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The Challenge of the Transition to Renewable Energies: A Geopolitical Approach in the Light of the International Competition for Rare Earth Elements

Abstract: This article aims to analyze the geopolitical dimensions of the transition to renewable energies in light of the international competition over securing access to rare earth elements (REEs), referred to as new geopolitical foundations that give the countries possessing them a geopolitical advantage. The study addressed three elements representing the geopolitics of REEs in renewable energy supply chains, global economic powers' strategies to ensure access to them based on China's dominant position in their markets as well as the geopolitics of international competition to secure access to REEs. The article concluded that the rising demand for REEs sparks a worldwide "mineral war," in which global economic powers line up to secure access to these strategic resources necessary to build a future for clean energy. However, challenges remain significant and complex given their interconnection with the current international energy security mechanisms after many regions with large REEs reserves have become theatres of geopolitical tensions.

Key words: Rare earth elements, Energy transition, Geopolitical dimensions, International competition, Supply chains

Introduction

Present discussions on vital minerals, especially Rare Earth Elements (REEs), revolve around the emerging geopolitical dimensions of the global energy transition. One of the future challenges involves strengthening efforts to decarbonize the global economy, reduce emissions, and progressively phase out fossil fuels, all while protecting energy systems worldwide. Addressing the climate change crisis requires accelerated deployment of renewable energy technologies – solar panels, wind power – and a shift towards electric vehicles. Manufacturing these technologies depends on the availability and supply of critical minerals, mainly REEs, necessary for permanent magnet production.

Meanwhile, global demand for oil and natural gas remains consistent, and the world's attention toward securing future raw material supplies for renewable energies, such as REEs, is also accelerating. Incorporating renewable energy sources into the energy mix promotes energy security to meet a growing share of global energy demand. While these REEs are available worldwide, it takes time for countries to possess reserves in substantial quantities or the capability to extract, develop, and expand their uses. This increases competitiveness among the world's economic powers to secure access to these elements. The geopolitical outlines of Rare Earth Elements are delineated between China and its dominance, the USA and its aspirations, and Europe with its ambitions. The three powers are taking extensive measures to promote the supply chain and develop alternatives to mining these elements, considering the possibility of their depletion within the next fifty to sixty years.

Based on the preceding context, this article aims to analyze the geopolitical dimensions of the shift toward renewable energies in light of the global competition over REEs as vital materials whose significance gradually multiplies for international energy security amid the global energy transition and escalating demand. This research paper will be achieved by addressing the following fundamental question: To what extent does international competition impact securing sustainable supply chains for REEs in shaping the geopolitical dimensions of the transition to renewable energies?

Geopolitics of REEs in Renewable Energy Supply Chains

The International Renewable Energy Agency (IRENA) defines the transition as “the pathway towards transforming the global energy sector from fossil fuels to net-zero carbon by the second half of this century.” While increased energy efficiency and expanding renewable energy sources are critical cornerstones of this energy transition, REEs contribute to both. Firstly, their unique features facilitate increased efficiency in energy systems. Secondly, they are essential to renewable energy technologies (Depraiter, Goutte, 2023, p. 11). This dynamic could create new relationships between countries rich in these resources and others. Disruptions in supply chains have implications not only on the economic aspect but also significantly impact energy security. This becomes crucial as 175 countries strengthened the global response to climate change, seeking to limit the increase in global average temperatures to below 2 degrees Celsius above pre-industrial levels, as outlined in the 2015 Paris Agreement. Besides, over 140 countries declared targets to achieve net-zero greenhouse gas emissions by 2050 or later, equivalent to 90% of global greenhouse gas emissions.

REEs, also sometimes referred to as rare earth metals (REMs), are a relatively new addition to the group of critical raw materials, which refers to non-fuel chemicals that are becoming increasingly important for national energy security. REEs are a group of 17 chemical elements that are considered essential due to their properties, depending on their atomic numbers. There are two groups of rare earths: the heavy rare earths (9 elements: dysprosium, yttrium, terbium, holmium, erbium, thulium, ytterbium, yttrium and lutetium) and the light rare earths (8 elements: cerium, lanthanum, praseodymium, neodymium, promethium, europium, gadolinium and samarium). Most REEs were discovered in the 19th century, except for yttrium (1794), lutetium (1907), and promethium (1943). Their innovative applications in telecommunications and electronics only started in the late 1980s. Despite their name, these elements are not rare; they are relatively abundant and widely available in the Earth’s crust – excluding the radioactive promethium. What makes these materials rare is the difficulty in their extraction and processing, considering two primary factors:

– REEs do not exist in the same types of mineral deposits. Most are dispersed across different locations in different concentrations, often coinciding with heavy metals and hazardous elements. While cost factors and technical performance requirements affect the extraction process, processing REEs is costly due to the low concentration of rare earth ore deposits and the chemical similarities among the elements. Additionally, high-purity, single-element products required for high-tech manufacturing further contribute to the expense of processing rare earth elements (Depraiter, Goutte, 2023, p. 11).

– These rare elements possess individual features that position them in specific markets and use. The U.S. Geological Survey (USGS) describes them as “vitamins” because they produce results that cannot be accomplished individually when added to other elements. They use the metaphor in Japan: “Oil is blood, steel is the body, and rare earth elements are the vitamins of the contemporary economy.” These analogies convey the idea of relatively small quantities being needed to fulfill desired effects (Calderón, Palacio, 2020, p. 341).

REEs, due to their electrochemical and magnetic properties, are an essential component of more than 200 products, including clean energy technology products such as solar panels and wind turbines.They play a key role in the transportation sector, mainly with a focus on Electric Vehicles (EVs), as well as in high-tech applications (such as computers and smartphones) and the defence industry (Bruni, 2022, p. 23). The closures resulting from the COVID-19 pandemic accelerated the growth of the wind and solar energy sectors, fulfilling record economic levels and sales figures due to the urgent need to store renewable resources to guarantee uninterrupted energy supplies.

China, the USA and European Union represent the world’s largest wind energy markets. Demand for permanent neodymium magnets (Nd-Fe-B), classified as rare earth elements, is expected to increase by over 600% from 4,900 tons in 2020 to 37,700 tons by 2040, with their share in clean energy technologies rising from 16 to 41% during that period. The United States is at the forefront of the growing solar energy market, with 23 gigawatts of installed photovoltaic solar power in 2021, intensively working to extend the clean energy approach incorporating REEs extraction. Developing solar panels, crucial for diminishing carbon dioxide emissions, relies on the supply of indium and tellurium, whose demand is rapidly increasing. The automotive sector, specifically electric vehicles, is one of the crucial areas in discussions concerning climate change mitigation measures. Technological advances are projected to escalate the demand for neodymium to 11 times the 2021 level by 2032. The International Energy Agency (IEA) anticipates that to fulfill the Paris Agreement goals by 2040, global annual sales of electric cars and trucks will need to surpass 70 million new vehicles, demonstrating a production increase thirtyfold compared to current levels (Bruni, 2022, p. 23–27).

Most leading countries in the domain of clean energies – mainly the states above – categorize REEs within the list of vital minerals, represented as a critical component susceptible to supply disruption, serving a purpose considered important from evaluators’ perspectives. Hence, a mineral is essential when it serves a fundamental function and has few or no viable alternatives. Alongside specific needs and high demand, minerals become crucial when they demonstrate three dimensions: supply risks often attributed to geological, technological, political, or economic factors originating from their production concentration in specific regions, economic significance due to the increasing use of REEs in permanent magnet applications, and environmental dangers and damage caused by mining activities (Depraiter, Goutte, 2023, p. 07–08).

On the contrary, the supply process of REEs is complex, as their deposits are unevenly distributed geographically. Globally, REEs are located in inland and marginal areas of continents, including southern China and Inner Mongolia, rift zones in East Africa, the Kola Peninsula in northern Scandinavia, eastern Canada, south Brazil, and the USA. While 250 minerals containing rare earth elements have been determined, they are only extracted from a few. The primary economic sources of REEs remain Monazite, Bastnaesite, Xenotime, and Ion-adsorption clay. In contrast, others contain Euxenite, Apatite, Gadolinite, Laporite, Uraninite, Brannerite, Doverite, Pyrochlore, Allanite, Perovskite, Zircon (Depraiter, Goutte, 2023, p. 02–04).

The three primary deposits include:

– Bayan Obo (China): Located in the northwest of Baotou City, it is an industrial site in Northern China within the autonomous region of Inner Mongolia.
– Mountain Pass (USA): The Mountain Pass deposit, situated in the Mojave Desert in California, is the second-largest rare earth deposit in the world and the only rare earth mine in the USA.

Mount Weld (Australia): Mount Weld consists of four deposits, with most minerals containing rare earth elements, such as Monazite. These deposits are rich in heavy REEs, making it the only mine for heavy REEs outside China.

Another significant source of REEs is Ion-adsorption clay deposits stretching across seven provinces in southern China. The ease of extracting REEs, hefty ones, from these deposits makes them economically more viable than other deposits. Between 1988 and 2008, these deposits accounted for 26% of China's REEs production (Depraiter, Goutte, 2023, p. 07).

The present global annual production of Rare Earth Element Oxides (REO) is estimated at around 280,000 metric tons, with 60% coming from China, 16% from the United States, 9% from Myanmar, 8% from Australia, and 3% from Thailand (Depraiter, Goutte, 2023, p. 07). As of 2018 statistics, the global reserves of rare earth elements were estimated at 120 million metric tons. China holds the largest reserve with 44 million metric tons, followed by Vietnam (22 million metric tons), then Russia and Brazil with 21 million metric tons. Individual reserves from India, Australia, the United States, and Greenland surpass one million metric tons.

Table 1

Top 10 rqre earth producing coumtries and estimated reserves in 2018

Country	Official production in 2018 (tons)	Estimated reserves (million tons)
China	120,000	44.0
Australia	20,000	3.4
United States	15,000	1.4
Myanmar	5,000	N/A
Russia	2,600	12.0
India	1,800	6.9
Brazil	1,000	22.0
Thailand	1,000	N/A
Burundi	1,000	N/A
Vietnam	400	22.0

Source: Umbach, 2020, p. 12.

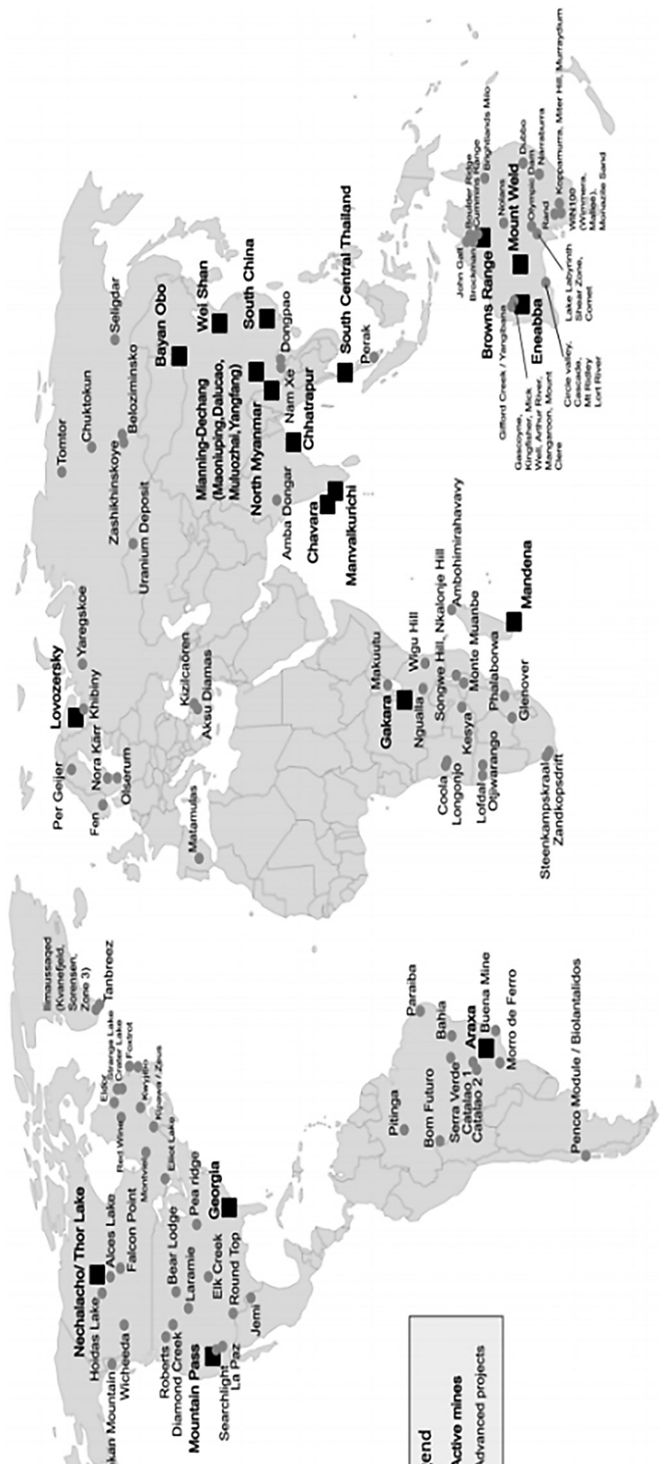

Figure 1. Current global distribution of REE projects, including both active mines and advanced projects

Source: Depraiter, Goutte, 2023, p. 05.

The economic entities’ production and refining in Vietnam, Myanmar, and Thailand may become more critical for the future global supply security of these entities despite their small share of present global production. Besides Chile and Australia (which have recently identified 15 potential rare earth electricity projects and other projects for customer relationship management), some African countries like Burundi may possess essential reserves. Nevertheless, they all need to manage the growing global concerns about the social and environmental conditions of mining and new regulations, which might raise production costs and impede global competitiveness with China-backed renewable energy production (Umbach, 2020, p. 12).

Access to these elements is critical to realizing renewable energy goals. Given several factors that may undermine supply security, the high demand for REEs will increasingly affect geopolitical dynamics in the coming years. These include substantial reliance on imports and potential supply risks, regarding the following factors:

Firstly, many countries heavily depend on REEs imports, varying reliance on the services and products countries produce along their supply chains. Nations making renewable energy technologies are closer to the refining phase in the supply chain than others. For instance, the European Union relies almost entirely on imports. Therefore, the EU has classified numerous raw materials as critical based on their economic significance, supply risks, potential environmental constraints on access to deposits or supplies, and substitutability.

Secondly, the concentrated production of REEs in a few countries has sparked concerns among nations heavily reliant on imports concerning supply risks**.** With the growing significance of renewable energy technologies for energy security and economic competitiveness, supply risks have become a more influential danger to national security. Supply disruptions might be incidental or due to political instability. However, supply disruptions could also be intentional, as transitioning to renewable energy gives countries significant mineral reserves to exert pressure on others. Export quotas or pricing metrics can be employed as strategic political tools, and the temporary suspension of REEs exports from China to Japan in 2010 is an example of the strategic usage of minerals in international relations (Ridder, 2011).

Strategies of global economic powers to secure access to REEs

Based on China’s dominant position in REEs markets, entities such as the U SA, the European Union, and Japan are increasingly concerned about a stable supply of these elements and their growing reliance on China amid rapidly rising global demand. This demand is closely tied to the worldwide expansion of “green technologies,” including renewable energy sources (Umbach, 2020, p. 10), after numerous governments implemented long-term programs and agreements. These initiatives range from the Paris Agreement in 2015 to the more challenging and ambitious Green Deal by the European Union, culminating in the November 2021 declaration to achieve net-zero greenhouse gas emissions by 2050.

While China currently dominates the global mining industry, the fracture of American dominance in rare earth mineral deposits mining since the 1980s led to its complete

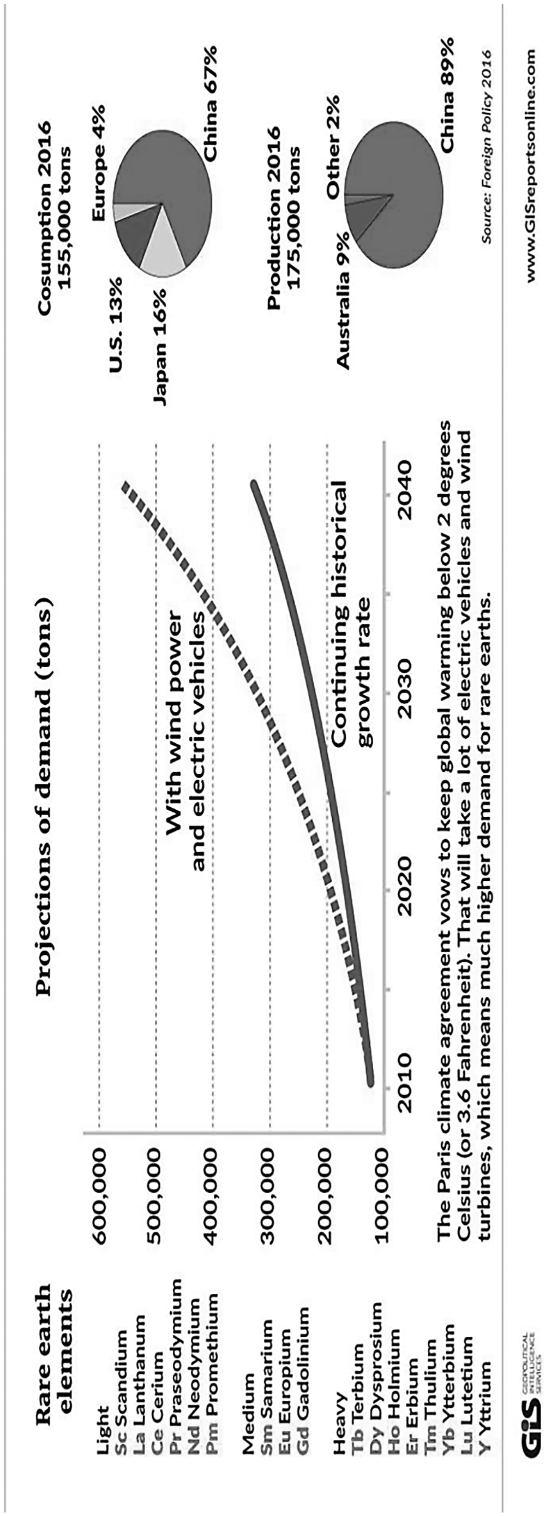

Figure 2. Rare Earth Elements: 2016 Demand–Supply Balance and Demand Projections to 2040 (metric tonnes)

Source: Umbach, 2020, p. 10.

dependence on international suppliers, mainly China, accounting for 72% of its supply, with the EU consuming 10% of the world’s rare earth element production. The primary concern for the European Union lies in ensuring a continuous import of these elements, with 90% of their demand met through imports from China, also its primary supplier. China has frequently exhibited a monopolistic hold over these resources and readiness to use them as a political lever. In response to a dispute with Japan over the Senkaku Islands in 2010, China imposed an export ban on REEs to Japan, subsequently using them as an effective geopolitical tool in political and economic disputes or to strengthen its negotiating position on diplomatic tables, mainly when dealing with adversaries like the USA and Japan (Bielawski, 2020, p. 139).

With the accelerating transition towards renewable energies, the global economic powers’ pursuit of securing access to rare minerals has led to the adoption of various policies and strategies:

China’s Strategy to Secure Access to REEs

China recognized the strategic value of rare earth element products when it began intensively organizing the industry. In 1992, Chinese leader Deng Xiaoping stated in a speech in January 1992: “The Middle East has its oil. China has rare earths… It is of extremely important strategic significance; we must be sure to handle the rare earth issue properly and make fullest use of our country’s advantage in rare earth resources” (Jaroni, Friedrich, Letmathe, 2019, pp. 02–03).

Although China accounts for only about 50% of known reserves of REEs, it produces 100,000 tons of Rare Earth Oxides (REO) out of approximately 112,000 tons worldwide. The primary mine in China, Bayan Obo, in Inner Mongolia, accounts for 48% of global resources. Hence, China now monopolizes mining and refining REEs and the associated technical knowledge. Besides, it has used extra policy tools such as export quotas (until 2015) and, in some cases, control over subsidiary markets producing rare earth element products (Jaroni, Friedrich, Letmathe, 2019, p.03). This position has allowed China to alter its rare earth export system several times over the past few decades. China supported rare earth exports from 1980 to 2003 (the supportive period). It shifted course from 2004 to 2007, imposing export duties and different restrictions (the restrictive period). Export restrictions gradually intensified from 2008 to 2011 (the prohibitive period). Accordingly, the World Trade Organization (WTO) issued a ruling in 2014 against China’s export quota restrictions, which had several impacts on prices (Ganguli, Cook, 2018).

The primary challenge for China lies in preserving its dominance within the renewable energy market. The results of China’s strategic analysis of critical minerals have led to proposing valuable solutions to improve raw material security. It is observed that availability is the primary indicator for determining a state’s raw material security regarding the non-renewable nature of mineral resources and their increasing demand. Consequently, experts have suggested the following solutions. First, continuous efforts in geological exploration and mapping of available raw resources are necessary. Second, a recommendation is to prioritize recycling vital raw materials, primarily focusing on REEs. In this context, China has taken the following steps:

– First, foreign producers must relocate their business activities to China, maintaining low prices and high supply.
– Second, Chinese companies decided to protect their dominance by controlling potential international competitors, as evidenced by the case of Lynas Corp, based in Australia, which announced plans to open a new rare earth mine. Therefore, in May 2009, a Chinese state-owned company offered $366 million, acquiring a controlling stake in the Australian company (Bielawski, 2020, p. 139).
– Third, merging large companies and winding up the scattered small enterprises. Besides, in early August 2018, the Chinese Ministry of Industry and Information Technology (MIIT) set minimum turnover thresholds for local companies, preventing small renewable energy producers from profitable extraction. Furthermore, China approved establishing a Chinese rare earth metals company, "China Rare Earth Group" (Bruni, 2022, p. 48).

Contrary to China's near-complete monopoly over REEs, the supply chain of these elements depends on small, diverse producers and exporters within China. This restricts the Chinese government's ability to influence price negotiations. As a result, the restructuring and unification of the REEs industry became a political initiative pursued

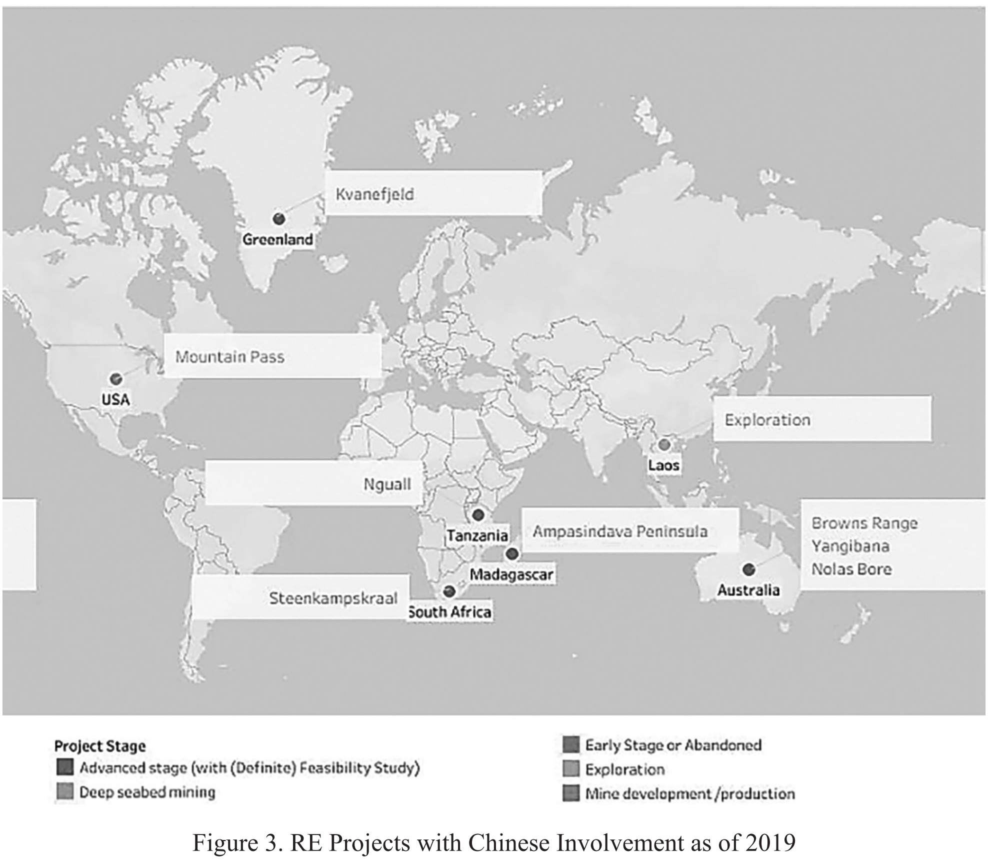

Figure 3. RE Projects with Chinese Involvement as of 2019

Source: Htun, 2023.

by Beijing. In 2021, the Chinese State-owned Assets Supervision and Administration Commission (SASAC) approved a plan to consolidate the “Big Six” rare earth groups to form a conglomerate, the Chinese Rare Earth Group. This merger included three critical players in the rare earth industry: Chinalco, Minmetals, and Ganzhou Rare Earth Group. Besides, it incorporated research institutes such as the China Iron and Steel Research Institute and the Grinm Group Corporation Ltd, both research entities, into the conglomerate. This step strengthens the central government’s direct control over China’s rare earth industry, seeking to promote its position as a dominant player.

Chinese President Xi Jinping created the “One Belt One Road” strategy in 2013, later known as the Belt and Road Initiative (BRI), to ensure a permanent supply of REEs. China established a network system that enabled Beijing to control REEs globally (Bruni, 2022, p. 48).

By 2019, China became the largest importer of raw REEs while remaining the primary exporter. Over the past decade, due to increased environmental restrictions and domestic raw materials limits, China transitioned into the leading global source and importer of REEs to compensate for domestic industrial requirements. Chinese state institutions substantially increased outside the country, particularly in Africa, South America, and Southeast Asia. Over half of China’s imported heavy and non-replicable rare earth materials come from Myanmar. The acquisition of these elements from abroad represents a long-term Chinese strategy to guarantee supply security, protect the Chinese industry from depleting domestic resources, and counteract declining raw material quality and rising mining costs due to stringent environmental regulations.

The USA strategy to secure access to rare earth elements

The USA sometimes depended on foreign suppliers to obtain REEs. Before the 1980s, the USA produced sufficient quantities for its industrial sector. Up to 99% of the global supply of heavy rare elements was derived from the United States’ titanium, phosphorus, and zircon reserves. Recently, the USA government and the private sector have taken several steps to address the country’s dependence on foreign sources for vital minerals, encompassing REEs. In 2008, a group of investors reopened the Mountain Pass mine owned by M.P. Materials, which is currently the only rare earth elements mine in the USA Analysts estimate this mine contains the eighth-largest reserve of REEs globally. However, the USA Department of Energy restricts American scientists from collaborating due to Chinese investor Shenghe Resources possessing nearly 10% of the mine and relying on Chinese sales and technology (Bekoe et al., 2022).

REEs are of utmost significance to the United States’ economic development and national security. An assessment by the National Policy Analysis Center in 2014 confirmed that rare earth elements supported over $298 billion in final economic activity, 535,000 jobs in the USA, and more than $33 billion in payrolls (Chapman, 2018, p. 83).

By 2017, the USA had only one domestic producer of REEs while importing almost all of its needs from China. Despite exporting some REEs concentrates in 2019, the USA imported 100% of its REEs minerals and compounds. According to the U.S. Geological

Survey, “The estimated value of imported REEs and compounds into the US in 2019 was $170 million” (Tracy, 2020). America’s dependence on imported REEs – especially from China, a strategic competitor – led to a review of all available market options. After Beijing’s threats in May 2019 and under directives from former President Trump, the American administration issued a Secretarial Order for “Critical Minerals Independence and Security.” This order aimed to outline four action lines for USA independence from other electromagnet energy suppliers:

- Identifying vital minerals and new sources mainly based in the USA;
- Expanding the list of vital minerals necessary for national security;
- Improving advanced topographic, geological, and geophysical mapping data and ensuring access to bolster private sector research into vital minerals;
- Facilitating leasing processes and allowing expedited exploration (Bielawski, 2020, p. 138).

In February 2021, President Biden issued an Executive Order (E.O.) directing government agencies to review the risks of the American supply chain related to vital minerals, encompassing REEs. This executive order represents the latest efforts by the U.S. government to manage its reliance on imported REEs. It also indicates the increasing role that REEs play in the contemporary economy (Bekoe et al., 2022).

The European Union’s strategy to secure access to REEs

Ensuring reliable and unlimited access to vital raw materials has become an urgent issue in the European Union. European demand is expected to remain at the forefront as various governments have applied long-term programs and agreements, from the Paris Agreement in 2015 to the more challenging and ambitious Green Deal by the European Union. Facing this challenge, the European Commission issued the Critical Raw Materials (CRM) list, which is regularly reviewed and updated. The list entails elements essential to the European Union’s economy and those at high risk of supply shortage. The 2017 assessment of criticality involved 61 materials, while the current CRM list consists of 27 critical raw materials categorized into three groups: HREEs (Heavy Rare Earth Elements), LREEs (Light Rare Earth Elements), and PGMs (Platinum Group Metals).

The European Union’s main challenge is ensuring permanent access to REEs. Estimates indicate that 90% of the demand is met through imports, with China being Europe’s leading supplier. Expecting a growing demand for REEs, the European Union pledged to improve access to these raw materials, decrease consumption, and improve European mining conditions. The European Rare Earths Competency Network (ERECON) was established to accomplish this objective. ERECON experts are divided into three working groups, focusing on barriers to the supply of REEs in Europe, European renewable energy resource efficiency and recycling, and finally, European end-user industries concerning energy supply trends and challenges. They also ensure the supply of REEs to promote dialogue and friendly diplomatic relations with the USA and Japan, such as organizing conferences, such as the one held on October 12, 2017, in Pittsburgh (Bielawski, 2020, p. 140).

Japan’s strategy to secure access to REEs

Japan seeks to vary its sources of imports for renewable energy to encompass countries such as Kazakhstan, Vietnam, and Malaysia while decreasing imports from China and gaining control over 50% of its renewable energy demand by 2030. In April 2018, Tokyo declared the discovery of 16 million tons of rare earth oxides within its exclusive economic zone (EEZ) on the seabed. The deposits are believed to be large enough to meet global demand for several centuries: equivalent to 780 years of yttrium supply, 620 years of europium supply, 420 years of terbium supply, and 730 years of dysprosium supply. Japanese researchers have also developed a new technology for extracting REEs from clay (Umbach, 2020, p. 18).

Japan represents the sixth-largest emitter of greenhouse gases globally, following China, the USA, the European Union, India, and Russia. It has established the “Green Growth Strategy.” It was initiated by the Ministry of Economy, Trade, and Industry in 2020 to neutralize Japan’s carbon and restart the current nuclear energy assets. Japan’s carbon removal will emphasize expanding renewable energy, especially offshore wind power, in addition to ammonia and “green hydrogen.” The strategy envisions renewable energy accounting for between 50% and 60% of electricity generation in the country by 2050, with hydrogen and ammonia contributing 10%. To accomplish this objective, the Japanese government approved the Sixth Basic Energy Plan on October 22, 2021, seeking to double the share of renewable energy in the energy mix from 2019 to 36–38% by 2030. Despite Japan’s explicit commitment to reducing greenhouse gas emissions to net zero by 2050, the transition toward clean energy in Japan faces important challenges related to REEs. Establishing robust supply chains is essential for Japan, which suffers from a scarcity of vital resources and heavily depends on importing most clean energy technologies. The Quadrilateral Security Dialogue (QUAD), comprising Australia, India, Japan, and the United States 2021, committed to financing new production technologies and establishing a global supply chain for these resources. India, which owns the sixth-largest producer of rare earth elements in the world, is regarded as a potential supplier of these resources within QUAD cooperation (Isetani et al., 2022, pp. 02–03).

Besides, various non-members of the Organisation for Economic Co-operation and Development (OECD) could play a significant role in managing REEs in the future, such as the Democratic Republic of Congo (DRC), Argentina, Bolivia, Russia, South Africa, Kazakhstan, and Brazil (Chapman, 2018, p. 63).

Geopolitics of the International Competition for REEs

Amidst the varied strategies of global economic powers to secure access to REEs, the geopolitical dimensions of the shift toward renewable energies are defined within the context of economic competition between China, the USA, Europe and Japan. These dimensions are interlinked with the current international energy security mechanisms, turning many regions into arenas for geopolitical tensions, notably the Exclusive Economic Zones (EEZs), Greenland, Myanmar, and Africa.

Exclusive Economic Zone (EEZ)

Japan discovered REEs within the Exclusive Economic Zone of the Okinotorishima and Minamitorishima Islands, which Japan claims in the Pacific Ocean. Japan allocated $240 million for renewable energy resource development. Besides, $83 million was earmarked to explore deep-sea mining potential for extracting REEs. This discovery quickly sparked diplomatic tensions between Japan and China after Japan announced 2010 its plans to construct maritime barriers around these islands. In response, China stated that Okinotorishima is not an island but merely a rock and cannot have its own Exclusive Economic Zone. Therefore, China opposed Japan's seabed mineral research. Tensions between these two countries persist, as Japan officially protested against unauthorized Chinese seabed research around Okinotorishima in 2018 in response to China's exploration of critical minerals in the same area (Kakisim, 2021).

Greenland

Greenland represents another area of geopolitical competition regarding renewable energy reserves. It is an autonomous region in the North Atlantic under Danish sovereignty. Its REEs reserves are estimated to be up to 38.5 million metric tons, which is essential compared to the global total of about 120 million metric tons (Umbach, 2020, p. 02). The Kvanefjeld region in southern Greenland is one of the largest reserves globally, hosting nine deposits of REEs. The potential of Kvanefjeld has sparked a new competition between China and the USA, leading both countries into a race for mining investments in the area (Kakisim, 2021).

Given China's dual interest in the Arctic and maintaining its dominance in the global supply chain of REEs, it is unsurprising to witness substantial Chinese investment in rare earth mining projects in Greenland. The Kvanefjeld project in the town of Narsaq presents a promising opportunity to achieve this. Presently, the site is controlled by Greenland Minerals and Energy (GME). This Australian company acquired it in 2007 and has invested around $60 million to develop the project to its current advanced stage. Notably, the Chinese company Shenghe Resources emerges as the largest shareholder in the company. This is one of several projects depicting a remarkable portion of Chinese Foreign Direct Investment in Greenland, accounting for 11.6% of Greenland's Gross Domestic Product in 2017 (Gupta, 2020, p. 12–13).

China stands for the establishment of research stations to explore the region's wealth while keenly developing diplomatic relations with Greenland on the one hand and concentrating its investments in the Kvanefjeld area on the other (Kakisim, 2021). A white paper issued by the State Council in January 2018 outlining China's Arctic policy seeks to bring stakeholders opportunities to collectively build the Polar Silk Road, facilitate communication, and promote sustainable economic and social development in the Arctic. With its infrastructure shortages and growth potential, China views Greenland as a fertile investment ground.

Given that Greenland requires foreign investments to benefit from its natural resources, it is inclined to establish commercial ties with China, which appears more willing

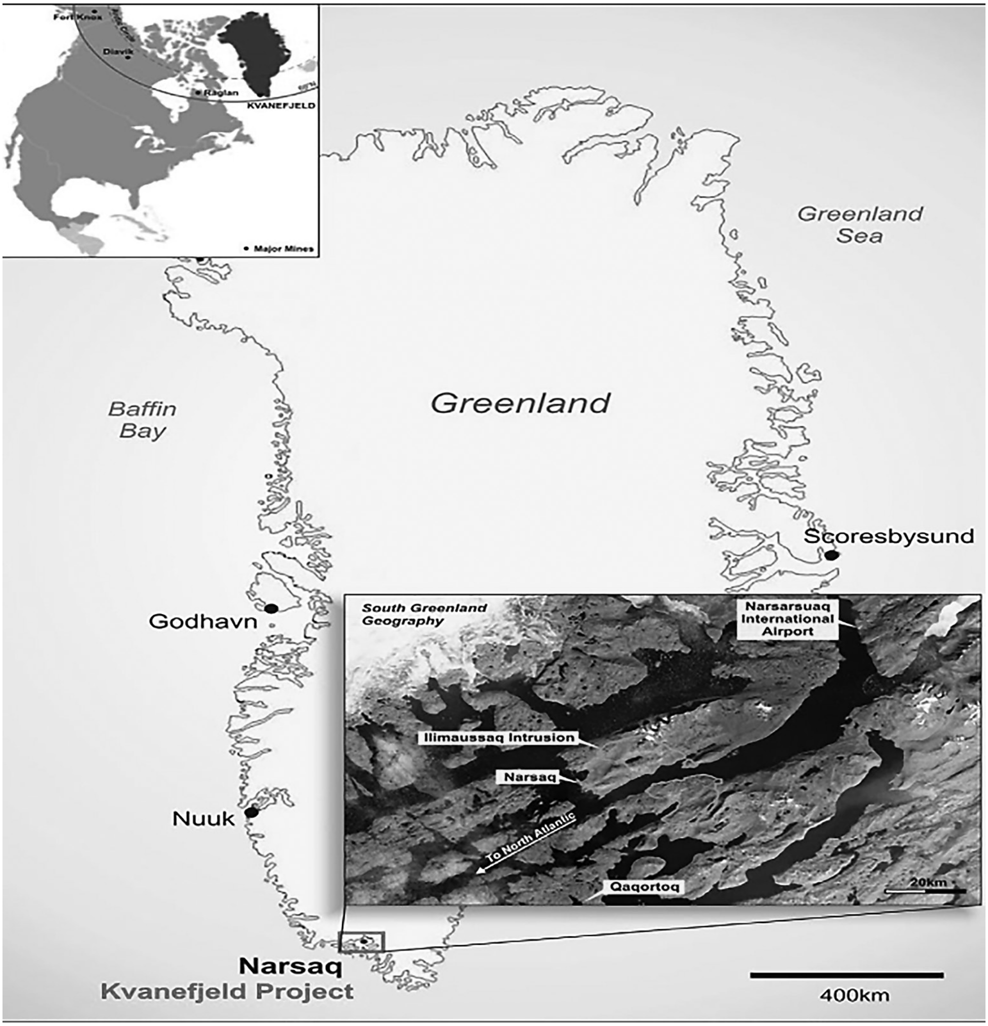

Figure 4. The Kvanefjeld Project is ideally located in southern Greenland

Source: Greenland Minerals and Energy Limited, 2015.

to assist Greenland. Greenland has warmly embraced such initiatives, while Denmark and the US remain skeptical of China’s moves in this direction (Gupta, 2020, p. 07–08). The USA was prompted by China’s initiatives and presence, including an airbase in Greenland. After Beijing’s threats in May 2019, the U SA signed a memorandum of cooperation with Greenland to bolster investment in renewable energy mining as part of broader efforts to diversify imports and achieve federal strategic goals by ensuring secure and reliable supplies of vital minerals through establishing alternative supply chains outside China. Taking another step, then-US President Donald Trump made a statement that shocked global public opinion, expressing their interest in purchasing Greenland (Kakisim, 2021).

On the other hand, Greenland has clarified that it is "not for sale, but open for business" (Gupta, 2020, p. 17). As an autonomous region within Denmark, Greenland governs decisions regarding marketing its resources. However, Denmark can override such decisions when national security matters are at stake. The debate around developing REEs revolves around this fine line. On one hand, it presents prosperous economic opportunities; on the other, it raises national and security implications. Furthermore, given Greenland's reliance on Denmark for a critical portion of its income, Greenlanders hope to chart a path toward financial independence and view REEs as a means to achieve that (Gupta, 2020, pp. 07–08).

Myanmar

Concerns within China about the environmental influence of rare earth mining, coupled with the enactment of stricter environmental regulations in southern Chinese provinces in 2016, have been a critical factor driving further mining of REEs in unregulated border areas such as Kachin State (Chinkaka et al., 2023). Most of Myanmar's REEs come from the northeastern border regions of Kachin State, adjacent to Yunnan. This area has been a stronghold for civil disobedience movements and armed resistance against the Myanmar government, aiming for greater autonomy, especially since 2011. It has been a stronghold for civil disobedience and armed resistance in Myanmar since the military coup in February 2021 following the collapse of a 17-year ceasefire agreement (Sadan et al., 2022, p. 09, 13).

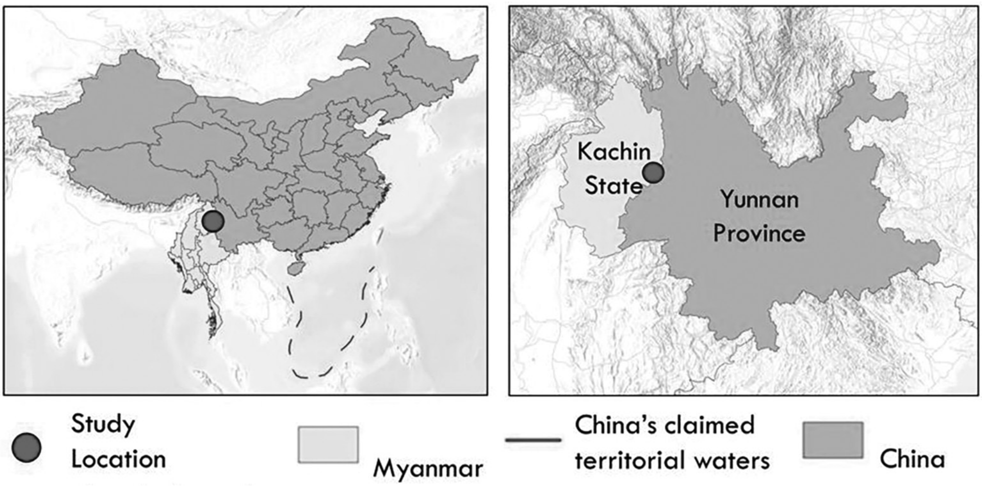

Figure 5. Study area (Myanmar–China border) – Myitkyina (Kachin State) and Nujiang

Source: Chinkaka et al., 2023.

The crisis in Myanmar emerges as a model of conflict, particularly regarding its prominent position in the REEs industry market. Myanmar holds half the world's rare earth ores, exporting its rich, heavy mineral wealth to China for extraction, processing, and subsequent exportation worldwide. This is due to geographic proximity to China, ideological alignment, and important integration between China and Myanmar, which has pushed China to be vigilant about keeping American influence away from Myanmar, given its status as a main source of China’s imports of these minerals with the likelihood of eight potential REEs –providing areas in Myanmar, as suggested by Ye Myint Swe (Nyunt et al., 2023).

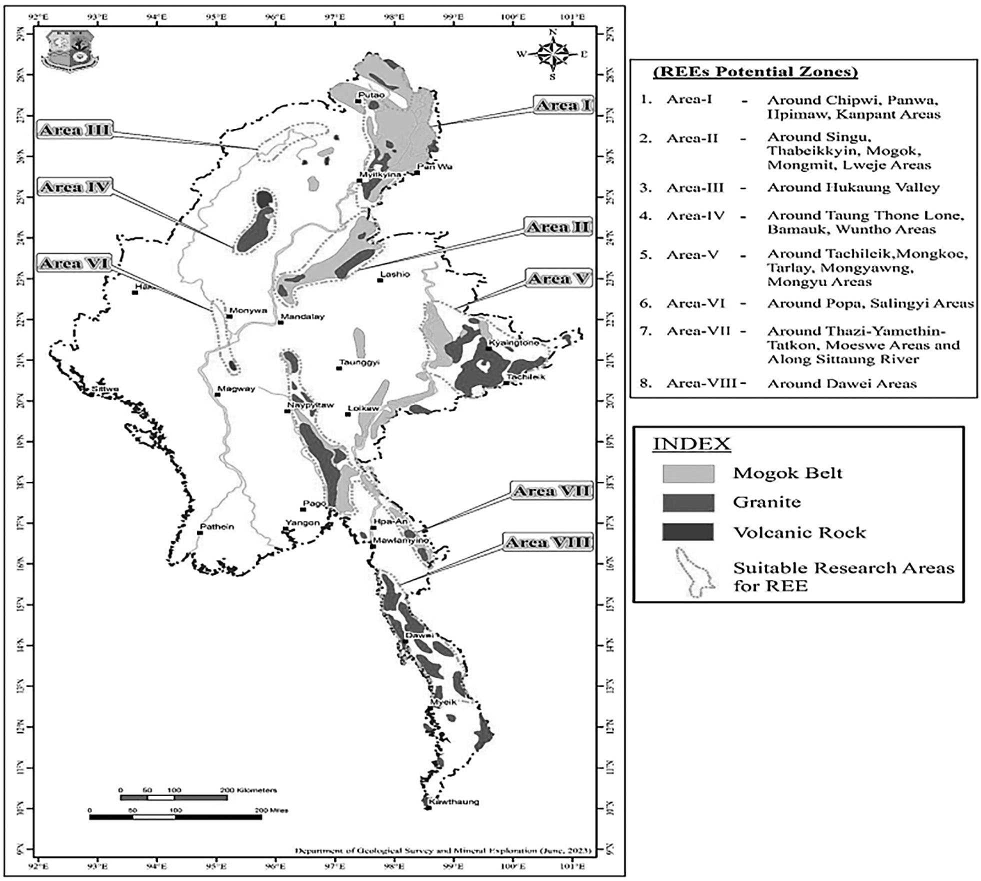

Figure 6. Potential areas for REEs occurrences in Myanmar

Source: Nyunt et al., 2023.

Reuters reported that in 2020, Myanmar supplied 71% of China’s imports of REEs mixtures with carbonates, 94% of rare earth compound imports, and 90% of major rare earth oxide imports. Therefore, Myanmar’s increased production and exportation propelled it to the forefront of global REEs producers. This was further supported by data from the USA Geological Survey, which ranked Myanmar (Burma) as the world’s third-largest global producer, nearly matching the output of the second-largest producer USA in 2019 and surpassing Australia’s fourth-largest producer by more than double in 2020. These statistics indicate that Myanmar’s current production from its border regions significantly contributes to global REEs supply chains (Sadan et al., 2022, p. 09).

Africa

Most mining companies exploring or producing REEs operate outside Africa. However, with the transition of global powers towards African markets to promote influence, the extraction of REEs on the continent will likely increase. The latest data from the US Geological Survey indicates the presence of 99 sites for REEs deposits in Africa, spread across 27 countries.

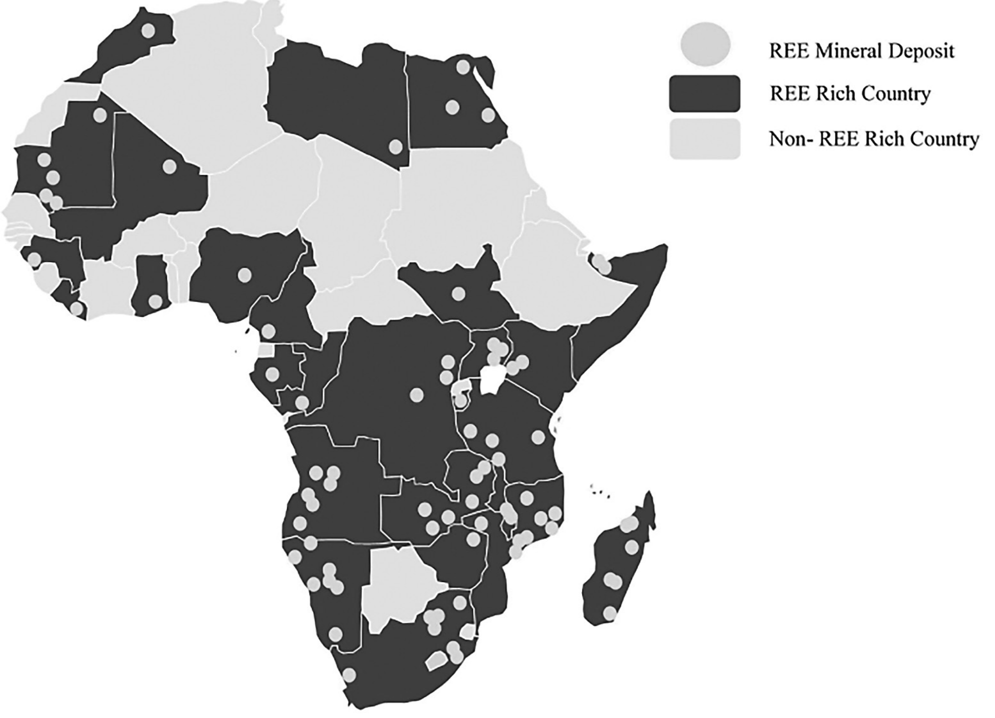

Figure 7. Distribution of REE Deposits in Africa

Source: Bekoe et al., 2022.

Only five African countries – Mozambique, Angola, South Africa, Namibia, and Malawi – possess half of Africa’s REEs deposit sites. Eight countries engage in mining, but as of January 2022, Burundi is the sole African country with a rare earth mine Gakara capable of commercial-scale production. No specific mining projects exist in the remaining nineteen countries with REEs deposits. Data indicates that ownership of African mines is concentrated in the hands of a few companies from Europe (Germany, Luxembourg, and the United Kingdom), Canada, Australia, and Africa (Mozambique and South Africa) (African Natural Resources Centre, 2021, p. 28).

As diversifying REEs sources outside China is essential for the economic and national security interests of the USA, there is increasing interest in African REEs mines due to the growing USA demand for these elements. This interest originates from China's control over the international supply of REEs as a strategic tool in its trade dispute with the USA in 2019. Recently, the CEO of Rainbow Rare Earths, managing the Gakara mine in Burundi, mentioned that an escalating trade war between the USA and China would "put us in a good position" (Bekoe et al., 2022). The Belt and Road Initiative has opened avenues for important investments and the acquisition of mining sites. On the other hand, the USA, the European Union, and Japan have relied on several policies, including the American Prosper Africa initiative, to secure future access to vital resources. In 2019, following the Presidential Advisory Council on Doing Business in Africa (PAC-DBIA) report for 2017, the Prosper Africa initiative was launched. The report highlighted that American companies' efforts to secure commercial contracts in the vital African mining sector were being undermined by foreign competitors, especially China and the Belt and Road Initiative (BRI). This initiative was particularly relaunched and reframed in 2021 due to limited progress and uptake by American companies. In July 2021, the Biden administration declared a reimagining of "Prosper Africa" to expand trade cooperation between the United States and Africa regarding a 100-day supply chain review (Andreoni, Roberts, 2022

Conclusion

Although RREEs do not constitute a traditional sector or industry, they are significant resources for several industries and sectors that have gained significance in the technological transition towards zero-carbon emissions. Energy transition has become an essential strategy for governments in tackling climate change, leading to increased demand for these elements. Wind turbine technologies, solar panels, and electric vehicles are expected to increase at an unprecedented scale and rate as governments commit to programs and agreements toward 2050 boundaries. This indicates that widespread consumption of Rare Earth Elements has yet to be thoroughly tested.

The risks associated with disrupting the supply chains of these elements go beyond threatening the transition to low-carbon technologies; they also threaten energy security. Delays or disruptions in deploying these technologies could endanger energy security.

The challenge of extracting REEs, amid global interest in securing future raw material supplies for renewable energies, has led many countries to depend on importing products containing these elements rather than developing their primary sources. This situation is exacerbated due to several factors that may increase the likelihood of disruptions in the supply of some of these elements, such as geological scarcity, disruptions in vital metal markets, and geographic concentration of certain ores in a few potentially unstable countries, which could be used as an effective geopolitical tool by dominant players like China. Furthermore, there is limited ability to recycle these elements after initial consumption, a continuous decline in their concentration in mineral ores, and a shortage of suitable alternatives.

The growing demand for REEs instigates a "metals war" globally, with global economic powers aligning to secure these strategic resources necessary for building the future of clean energy. The challenges remain important and complex, particularly regarding their interconnection with current international energy security mechanisms. Numerous regions holding vital reserves of REEs have become arenas for geopolitical tensions in the pursuit of securing sustainable supply chains for these critical earth treasures.

Author Contributions

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Wyzwanie przejścia na odnawialne źródła energii: podejście geopolityczne w świetle międzynarodowej konkurencji o metale ziem rzadkich

Streszczenie

Niniejszy artykuł ma na celu analizę geopolitycznych wymiarów przejścia na odnawialne źródła energii w świetle międzynarodowej konkurencji o zabezpieczenie dostępu do metali ziem rzadkich (REE), określanych jako nowe fundamenty geopolityczne, które dają krajom je posiadającym przewagę geopolityczną. Badanie dotyczyło trzech elementów reprezentujących geopolitykę REE w łańcuchach dostaw energii odnawialnej, strategii globalnych potęg gospodarczych mających na celu zapewnienie dostępu do nich w oparciu o dominującą pozycję Chin na ich rynkach, a także geopolityki międzynarodowej konkurencji o zabezpieczenie dostępu do REE. Artykuł zakończył się wnioskiem, że rosnący popyt na REE wywołuje światową „wojnę mineralną”, w której globalne potęgi gospodarcze ustawiają się w kolejce, aby zabezpieczyć dostęp do tych strategicznych zasobów niezbędnych do zbudowania przyszłości dla czystej energii. Jednak wyzwania pozostają znaczące i złożone ze względu na ich powiązanie z obecnymi międzynarodowymi mechanizmami bezpieczeństwa energetycznego po tym, jak wiele regionów z dużymi rezerwami REE stało się teatrami napięć geopolitycznych.

Słowa kluczowe: metale ziem rzadkich, transformacja energetyczna, wymiary geopolityczne, międzynarodowa konkurencja, łańcuchy dostaw

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