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Abstract: Rare Earth Elements (REEs) are fundamental components in modern technology, yet often overlooked. Once confined to specialized fields, these elements are now recognized for their pivotal role in green energy and high-tech industries. REEs are crucial for renewable energy technologies, such as wind turbines and electric vehicles, and are integral to advanced military systems. China's dominance in REE production has created geopolitical tensions and supply chain vulnerabilities, pushing other nations to secure alternative sources and develop their own sustainable processing methods. This dominance also has potential geopolitical implications, as it gives China significant leverage in global power dynamics and international relations. This essay examines the strategic importance of REEs in these contexts, highlighting the need for diversified supply chains and innovative extraction technologies.

Sometimes, the most fundamental components in our lives are the ones we overlook. What has long been only known to chemists, geologists, specialized materials scientists, and engineers has become a hot topic in many areas of the world. Rare Earth Elements (REEs), frequently utilized in modern technologies and the transition to clean energy, are gaining recognition as a result of the distinctive characteristics they possess. Before discussing the various technological uses of REEs and the geopolitical conflicts related to their supply, it is essential to define what REEs are. Rare Earth Elements (REEs) consists of 15 metallic elements, ranging from lanthanum (atomic number 57) to lutetium (atomic number 71), collectively known as lanthanides on the periodic table. Although yttrium (atomic number 39) is not a lanthanide, it is frequently grouped with REEs because of its similar chemical properties and its presence in the same mineral deposits. Scandium (atomic number 21) also shares chemical similarities but is less commonly included in the REE category. REEs are divided into light and heavy subgroups and are valued for their unique magnetic, optical, and electrochemical properties, which make them essential in diverse areas of high-tech applications. These include social networking, internet browsing, computing, buying, transportation, environmental sustainability hacking, and warfare. To illustrate the power of REEs, a rare-earth magnet is stronger per unit weight than any other magnet that exists.[1]

Despite their name, REEs are relatively abundant in the Earth's crust, though concentrated and economically lucrative deposits are rare. The extraction of rare earth elements is challenging because they are seldom found in concentrated, pure forms and are usually mixed with other minerals. Consequently, the separation and refining processes are both complex and costly.[2] In essence, rare earth elements are a strategic commodity over which states actively compete for control. Their scarcity or limited availability poses a

[1] Philip J. King, "Rare Earth Elements: A Critical Resource for High-Tech Industries," *Elements* 8, no. 5 (2012): 333, https://doi.org/10.2113/gselements.8.5.333.

[2] Bradley S. Van Gosen et al., working paper, *The Rare-Earth Elements— Vital to Modern Technologies and Lifestyles* (USGS Mineral Resources Program, 2014), 1-2, https://pubs.usgs.gov/fs/2014/3078/pdf/fs2014-3078.pdf.

significant risk to economic prosperity and national security, highlighting potential vulnerabilities that could undermine a nation's stability. Consequently, securing access to rare earth elements is essential for a country's economic security and strategic resilience.[3]

Analysis

Rare earth elements were largely overlooked until the 18th century. Not until the 19th century were they identified as distinct elements, when their use began to take hold. From the 1960s through the late 1990s, the United States dominated global REE production, a picture that has since been inverted. The Mountain Pass mine in California, which opened in the 1960s, epitomized this dominance. However, the Mountain Pass mine faced significant challenges. In 2002, it closed following a toxic waste spill. Molycorp acquired the site in 2008, investing $1.7 billion to modernize and restart operations. Despite initial optimism, Molycorp struggled and filed for bankruptcy in 2015. The trial and error continued when MP Materials acquired Mountain Pass in 2017, supported by the Pentagon’s funding.[4]

Before the 1980s, the U.S. was entirely self-sufficient in meeting its own needs for REEs and ranked as the world's largest extractor of these elements. However, over the past few decades, the landscape of REE mining and production has changed dramatically, particularly in the 1980s and 1990s. China entered the market, flooding it with low-priced RREs while simultaneously expanding its electronics and other manufacturing industries. Mines globally struggled to compete with China’s prices and began to close. Environmental regulations and higher labor costs in the U.S. made domestic production less economically viable. The U.S. government and manufacturers found sourcing REEs from countries with less stringent environmental regulations more cost-effective. By the late 1990s, China

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[3] Ryan D. Kiggins, “The Strategic and Security Implications of Rare Earths,” in *The Political Economy of Rare Earth Elements Rising Powers and Technological Change*, ed. Ryan D Kiggins (London: Springer Nature, 2015), 2.

[4] “History and Future of Rare Earth Elements,” Science History Institute, May 11, 2023, https://www.sciencehistory.org/education/classroom-activities/role-playing-games/case-of-rare-earth-elements/history-future/.

supplied 85%-95% of the world's REEs, establishing a near-monopoly.[5] In July 2010, China announced a 72% cut in rare earth exports, and in September 2010, it temporarily halted rare earth exports to Japan due to a maritime dispute.[6]

China's dominance in REE production has led to its aggressive pursuit of new sources globally, particularly in Africa and Latin America. This expansion strategy aims to secure China's position in the REE market and extend its influence in developing regions. In Africa, China has exchanged infrastructure development for mining rights. For instance, in the Democratic Republic of Congo, China gained access to lithium, cobalt, and coltan mines in exchange for building essential infrastructure. Similarly, Kenya received $666 million from China for a data center project while granting commercial licenses for mineral exploration, including REEs. China has targeted several other African countries rich in strategic minerals, including Cameroon, Angola, Tanzania, and Zambia. This expansion is not limited to Africa. China has significantly increased its economic presence in Latin America and the Caribbean. Trade between China and Latin America grew from negligible levels in 1990 to $270 billion by 2012. The discovery of a significant rare earth deposit in Brazil in 2012, valued at $8.4 billion, further solidified China's interest in the region, with China becoming Brazil's top trade partner.[7]

The risk of China's hold on REEs is not a future concern but a present reality. Production of F-35 jets for defense was halted after components were found to include materials sourced from China, contrary to military requirements. More broadly, the shift in production to China has led to increasing geopolitical tensions and supply concerns.[8]

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[5] See note 2.

[6] Jeffery A. Green, "The Collapse of American Rare Earth Mining — and Lessons Learned," *DefenseNews*, November 12, 2019, https://www.defensenews.com/opinion/commentary/2019/11/12/the-collapse-of-american-rare-earth-mining-and-lessons-learned/.

[7] Russel Parman, "An Elemental Issue," *U.S. ARMY*, September 26, 2019, https://www.army.mil/article/227715/an_elemental_issue.

[8] Lara Seligman, "China Dominates the Rare Earths Market. This U.S. Mine Is Trying to Change That," *Politico,* December 14, 2022, https://www.politico.com/news/magazine/2022/12/14/rare-earth-mines-00071102.

However, the majority of processing still occurs in China, with U.S.-mined rare earth concentrate being sent there for processing.

The U.S. is taking steps and financial costs to swing the pendulum back on its standing in the race for rare earth elements. Among these efforts are the Lynas Rare Earths Projects aimed at processing light rare earth elements. The U.S. has plans for the first commercial-scale separation facility of heavy rare earth outside China.[9] M.P. Materials has gained contracts from the U.S. Department of Defense for rare earth production. The EMBER Project focuses on developing new REE extraction and processing technologies, exploring methods including using microbes and engineered proteins.[10] Notably, for mining heavy REEs, which are more scarce in the U.S., the country will likely look to Latin America. As the U.S. seeks to turn the tides in the tug-of-war of rare earth, these developments underscore China's global strategy to secure rare earth supplies and expand its economic influence, particularly in resource-rich developing regions. China's approach not only strengthens its position in the REE market but also increases its geopolitical leverage, potentially complicating efforts by other nations to diversify their rare earth supply chains away from Chinese dominance.[11] This vulnerability was highlighted in 2010 when China temporarily blocked Japan's access to REEs, prompting increased attention from the U.S. government.

The importance of REEs in defense applications is hard to overstate. Due to their unique properties, such as high magnetic strength and resistance to demagnetization, they are critical for defense and weapon systems. These elements are used in the production of powerful magnets essential for precision-guided munitions, missile guidance systems, and

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[9] Maiya Clark and Ryan Williams, "Rare Earth Elements Aren't That Rare, but They're Vital to National Security," *The Heritage Foundation* (blog), February 26, 2021, https://www.heritage.org/defense/commentary/rare-earth-elements-arent-rare-theyre-vital-national-security.

[10] Mikayla Easley, "U.S. Begins Forging Rare Earth Supply Chain," *National Defense Magazine*, February 10, 2023, https://www.nationaldefensemagazine.org/articles/2023/2/10/us-begins-forging-rare-earth-supply-chain.

[11] Patricia Garip, "Rare Earth Elements Are Trending. Will They Drive Latin America's Next Mining Boom?," *Americas Quarterly,* June 27, 2024, https://www.americasquarterly.org/article/rare-earth-elements-are-trending-will-they-drive-latin-americas-next-mining-boom/.

advanced radar and sonar technologies. Precision-guided munitions use REE-based permanent magnets in their guidance systems to control and direct the munition to its target. Similarly, samarium-cobalt, a type of REE, is used to develop missile fins that direct the missile according to guidance data.[12] Advanced military technologies, such as the F-35 jet and Virginia-class submarines, require substantial amounts of these elements. The F-35 fighter jet contains nearly 1,000 pounds of REEs. REEs are crucial components in guidance systems, electronic warfare systems, and precision weapons, enabling the technology synonymous with modern military equipment.[13]

Government stake in rare earth production and processing is crucial for defense and the energy industry. As global efforts to achieve sustainability goals intensify, the demand for green technologies is surging, increasing the strategic importance of REEs. These elements are essential for the transition to renewable energy due to their application in technologies like wind turbines and electric vehicles (EVs). With their distinct magnetic properties, neodymium, praseodymium, dysprosium, and terbium are needed to produce the powerful permanent magnets used in EV motors and wind turbine generators. These are used for effective energy conversion and storage.[14]

Nations and industries that control the supply and processing of these elements gain significant leverage in the global push toward a greener future. The geopolitical implications of this shift are profound. REEs play a pivotal role in the global transition towards clean energy and sustainable technologies, extending far beyond their applications in defense systems. As the world intensifies its efforts to combat climate change, the importance of REEs in enabling green technologies has become increasingly apparent. Without a stable

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[12] James B Hedrick, "40th Forum on the Geology of Industrial Minerals" (Bloomington, Indiana, 2004), 4-5, http://www.usmagneticmaterials.com/documents/RARE-EARTHS-IN-US-DEFENSE-APPS-Hendrick.pdf.

[13] Peter Grier, "Rare-Earth Uncertainty," *Air & Space Forces Magazine*, December 21, 2017, https://www.airandspaceforces.com/article/rare-earth-uncertainty/.

[14] Dolf Gielen and Martina Lyons, report, *Critical Materials for the Energy Transition: Rare Earth Elements* (Abu Dhabi: International Renewable Energy Agency, 2022), 6-11. https://www.irena.org/Technical-Papers/Critical-Materials-For-The-Energy-Transition-Rare-Earth-elements.

supply of REEs, the scalability and efficiency of renewable energy technologies would be significantly compromised, slowing global efforts to reduce carbon emissions and combat climate change.[15]

Contrary to the common belief that REEs are purely beneficial for the energy transition, recent studies have highlighted the environmental costs associated with their extraction. While environmental regulation has long been a crucial concern in REE mining, the rapid development of green energy technologies has led to unsustainable consumption of these elements and increased greenhouse gas emissions during the extraction phase. A study by Langkau and Erdmann examined the specific environmental impacts of REEs used in magnet applications and explored potential policy measures to mitigate these adverse effects. Among the most promising strategies are the more efficient use of REEs, improving the environmental standards of mining practices, and preventing illegal mining—particularly in China, the world's largest producer of REEs.[16]

Simultaneously, the growing demand for REEs in civilian technologies, particularly in the renewable energy sector, has led to a nearly 20-fold increase in neodymium demand since 2000.[17] This surge, coupled with China's dominance in the global REE market, has intensified concerns about supply chain vulnerabilities. Establishing a robust, independent REE supply chain is a long-term endeavor that requires significant investment and time, posing challenges for both immediate defense needs and long-term energy technology development.

[15] See note above.

[16] Sabine Langkau and Martin Erdmann, "Environmental Impacts of the Future Supply of Rare Earths for Magnet Applications," *Journal of Industrial Ecology* 25, no. 4 (November 27, 2020): 14-15, https://doi.org/10.1111/jiec.13090.

[17] Tianli Yao et al., "Dynamic Neodymium Stocks and Flows Analysis in China," *Resources, Conservation and Recycling* 174 (July 5, 2021): 27, https://doi.org/10.1016/j.resconrec.2021.105752.

Conclusion

China is aware of its upper hand and is eager to maintain it, acquiring REE production companies globally. Concerns about driving down prices to make competitors unprofitable should be addressed.[18] The U.S. is required to be not only vigilant in addressing supply challenges but also creative in projecting demands. Forward-thinking methods like using microorganisms for extraction or substituting alternative materials to replace REEs in specific applications are being explored. Increased collaboration among allied nations to develop REE supply chains and share technologies could help counter China's market dominance. This concentration of power of supply creates vulnerabilities for other nations, especially those with ambitious green energy and defense agendas. A disruption, of any form, in the supply of REEs is more than likely to hinder technological advancements and impact national security and economic stability.

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[18] Alyk R. Kenlan, "Rare Elements of Security," *Air & Space Forces Magazine*," November 6, 2020, https://www.airandspaceforces.com/article/rare-elements-of-security/.

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