in this field declined dramatically. In addition, the country invested a significant amount in oil and gas (for every USD 1.4 spent on clean energy) and increased to USD 280 billion in 2023 from USD 200 billion in 2020 (Figure 4). Meanwhile, the IRA tax credit encourages investment in vulnerable energy communities and makes clean energy projects in the United States more competitive. Increased investment in clean energy is driving capital flows toward a long-term goal: achieving clean energy by 2050. However, clean energy investors face a number of challenges, one of which is higher costs as a result of higher benchmark interest rates, which have risen to over 5.0% since the summer of 2023. In some cases, delays have also been caused by licensing issues and finalizing IRA tax credit guidance. About 19 percent of the total cost that the United States spends on fossil fuels comes from the country, which is the world's largest producer of gas and oil (International Energy Agency, 2024d).

The United States hosts about 40% of the wave of new LNG export capacity that will be launched in the second half of this year. The US spending on clean fuels is also increasing as a result of a surge in interest in the prospect of low-emission hydrogen and CCUS. According to the IEA's Announced Pledges Scenario (APS), lower demand for fossil fuels will lead to a significant decline in upstream and midstream spending, while investment in low-emission power will double and energy efficiency will nearly triple by 2030 (International Energy Agency, 2024d).



Source: International Energy Agency (2024d)

Figure 4. Economic and financial indicators, Energy investment indicators, Energy investment trends, and amounts needed to align with the US energy and climate goals.

Europe

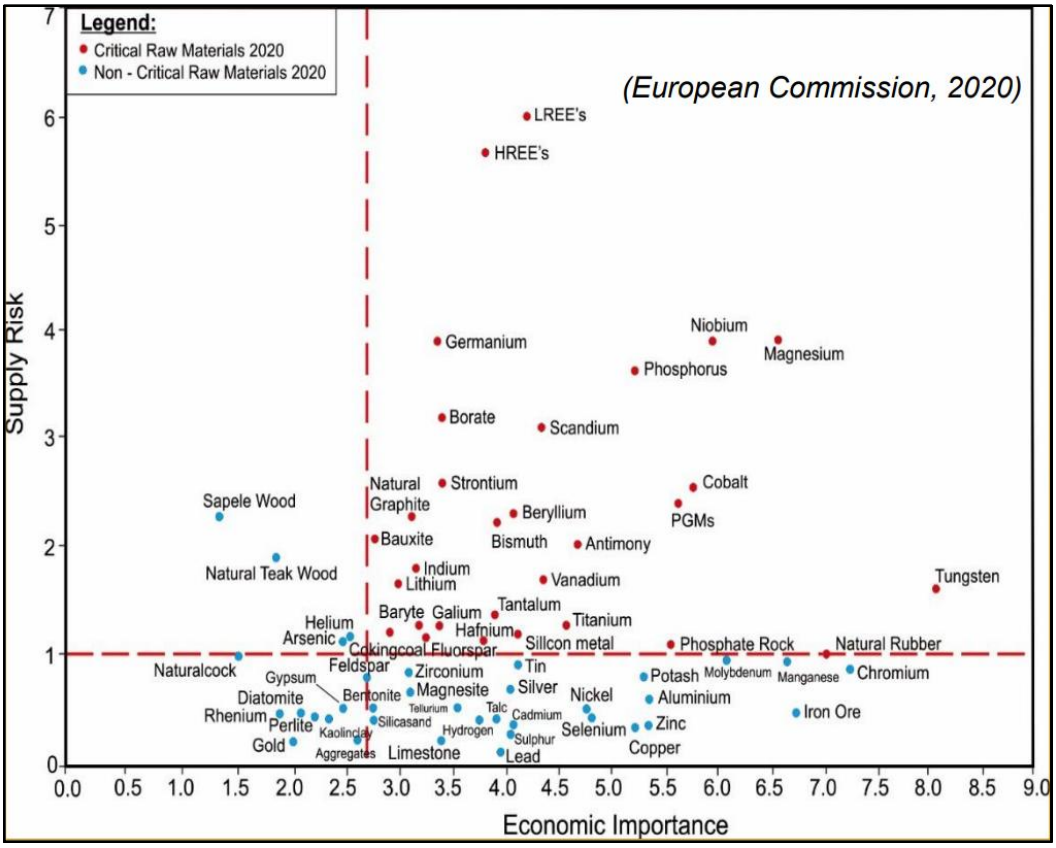
Although the European Union has many critical minerals, it faces major issues regarding supply chain risks, environmental effects and geopolitical considerations. To ensure a safe and sustainable supply of raw materials, the zero-interest Industry Act and the European Critical Raw Materials Act (CRMA) are important steps. However, to accommodate these critical minerals for the EU's energy transition, continued efforts are needed (International Energy Agency, 2021).

As the EU divests from fossil fuels and transitions to clean energy systems, it is expected that demand for critical minerals will increase exponentially. For example, from 2020 to 2050, demand for aluminum is projected to increase by 543% (Jain and Chandran, 2024). To meet the increase in demand, a secondary supply for recycling will be increasingly important, especially after 2030. By 2030, the EU expects to recycle 25% of its annual consumption of strategic minerals (International Energy Agency, 2024a).

Some raw materials, considered critical raw materials (CRMs), are critical to the advancement of strategic industries such as renewable energy, electric vehicles, defense and aviation, and digital technology. Economic and supply chain importance factors are mentioned in CRMs (Figure 5) (European Commission, 2020).

It is crucial for Europe to have strategic autonomy, especially in relation to the global shift towards renewable energy and electric mobility. Countries such as Portugal, Spain, Finland, Sweden, Greenland, Norway, and Greece have large reserves of nickel, lithium, cobalt, and rare earth elements. These reserves are critical for the production of wind turbines, batteries, and other advanced technologies. However, to capitalize on this potential, we must face a number of issues, such as environmental concerns, legal barriers, and competition from global producers.

EU rivalries over critical mineral resources have significant geopolitical consequences. The region is increasingly dependent on trade agreements with countries in the Global South, which are rich in natural resources. This could lead to unbalanced trade and continued resource extractivism (González and Verbeek, 2024). Recognizing the importance of critical mineral resources to the continent's economic and technological future, the European Union has taken major steps to support the exploration and development of critical mineral resources domestically. To ensure that Europe can obtain the critical minerals necessary to meet



Source: European Commission (2020)

Figure 5. Critical minerals based on supply risk and economic importance.

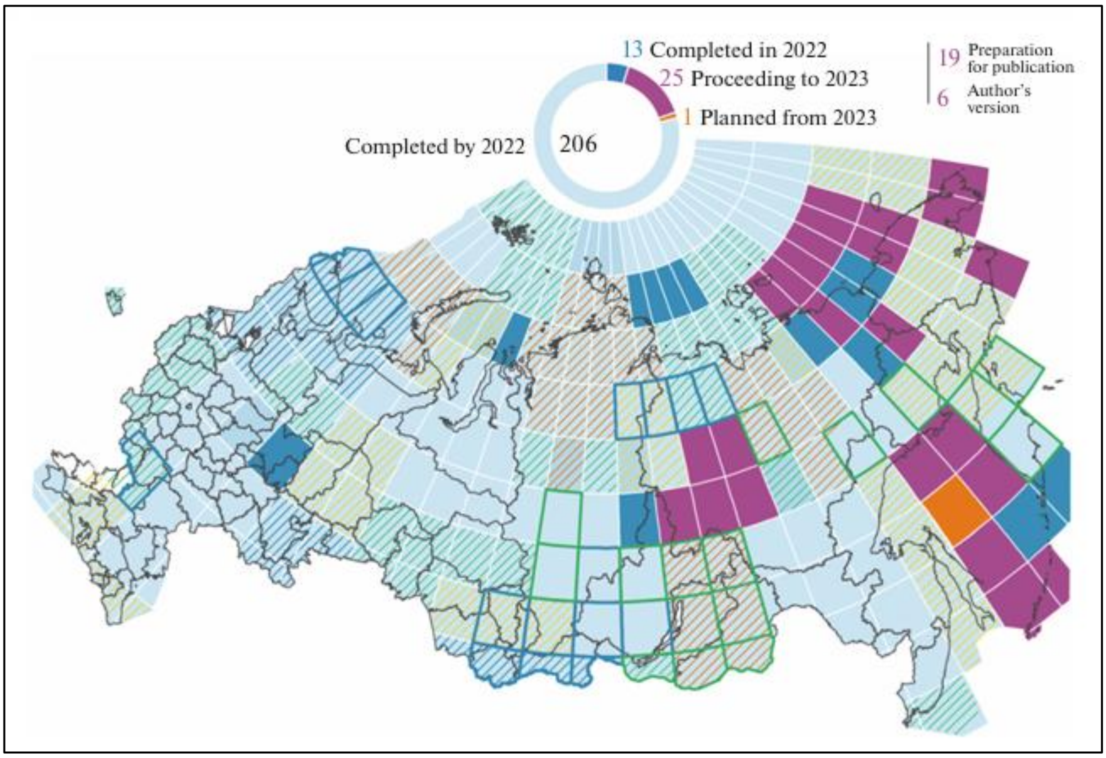
its environmental and industrial goals, it will be critical to invest in sustainable mining practices, technological innovation, and the development of resilient supply chains.

Russia

A mineral is considered strategic only if it performs an essential function and has few or no substitutes. If there is an assessment indicating that the supply of the mineral may be limited, due to unavailability or significantly higher prices, the mineral is considered critical (Bortnikov *et al.*, 2016). Russia accounts for 10% of the global production of nickel, which is important for stainless steel production and battery technology. In addition, Russia is the third largest producer of nickel in the world. Russia produces a lot of copper which contributes to electrical infrastructure and various clean energy technologies (Johnston, 2022).

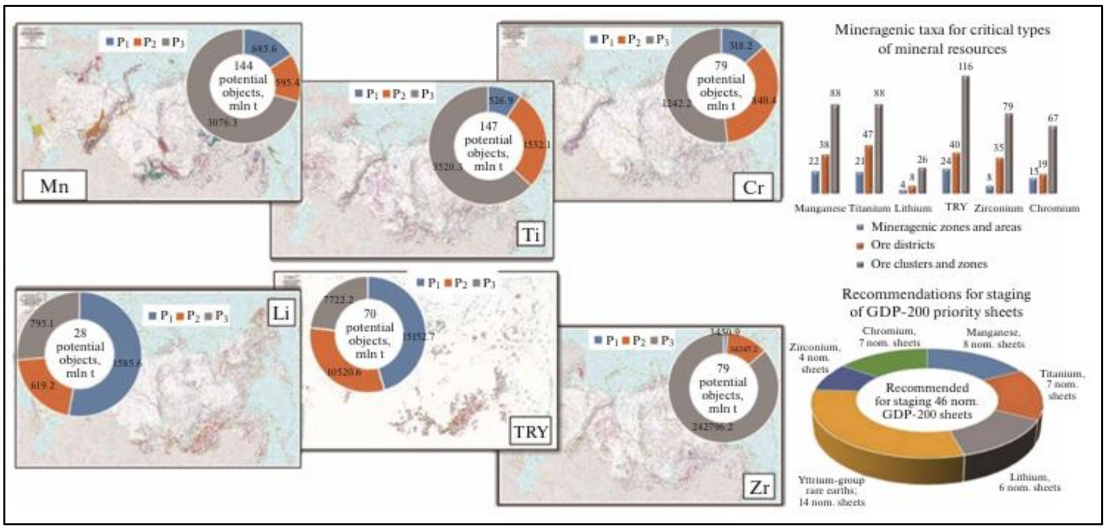
Nickel is used in battery technology and is essential for the manufacture of stainless steel (Islam *et al.*, 2024). Russia has sizable stocks of platinum group metals (PGMs), including rhodium, platinum, and palladium. These metals are essential for catalytic converters in industrial applications such as vehicles (Vikentiev, 2023; Islam *et al.*, 2024). Russia has some reserves of REEs, which are essential for modern electronics and renewable energy technologies, although not as high as China (Petrov *et al.*, 2023; Vikentiev, 2023). Zirconium is used in nuclear reactors and other high-tech applications; Russia's zirconium reserves amount to 12.3 million tons (Petrov *et al.*, 2023). Russia has huge reserves of uranium, which is essential for nuclear energy, and as its main producer, there are ongoing efforts to strategically support it (International Energy Agency, 2023).

For subsurface use on a small scale, modern geological maps of the third generation 1:1000000 were created. These maps involve the assessment of mineral resource potential in large mineralogical zones, ore districts, clusters, and sedimentary basins (Figure 6). Therefore, the monitoring evaluation of Russia's mineral resource potential is very important. This is due to the fact that these maps integrate information on ore deposits and occurrences in the State Cadastre as well as the potential of undiscovered mineral resources in our country. There are more than 52 thousand promising objects at the moment (Petrov *et al.*, 2023).



Source: Petrov *et al.* (2023)

Figure 6. State geological mapping of the territory of the Russian Federation and its continental shelf.



Source: Petrov *et al.* (2023)

Figure 7. 1:2500,000 map of the regularity of location and approximate main geological and industrial types of important mineral deposits on the territory of the Russian Federation.

In 2022, VSEGEI completed the development of a 1:2500000 digital monometric map containing distribution patterns and predictions for strategically important mineral types such as manganese, chromium, titanium, zirconium, beryllium, lithium, and rare earth metals (Figure 7).

Russia's economic development depends on minerals, especially high-tech industries. The extraction and processing of these minerals benefit many industries, such as aerospace, defense, and renewable energy. Strategic minerals such as nickel, copper, and PGMs are vital to Russia's security and defense. These metals are used in military technology and equipment (Vikentiev, 2023). Russia has a significant position in the global market for valuable commodities. Various minerals are extracted in different places in the country's mining sector, which is very diverse (Islam *et al.*, 2024).

Geopolitical tensions and possible sanctions jeopardize Russia's supply chain. Russia is vulnerable to changes in the global market due to its dependence on exports (Johnston, 2022). In terms of technological advances in mineral processing, Russia lags behind other countries. To maximize the value of its mineral resources, this limitation must be overcome (Petrov *et al.*, 2023). Russia aspires to become a major player in the international market for critical minerals. Part of the country's broader geopolitical strategy is to capitalize on its mineral resources.

Middle East

The Middle East has great potential to become a critical supplier of minerals that are vital to the clean energy transformation worldwide. The region can help shape safer and more sustainable mineral supply chains around the world by utilizing its mineral resources wisely and adhering to high standards. This can enable innovation that drives equitable growth and prosperity in a decarbonizing world (Pouran, 2023).

As the global transformation towards high-tech industries and renewable energy, the Middle East's critical mineral wealth is a point of interest. In addition to its oil and gas resources, the region also has reserves of critical minerals such as copper, rare earth elements, lithium, cobalt, nickel, and phosphate. The development of these resources brings both challenges and opportunities to the region. Environmental concerns, the geopolitical complexity of the region, and large investments in infrastructure and technology are some of the challenges. However, the transition to a low-carbon economy has driven an increase in demand for critical minerals worldwide. This provides a great opportunity for the Middle East to diversify its economy and reduce its dependence on oil.

To capitalize on its significant mineral resource potential, the Middle East must invest in sustainable mining practices, build the necessary infrastructure, and establish international partnerships. By doing so, the country will have the ability to play an important role in the global energy supply chain, contribute to the global energy transition, and increase its economic resilience in the face of changing global markets.

China

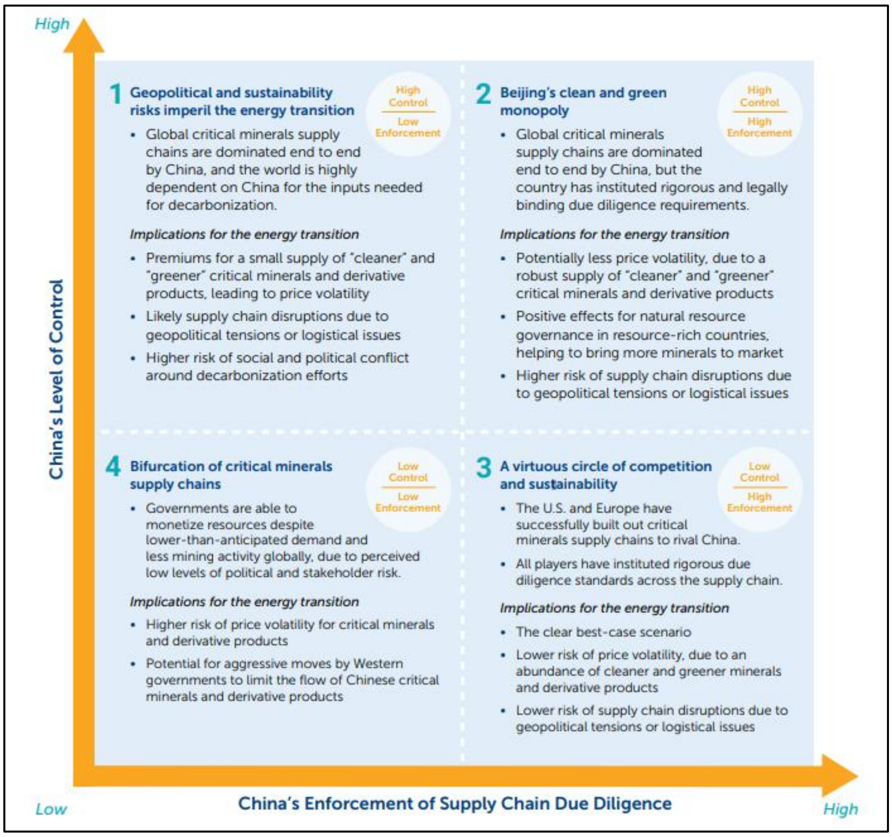
China's critical minerals potential is huge, driven by strategic investments and a focus on battery metals. However, the country faces challenges related to supply chain risks, environmental impacts, and geopolitical considerations. To maintain its position, China must continue to diversify its supply chain while ensuring sustainable and responsible practices.

In addition to large investments in lithium mining and processing, China is the world's third-largest lithium producer. Chinese companies have purchased several lithium assets in Africa and Latin America, such as the Arcadia lithium project in Zimbabwe and Tres Quebradas in Argentina. Following the ban on nickel ore exports from Indonesia in 2020, Chinese companies have increased their investment in nickel mining and supporting infrastructure through the Belt and Road Initiative (BRI). China is actively investing in cobalt mining assets in Africa and Latin America to diversify its supply, as China is almost completely dependent on the Democratic Republic of Congo for cobalt mining. China is the world's largest REE refiner, processing more than half of all lithium, cobalt, graphite, and REEs. However, China is not a major mining center for these minerals, and relies more on concentrates and raw materials imported from outside. To meet the growing demand for graphite, China has invested heavily in graphite mining and processing (International Energy Agency, 2024a).

With a focus on battery metals such as lithium, nickel, and cobalt, China's investment in the metals and mining sector has increased significantly, especially under the Belt and Road Initiative. This investment reached 19.4 billion dollars in 2023, a 160% increase from 2022. During low commodity prices, China has accumulated national stocks of essential materials. This strategy keeps the supply chain stable and prevents short-term disruptions (International Energy Agency, 2024a). China is diversifying its feedstock portfolio by investing in mining assets in Africa and Latin America to reduce supply chain risks. Chinese companies invested more than 4.3 billion dollars from 2018 to the first half of 2021 to acquire lithium assets, double the amount invested by companies from the United States, Australia, and Canada during the same period (International Energy Agency, 2023).

Other countries face energy security risks due to China's dominance in processing critical minerals. Concerns have been raised about China's dependence on these minerals and their derivative products. It is critical to ensure responsible sourcing practices. To avoid the negative social and environmental effects of mineral extraction and processing, due diligence requirements are needed. Other countries are seeking to diversify their supply chains, causing the global market for critical minerals to continue to expand. This competition may threaten China's dominance in the future (Castillo and Purdy, 2022).

The vertical axis takes into account the worldwide proportion of China's dominant upstream, midstream, and downstream essential minerals operations (Figure 8). A low-concentration scenario is predicated on other countries, such as the United States and Europe, significantly increasing capacity along the supply chain. China's high degree of control over vital mineral supply chains is assumed in a high-concentration scenario (Castillo and Purdy, 2022).



Source: Castillo and Purdy (2022)

Figure 8. Potential scenarios for China's critical mineral supply chain.

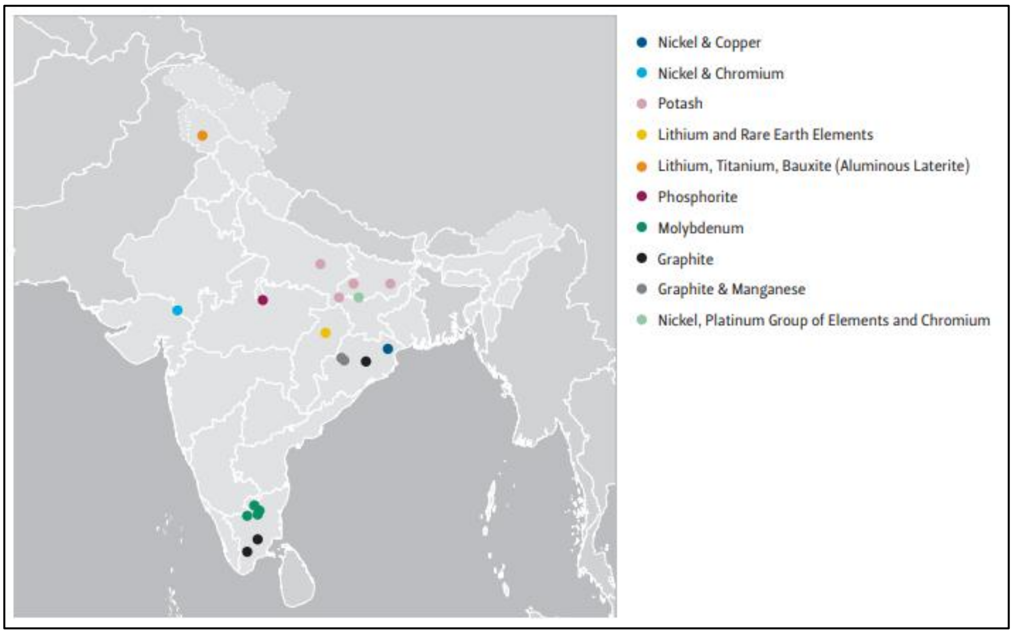
India

In the manufacturing industry, the economic value of each mineral should be considered as a strategic or important criterion. The economic value of a mineral is the overall score derived from the distribution of its use across manufacturing industries for various economic purposes measured by value addition. Economic value considers two factors: first, the overall structure of the economy (as well as the industrial sectors within it); and second, the way minerals are consumed in each industrial subsector (Gupta, Biswas and Ganesan, 2016).

India has large reserves of important minerals, including graphite, REEs, lithium, cobalt, nickel, and other important minerals. India must continue to diversify its supply chain while ensuring sustainable and responsible practices to maintain its position in the global market for critical minerals. However, the country faces challenges relating to supply chain risks, environmental impacts, and geopolitical considerations.

India is exploring domestic sources of lithium, having identified that lithium is one of the critical minerals. The country is also investigating its own sources, including the estimated 5.9 million tons of lithium deposits found in Jammu and Kashmir State (PIB Delhi, 2023). Another component of cobalt is essential for lithium-ion batteries. India relies heavily on cobalt imports, especially from China, which poses a significant risk to the country's supply chain (Anand, 2024). India has large reserves of nickel and is exploring ways to increase its production. It is also important for stainless steel manufacturing and battery technology (Jain and Chandran, 2024). REEs play an important role in electronic technology and renewable energy. Although India has large reserves of REEs, their processing and refining depend on imports (Vaid, 2024).

A map showing the locations of significant mineral blocks up for sale in India (Figure 9). In order to ensure a steady supply of vital minerals from other nations, it has also formed a public sector enterprise known as Khanij Bidesh India Ltd. (KABIL). Additionally, in 2024, the states of Rajasthan and Karnataka issued an Exploration Licence for deep-seated and important minerals, and other states have since followed suit. The strategy also called for lower royalty rates and the creation of the National Mineral Exploration Trust (NMET) in 2015. Therefore, as their economies diversify and progressively wean themselves off of coal consumption, this might also be an equitable energy transition pathway for these states (Jayaram and Ramu C. M., 2024).



Source: Jayaram and Ramu C. M. (2024)

Figure 9. Map of critical mineral blocks for the first phase of auction in India.

Significant but undeveloped resources will be critical to its future energy security and technological advancement. India has a tremendous opportunity to leverage its own resources and reduce its dependence on imports due to the growing global demand for essential minerals, fuelled by the shift towards renewable energy, electric vehicles, and advanced technologies.

India faces several challenges in the industry, such as environmental concerns, the need for large investments in exploration and infrastructure, and competition in a global market dominated by established producers such as China. However, there are equally great opportunities. Developing graphite, rare earth elements, cobalt, and lithium resources can help India strengthen its position in the global supply chain, support the growth of the electric vehicle and renewable energy industries, and achieve greater economic and strategic autonomy.

India can emerge as a key player in the world's critical mineral markets, boost its economic growth, and contribute to global efforts toward a more sustainable future if it adopts a multi-faceted strategy that includes government support for exploration and development, international partnerships, and investment in sustainable mining technologies.

Japan

Japan's critical minerals potential is vast, fuelled by strategic initiatives aimed at diversifying supply chains, promoting sustainable procurement practices, and enhancing cooperation with other countries. By effectively utilizing these strategies, Japan can ensure a steady supply of critical minerals necessary for the clean energy transition and high-tech industries.

Japan has critical mineral resources, especially unexplored marine resources, which make it an important player in the global market. However, to develop these resources, the country must face technological, environmental, and geopolitical challenges. Policy support, international cooperation, and ongoing research will be crucial to realizing this potential.

As REEs are essential for high-tech equipment such as semiconductors and renewable energy technologies, Japan is concentrating on ensuring a stable supply of REEs. The country is trying to lower its dependence on Chinese REEs, which currently provide about 58% of Japan's needs (Hatayama and Tahara, 2015). Japan is also investing in mine exploration and development to increase its domestic production capacity, as the country has important sources of lithium and cobalt for battery technology (International Energy Agency, 2024c). Japan also uses graphite as a critical mineral in lubricants, batteries, and fuel cells. The country is investigating methods to increase its domestic graphite production and processing (Hatayama and Tahara, 2015).

The Japan Organization for Metals and Energy Security (JOGMEC) is responsible for safeguarding Japan's overseas mineral resources. Through public-private partnerships, JOGMEC supports Japan's mineral diversification and access (International Energy Agency, 2024c). To lower its dependence on China, Japan has diversified its mineral supply chain, which includes strategies that include investing in overseas mines, developing new technologies that reduce the use of rare earths, and more. As seen (Figure 10), the criticality scores for Japan in 2012 were assessed based on the findings. Half of the 22 metals got aggregate scores between 16 and 18, with the average being 17.9. For neodymium, dysprosium, indium, and niobium, high criticality was noted. Due to their high demand concerns, indium, neodymium, and dysprosium have higher total ratings (Hatayama and Tahara, 2015).

Korea

By 2030, South Korea wants to reduce its dependence on imports of lithium, cobalt, graphite, and other critical minerals from the current 80% to 50%. As South Korea aims to grow into a high-tech industrial powerhouse, this plan will maximize the utilization of domestic mineral resources and help stabilize the supply chain (International Energy Agency, 2024b). To ensure a stable and reliable supply of graphite, the government is actively working with domestic battery manufacturers. To ensure that companies have a consistent supply of graphite, agencies such as the Korea Trade Investment Promotion Agency (KOTRA) have established a ‘Graphite Supply Task Force’ (Dickens, 2024).

	Supply risk	Price risk	Demand risk	Recycling restriction	Potential risk	Aggregated score
Al	2.3	4.4	1.9	2.3	0.0	11.0
Cr	3.5	7.3	1.9	2.3	0.9	15.9
Mn	3.5	8.8	1.9	2.3	0.9	17.4
Fe	2.9	8.8	2.9	2.3	0.0	16.9
Co	2.9	5.8	3.9	4.7	0.0	17.3
Ni	3.5	7.3	1.0	2.3	0.9	15.0
Cu	2.9	8.8	0.0	4.7	0.0	16.3
Zn	3.5	8.8	1.0	4.7	0.0	17.9
Nb	6.4	8.8	2.9	4.7	0.0	22.8
Mo	2.9	8.8	1.9	2.3	0.0	15.9
Rh	3.5	8.8	0.0	4.7	0.0	16.9
Pd	3.5	8.8	0.0	4.7	0.0	16.9
Ag	3.5	8.8	1.9	4.7	0.0	18.9
In	1.8	8.8	7.8	4.7	0.0	22.9
Sn	3.5	8.8	0.0	7.0	0.0	19.3
Nd	2.9	8.8	5.8	7.0	0.0	24.5
Dy	2.9	8.8	5.8	7.0	0.0	24.5
Ta	1.8	8.8	0.0	7.0	0.0	17.5
W	4.7	8.8	0.0	2.3	0.0	15.8
Pt	3.5	8.8	0.0	4.7	0.0	16.9
Au	3.5	8.8	0.0	4.7	0.0	16.9
Pb	2.9	8.8	1.9	2.3	0.9	16.8

Source: Hatayama and Tahara (2015)

Figure 10. Criticality scores for five risk categories.

South Korea has vast critical mineral resources, which are fuelled by strategic initiatives aimed at diversifying the supply chain, encouraging sustainable procurement practices, and increasing cooperation with other countries. By properly implementing these strategies, South Korea will be able to ensure a steady supply of critical minerals necessary for the clean energy transition and high-tech industries.

While South Korea has limited reserves of critical minerals, such as lithium, cobalt, and REEs, most of its mineral resources concentrate on more abundant metals such as zinc, copper, and gold, but not many critical minerals. South Korea has invested heavily in the recycling of critical minerals due to its limited natural resources. The country is developing advanced recycling technologies to obtain valuable materials from electronic waste, which is a source of critical minerals.

In recent years, many investments have been made in Korea due to the push for energy security and the transition to clean energy sources. Announcement of the National Basic Plan for Carbon Neutrality and Green Growth in 2023 and aims to achieve carbon neutrality by 2050. The plan aims to increase energy production from nuclear power and renewable sources, develop core green technologies, build new green industries with policy support and private financing, and improve relevant systems. Better financial support, such as a response fund that mobilizes private investment, supports the commitment to enhance carbon neutrality policies. Another goal of Korea is to initiate emissions permit trading and improve the emissions trading system (ETS). In addition, Korea committed to increasing development assistance aimed at the global fuel and energy transition by 2025, targeting the industrialization of nuclear exports, as well as the electric vehicle, renewable energy, hydrogen, and CCUS industries. Exports and international cooperation are also considered key pillars of the country's plan to help finance the energy transition (International Energy Agency, 2024d).

Southeast Asia

The critical mineral potential in Southeast Asia is vast, with significant reserves of nickel, tin, REEs, and bauxite. However, the region faces challenges related to downstream processing, environmental impacts, and geopolitical considerations. By addressing these challenges through strategic initiatives and regional cooperation, Southeast Asia can increase its role in the global critical minerals supply chain and support the clean energy transition. The region's important mineral resources provide significant economic opportunities for diversifying conventional economic sectors such as agriculture and manufacturing. Southeast Asia (Figure 11) can increase its industrial production and an export basket by utilizing these resources. Singapore, Malaysia, Thailand, and Vietnam already have robust energy and digital technology manufacturing capacities. Vietnam, Malaysia, and Indonesia are all growing their own EV businesses, while Thailand is the region's biggest automaker and a recent newcomer to the EV market. In addition to being large producers of solar PV panels with worldwide significance, Malaysia and Vietnam are also prominent electronics manufacturers with substantial advantages and skills (IGF, 2023).

The deployment of clean energy increases the demand for valuable commodities. In Southeast Asia, mineral reserves of nickel, cobalt, and lithium are critical for the production of low-carbon technologies such as solar power, wind turbines, and electric vehicles (Seah and Huda, 2024). However, the significant availability of minerals in the region creates a geopolitical problem. The most influential economic and geopolitical powers may emerge as a result of this concentration (Bilqis, Febriyanti and Munardy, 2024).

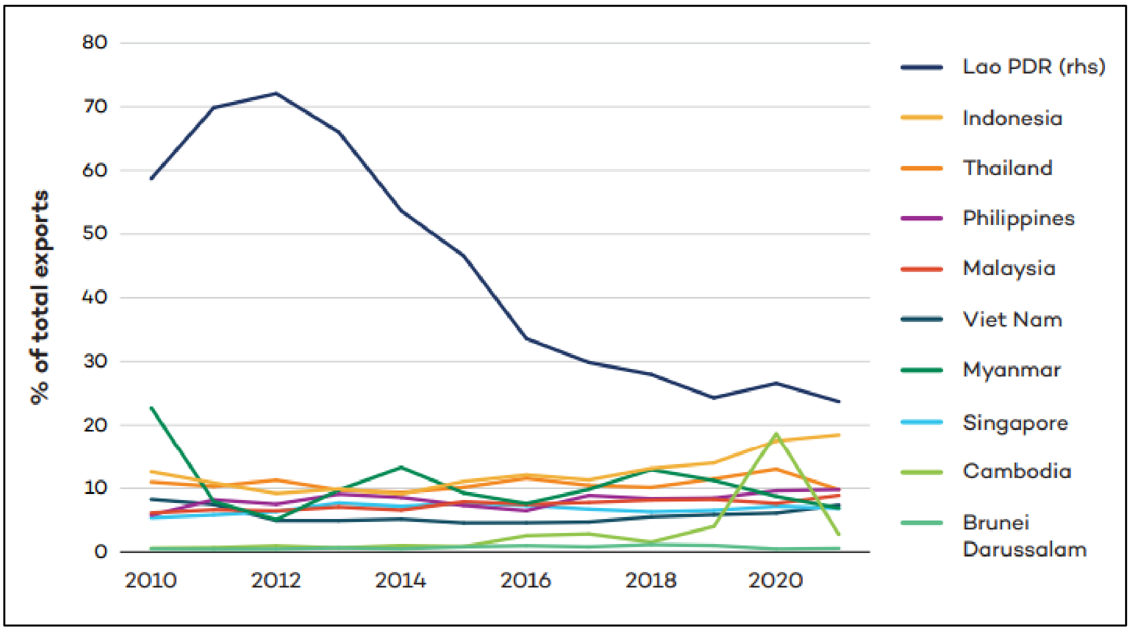
Copper and nickel had decreases of over 61% and 65%, respectively, while overall exploration spending in the region fell by more than 32%. Investors are cautious about greenfield exploration, as seen by the fact that the majority of exploration funds (56%) were allocated to already-existing mines, with grassroots and late-stage development making up just around 22% and 21% of total exploration budgets in 2020, respectively (Figure 12). Although it is unknown what percentage of exploratory expenditures are devoted to Class I and II nickel exploration, Indonesia, which accounts for a sizeable fraction of overall exploration spending, has seen a fall of almost two-thirds during the early 2010s (IGF, 2023).

Myanmar

Myanmar's critical mineral potential is considerable, with reserves of REEs, PGMs, titanium, zircon, lithium, copper, nickel, chromite, lead-zinc-silver-copper, and tin-tungsten. Nonetheless, downstream processing, environmental effects, and geopolitical factors present difficulties for the nation. Myanmar can strengthen its position in the global supply chain for vital minerals and aid in the transition to sustainable energy by tackling these issues through strategic initiatives and regional collaboration.

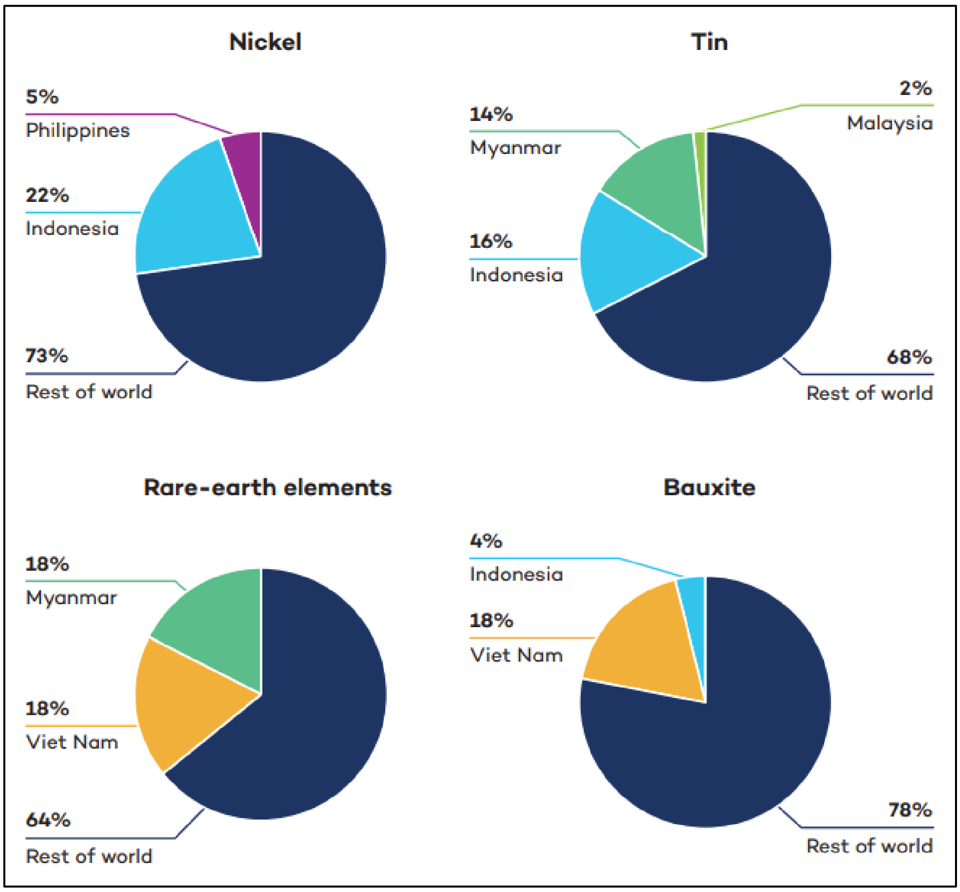
Myanmar has significant REE reserves, which are critical for renewable energy and modern electronic technologies. REE reserves in the country are mainly found in the Belt of Mogok Metamorphic (MMB) and other regions, such as the Belt of Central and Eastern granitoids. PGMs are also critical minerals found in Myanmar, especially in the secondary layers of the Chindwin basin. Zircon and tantalum are also important, with their deposits found in beach sands and plasmas in the southern part of Myanmar. In the MMB, lepidolite and petalite mica in pegmatite dykes contain lithium. The centre of the volcanic belt and the Tagaung-Myitkyina belt contain copper. In the western fold belt, ultramafic rocks of the ophiolite suite are associated with chromite and nickel. These metals are found in strata bound and stratiform deposits in Sibumasu volcanic rocks and Paleozoic carbonate sediments. In the Tanintharyi Region and SW Kayah State, primary tin-tungsten deposits are associated with S-type granitoid belts. They also occur as placers in the surrounding areas (Nyunt *et al.*, 2023).

The huge economic opportunities from Myanmar's mineral resources allow diversification of conventional economic sectors such as agriculture and manufacturing. Myanmar can increase its industrial production and an export basket by utilizing these resources. The deployment of clean energy increases the demand for valuable commodities. Myanmar's nickel, cobalt, and lithium resources are critical for the development of low-carbon technologies such as solar photovoltaic panels, wind turbines, and electric vehicles. Important mineral reserves in the region pose a geopolitical problem as these resources are concentrated in multiple countries. The most influential economic and geopolitical powers may quarrel over this concentration (Phoumin, 2024).



Source: IGF (2023)

Figure 11. ASEAN mining, metals, and metallurgy exports as a share of total exports.

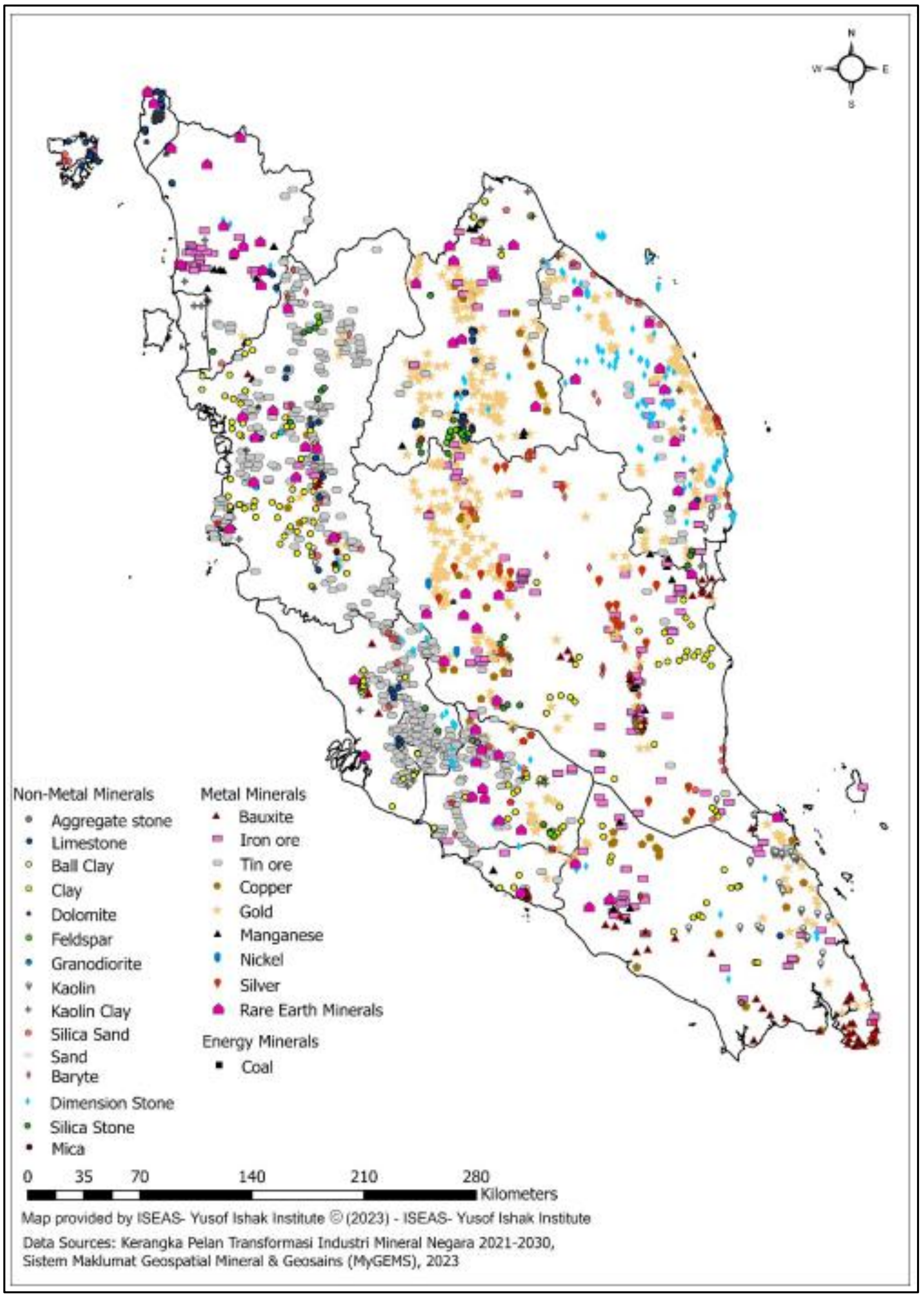


Source: IGF (2023)

Figure 12. Selected mineral reserves.

Malaysia

Non-radioactive rare earth elements (NR-REEs) in Malaysia are estimated to have a value of about RM 747.42 billion, or about US$160 billion, and are critical for EV development. This is mainly related to the magnets that form the main drive motors. Besides bauxite, another strategic mineral valued at about RM20.3 billion, it is critical to the production of aluminum, which is used in the manufacture of EV batteries. Tin ore, historically a critical resource in Malaysia, has seen its production increase due to global demand for EVs and other clean energy technologies. Silica sand and kaolin also have significant potential, with an estimated value of RM 27.9 billion and RM 25.5 billion, respectively. These minerals are used in various industrial applications, such as in construction and ceramic manufacturing (Yean and Rebecca, 2023).



source: Yean and Rebecca (2023)

Figure 13. Mineral resources in Peninsular Malaysia, 2023.

The objective of Malaysia's National Mineral Industry Transformation Plan 2021-2030 (NMITP), launched in 2021, is to make the mineral industry a new source of growth for Malaysia in a sustainable way that involves the value chain. According to this plan, the country's mineral resources consist of metallic and non-metallic minerals. Its extensive presence in all regions of Malaysia can be seen in Figure 13 (Yean and Rebecca, 2023).

Malaysia has many critical mineral resources, including bauxite, tin ore, silica sand, kaolin, and rare earths. However, the country faces issues related to environmental impacts and must comply with international ESG standards. Malaysia can sustainably develop its critical mineral resources and contribute to the global clean energy transition by capitalizing on strategic initiatives and attracting foreign investment.

Indonesia

Indonesia has large reserves of tin, nickel, copper, and bauxite, as well as other critical minerals. However, Indonesia must deal with environmental impacts and comply with international standards on environmental, social, and governance (ESG). Indonesia has the ability to sustainably develop its critical mineral resources and contribute to the global clean energy transition by capitalizing on strategic initiatives and attracting foreign investment.

In order to ensure the supply of mineral raw materials for domestic strategic industries and improve the national defense and security economy, it is necessary to establish criteria for critical minerals and their classification as critical minerals. Currently, the mining industry still focuses on the extraction of the main product and the main by-product. Combining products enables economical extraction, and collaboration between geologists, miners, metallurgists, and the mineral industry enables economical extraction and refining. The types of commodities classified as critical minerals can be seen in Table 2.

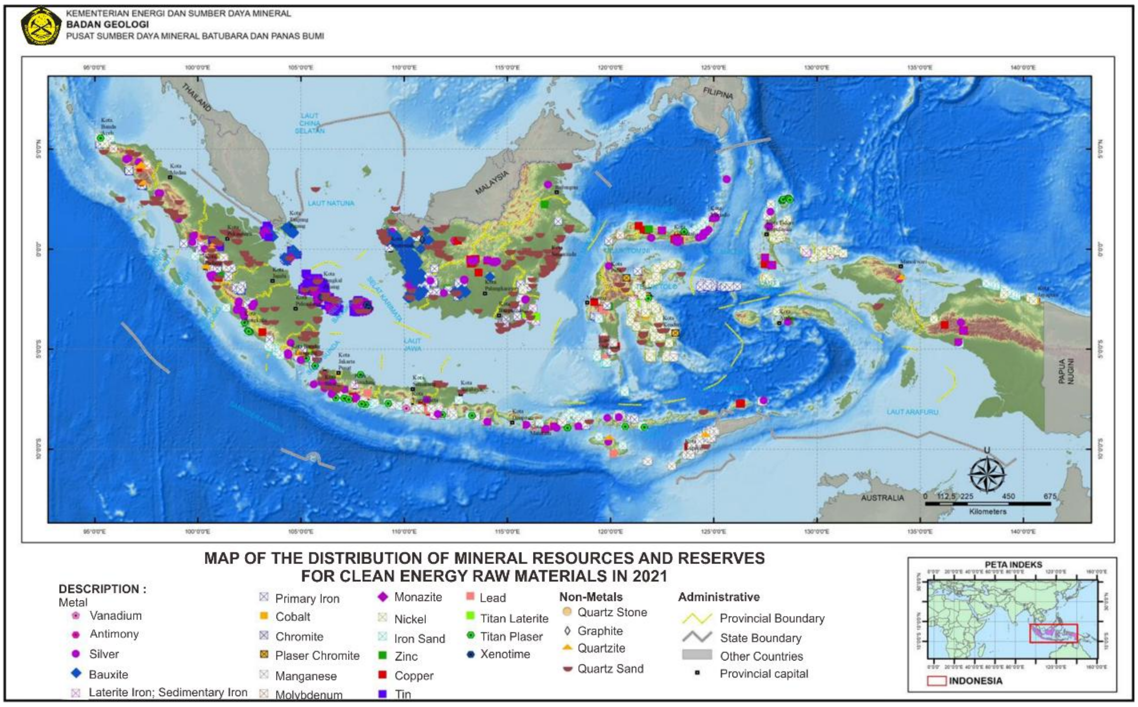
One of the resources used by PSDMBP to perform inquiry activities is a map of REE Indonesia that was created based on the findings of the REE literature study activities from numerous earlier papers. In Sumatra and Bangka Belitung, there are numerous signs; in Kalimantan, Sulawesi, and Papua, there are indications in the form of zircon. The distribution of metal mineral locations, base metal groups like zinc, copper, and tin, iron metal and iron alloy groups like nickel, cobalt, manganese, laterite iron, sedimentary iron, iron sand, and primary iron, as well as the map of strategic minerals and REE based on the released data, are all included in this map. Among the group of precious metals are primary gold, alluvial (Dirjen Minerba, 2020).

Table 2. Critical minerals in Indonesia

No	Elements	No	Elements
1	Aluminum (Al)	25	Manganese (Mn)
2	Antimony (Sb)	26	Mercury (Hg)
3	Iron (Fe)	27	Molybdenum (Mo)
4	Barium (Ba)	28	Nickel (Ni)
5	Beryllium (Be)	29	Niobium (Nb)
6	Boron (B)	30	Palladium (Pd)
7	Bismuth (Bi)	31	Platinum (Pt)
8	Cadmium (Cd)	32	Ruthenium (Ru)
9	Feldspar	33	Selenium (Se)
10	Fluorspar (F)	34	Zinc (Zn)
11	Phosphorus (P)	35	Silica (Si)
12	Galena (Pb)	36	Sulfur (S)
13	Gallium (Ga)	37	Scandium (Sc)
14	Germanium (Ge)	38	Strontium (Sr)
15	Graphite (C)	39	Tantalum (Ta)
16	Hafnium (Hf)	40	Tellurium (Te)
17	Indium (In)	41	Copper (Cu)
18	Potassium (K)	42	Tin (Sn)
19	Calcium (Ca)	43	Titanium (Ti)
20	Cobalt (Co)	44	Torium (Th)
21	Chromium (Cr)	45	Wolfram (W)
22	Lithium (Li)	46	Vanadium (V)
23	Rare Earth Elements (REE)	47	Zirconium (Zr)
24	Magnesium (Mg)		

sources: Menteri Energi dan Sumber Daya Mineral (2023)

Of the total 28 REE mineralization sites (Figure 14), mineralization sites (30%) have been initially explored, but around 19 REE mineralization sites (70%) have not been carried out / have not been optimally explored; this is an opportunity and the main target of the Geological Agency in the future to be offered to investors (Kementerian Energi dan Sumber Daya Mineral, 2020).



Source: Badan Geologi (2022)

Figure 14. Location distribution of mineral resources and reserves for clean energy raw materials.

Challenges on Critical Minerals in Indonesia

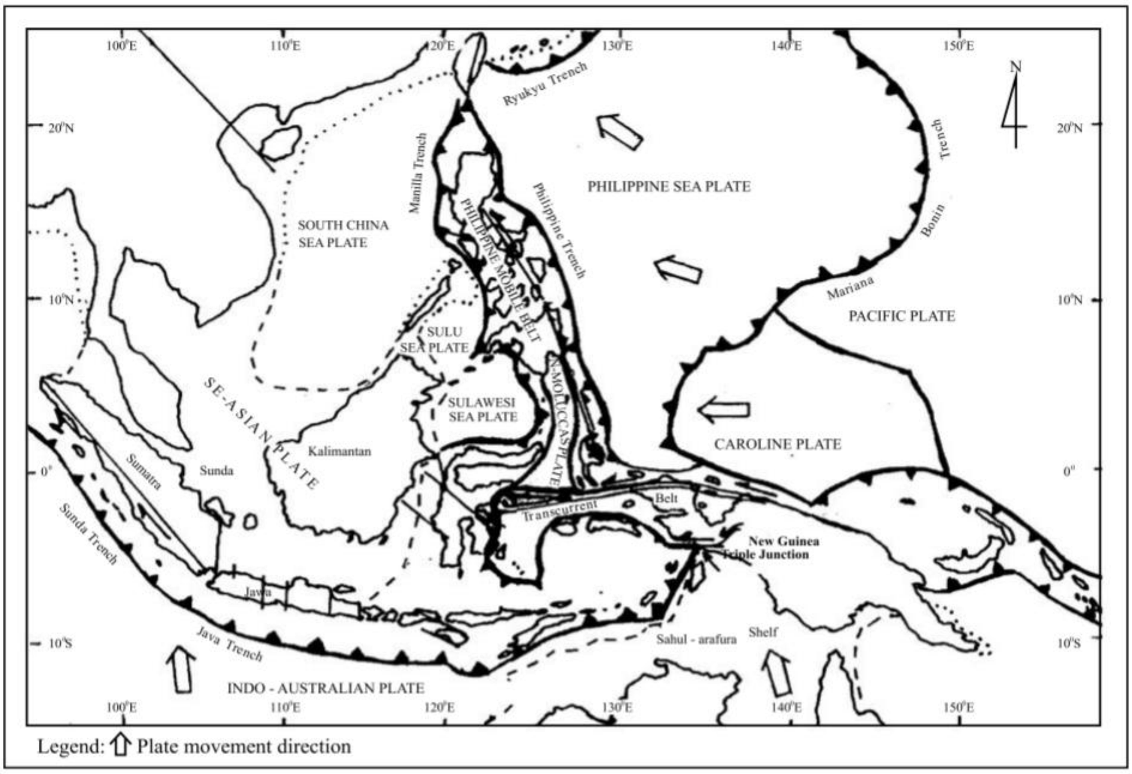
Plate Tectonics

Indonesia is on the Pacific Ring of Fire, a place of high tectonic activity indicated by volcanic and seismic activity. Various minerals such as nickel, gold, and copper can be formed (Wang *et al.*, 2023). Indonesia is located between three major earth plates namely Eurasia, India-Australia and the Pacific. This complex tectonic setting causes many geological phenomena that cannot be fully explained by plate tectonics (Figure 15) (Verstappen, 2010). The area is characterized by subduction zones, volcanic arcs and orogenic belts that create a good environment for the formation of nickel laterite deposits and Pb-Zn skarn deposits.

The exploration process is made more difficult by the presence of compartmental faults and transcontinental faults such as those found in Java and Sumatra. For example, the North Moluccan plate that lies between the Asian and Pacific plates tapers northward in the Philippine Strait Belt and gradually disappears (Verstappen, 2010). Due to the structural complexity of this region, accurately assessing and locating reserves requires sophisticated geological and geophysical techniques. This complexity makes predicting and exploring mineral reserves extremely difficult. Risks such as earthquakes and volcanic eruptions that can disrupt operations and damage infrastructure make exploration more difficult due to tectonic activity.

Mineral Deposits

In Indonesia, nickel deposits and Pb-Zn skarns are formed through various geological processes (König, 2021). Indonesia has many mineral resources including nickel laterites in Sulawesi that are an important part of electric vehicle batteries. The area consists of rocks of Cretaceous-Miocene age, such as ultramafic-mafic igneous rock complexes and limestone. The Lawanopo and Matano shear faults influence the morphology of Southeast Sulawesi (Fatimah *et al.*, 2023). This hinders strategic planning for nickel-related industries such as defense and electric vehicle batteries.



Source: Verstappen (2010)

Figure 15. The plate-tectonic configuration of Indonesia and its surroundings.

The Pb-Zn skarn deposit at Ruwai, Lamandau Regency, Central Kalimantan, is equally important for its critical minerals. These deposits are characterized by prograde and retrograde mineral assemblages with high base metal contents such as Pb-Zn-Cu-Ag. Because retrograde minerals, such as calcite and chlorite, while prograde minerals formed at low temperatures (Budiawan, Bargawa and Idrus, 2022). Challenging, complex Pb-Zn skarn deposits to identify mineralization and geochemical characteristics; the complexity of these deposits requires advanced petrographic analysis and microscopic ore analysis.

In Central Java, the Luk Ulo Complex is one place that shows potential for lithium. With lithium concentrations between 18.2 ppm and 84.7 ppm, the phyllite rocks in the region contain higher concentrations of lithium than the average concentration of lithium in the earth's crust. It is crucial for Indonesia to develop lithium deposits due to the growing demand for lithium-ion batteries worldwide. However, exploration and development of these deposits require funds for infrastructure and technology (Isyqi, Setiawan and Anggara, 2024).

Exploration

This exploration stage consists of various aspects, such as conducting geological surveys to locate mineral deposits and studying rock formations and soil types. Methods used include remote sensing technologies (such as using satellite images to find patterns and anomalies that indicate the presence of minerals), geophysical methods (such as seismic, magnetic, and gravity surveys), or geochemical analysis of soil, rock, or water samples (Rice *et al.*, 2017). Comprehensive geochemical and mineralogical studies of granitoids and their weathered crusts are essential for identifying new REE deposits (Setiawan, 2018).

The measurement of strategic minerals, critical minerals or REE requires an advanced laboratory, which is essential and needed now and in the future. Laboratory analysis work includes physical and chemical analysis. Physical analysis carried out includes petrographic analysis, mineragraphy, grain mineralogy, X-Ray Diffraction (XRD), SEM. Chemical analysis can be done with Inductively Coupled Plasma (ICP), which is used for critical mineral analysis is ICP-OES, ICP-MS, LA-ICP MS. Other equipment that can also be used are Electron Probe Micro Analysis (EPMA), QemScan, Atomic Absorption Spectroscopy (AAS), Neutron Atoms Absorption (NAA), X-Ray Fluorescence (XRF), and stable isotope analysis have been employed to characterize REE mineralization. These techniques have provided insights into the mineral composition and the conditions under which these minerals formed (Badan Geologi, 2019; Tampubolon *et al.*, 2022). Understanding the weak correlation between elements can vectoring to ore future exploration by focusing on specific geological environments where these elements may be independently concentrated. This knowledge can improve resource assessment strategies for critical minerals and REE mining operations in Indonesia (Tampubolon *et al.*, 2024).

Extraction Process

Indonesia is seeking to improve its domestic processing capabilities especially for laterite nickel. However, there are concerns about sustainability due to the energy-intensive and environmentally damaging extraction process. Processing laterites, which often requires pyrometallurgical methods, is energy-intensive, which increases operational costs and environmental impacts (König, 2021). In addition, the extraction and processing of these minerals are hampered by a lack of transparency in the supply chain and a lack of policy synchronization (Fatimah *et al.*, 2023). The complex mineralogy of Pb-Zn makes extraction of Pb-Zn skarn deposits difficult. Specialized mining and processing techniques are required to distinguish critical minerals from associated rocks. This requires advanced technology and higher extraction costs (König, 2021).

Industry

Indonesia's mining industry affects society as a whole. Mining projects have the potential to displace local communities, disrupt their livelihoods, and reinforce existing social inequalities. Meeting the needs of affected communities and ensuring equitable benefit sharing remains a significant challenge (PT Pamapersada Nusantara, 2023). Despite its vast mineral reserves, Indonesia faces challenges in processing due to a lack of infrastructure and technological capacity. Indonesia depends on foreign technology and experience, especially from China and Japan as smelting and refining processes are still very new (Corio *et al.*, 2023).

Critical Mineral Exports

To encourage domestic processing and value addition, Indonesia has implemented strict export regulations on unprocessed minerals, especially nickel. This policy has a significant impact on the worldwide supply chain of critical minerals causing price fluctuations and influencing global market dynamics (Santoso, Dermawan and Moenardy, 2024). Indonesia in the global trade network and the ability to negotiate favorable terms. Being affected by Indonesia's export policies has created tensions with key trading partners, especially in Europe and China, who depend on Indonesian nickel for their industries (König, 2021) regarding allegations that regulations violate international trade agreements.

CONCLUSION AND SUGGESTION

Critical minerals, particularly REE, are not evenly distributed globally, with China dominating production (85%), followed by Australia (10%), and other countries contributing minimally. The total identified REE resources worldwide amount to 478 million tons, with significant concentrations in specific regions like China and Brazil. The demand for critical minerals such as REEs, lithium, cobalt, and nickel is projected to increase significantly, with estimates indicating a doubling of demand by 2040. This surge is driven by the shift towards renewable energy technologies and electric vehicles. Australia has emerged as a major player in the critical minerals market due to its substantial reserves and stable political environment. It leads in lithium production and is a significant supplier of nickel and rare earth metals. Africa holds about 30% of the world's critical mineral reserves, particularly in countries like the Democratic Republic of Congo and South Africa. However, political instability and governance issues hinder its full potential in the global market. The US faces supply chain vulnerabilities for critical minerals despite having significant reserves. The government is taking steps to enhance domestic production through policy support and investment in clean energy technologies. The EU is addressing supply chain risks through legislative measures like the European Critical Raw Materials Act while aiming for strategic autonomy in sourcing these minerals to meet its clean energy goals. The competition for critical mineral resources is intensifying, particularly between the US and China. This competition has implications for global supply chains and geopolitical stability as countries vie for access to essential resources needed for clean energy transitions.

Indonesia is rich in various critical minerals, including nickel, cobalt, and REE. The country has significant reserves that are crucial for the global transition to clean energy and technological advancements. As a major producer of nickel, which is essential for batteries in electric vehicles and renewable energy storage, Indonesia plays a pivotal role in the global supply chain for critical minerals. The demand for these minerals is expected to rise sharply due to increasing investments in green technologies. The regulatory framework in Indonesia can be complex and may pose challenges for foreign investment. Navigating local laws and securing permits can be time-consuming and uncertain, potentially deterring exploration efforts. nadequate infrastructure, particularly in remote mining areas, hampers efficient extraction and transportation of minerals. Investments in infrastructure development are necessary to support the mining sector and improve access to markets. The environmental impact of mining activities is a significant concern. Sustainable practices must be prioritized to mitigate ecological damage and ensure compliance with both local and international environmental standards. Indonesia's strategic position in the global mineral market makes it a focal point for geopolitical competition, particularly between major powers seeking to secure access to critical resources. This competition can lead to pressure on local governance and resource management practices.

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