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Rare Earth Elements in the Defense Industry: Strategic Dependency and Geo-economic Competition

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Abstract

This study examines the decisive role of Rare Earth Elements (REEs) in the modern defense industry within the context of global supply chain structures, great-power competition, and the defense economy. As traditional warfare doctrines have evolved from a "steel and gunpowder" axis toward an "electron- and photon-based" paradigm, REEs have become indispensable inputs for modern military systems. The strategic dependency created by China-centered production and refining structures constitutes a critical vulnerability for the United States, Europe, and emerging economies alike, while regions such as Greenland, Venezuela, and the Middle East are emerging as new arenas of geopolitical competition.

Within this framework, the study evaluates the high reserve potential identified in Türkiye's Eskişehir–Beylikova field in terms of the defense industry, economic independence, and strategic autonomy. The analyses conclude that REEs are not merely industrial inputs but represent a decisive "strategic lever" in the power struggles of the 21st century.

Keywords: *Rare earth elements, defense industry, geoeconomics, strategic dependency, Beylikova, global power competition.*

Introduction

Military power throughout history has been shaped not only by the weapons technologies possessed, but also by the material infrastructure that enables those technologies. In Guns, Germs, and Steel, Jared Diamond emphasizes that global power asymmetries are rooted not merely in political or military decisions, but fundamentally in disparities in access to materials, technology, and production capacity (Diamond, 2018). The ability to process steel, mass-produce firearms, and organize industrial production historically transformed military superiority into a lasting advantage.

In the twenty-first century, a comparable structural shift has emerged—this time replacing steel and gunpowder with rare earth elements, advanced materials, and electronic systems. Modern defense systems are built upon dominance of the electromagnetic spectrum, sensor networks, precision guidance technologies, and advanced data-processing capabilities. The physical and technological foundation of these systems is formed by Rare Earth Elements (REEs) (Gül, 2023; Humphries, 2024).

In this respect, REEs may be regarded as the "steel" of the contemporary world. Global competition today is no longer defined solely by possession of these resources, but rather by the capacity to process, refine, and transform them into high-value technological outputs. China's dominant position within global production and refining chains has effectively turned rare earth elements into a geopolitical instrument of power (Nakano, 2024; USGS, 2024). This reality has compelled major actors—particularly the European Union and the United States—to develop new strategic frameworks aimed at securing critical raw materials (European Commission, 2023; Humphries, 2024).

This study constitutes a qualitative analysis that examines the strategic significance of rare earth elements in the context of the defense industry from the perspectives of geopolitical competition, global supply chains, and defense economics. The research does not rely on quantitative data collection or empirical measurement methods; rather, it is based on review-based and comparative evaluations of existing academic literature, international reports, official institutional publications, and policy documents (IEA, 2023; World Bank, 2023).

Within this framework, the study aims to analyze, in a holistic manner, the structural role of rare earth elements in defense systems, the strategic dependencies arising from global production and processing capacities, and the strategic opportunities emerging in the case of Türkiye's Eskişehir–Beylikova deposit (Republic of Türkiye Ministry of Energy and Natural Resources, 2023; Presidency of Defence Industries, 2024). The adopted approach is inherently interdisciplinary, integrating insights from the literatures on defense industry, geoeconomics, and strategic resource management.

1. Rare Earth Elements and Their Structural Role in Defense Systems

Rare Earth Elements (REEs) constitute one of the fundamental inputs in the modern defense industry that generate a "force multiplier" effect. This effect is concentrated in three main functional domains that define the performance boundaries of contemporary defense technologies (Gül, 2023; Humphries, 2024).

The first domain is magnetic superiority. High-performance permanent magnets produced using rare earth elements such as neodymium, dysprosium, and praseodymium play a decisive role in determining the size, weight, and energy efficiency of guided munitions, radar systems, unmanned platforms, and electric propulsion systems. Without these magnets, it would not be possible for modern weapons systems to achieve their current levels of performance (USGS, 2024; Humphries, 2024).

The second domain is optical and electronic warfare capability. Optical and photonic materials doped with yttrium, erbium, and lanthanum form the technological backbone of laser target designation, range-finding, night vision, and thermal imaging systems. These capabilities constitute a critical component of information superiority and situational awareness on the modern battlefield (Gül, 2023; European Commission, 2023).

The third domain concerns high-temperature resistance and structural durability. Advanced ceramic coatings and high-performance alloys used in jet engines, hypersonic platforms, and missile systems are able to withstand extreme thermal, mechanical, and environmental conditions due to the incorporation of rare earth elements such as lanthanum and yttrium. This directly influences the operational lifetime, reliability, and mission continuity of defense platforms (IEA, 2023; World Bank, 2023).

2. Global Reserves, Production–Processing Capacity, and Chinese Hegemony

Although rare earth elements are geologically distributed across many regions worldwide, their production and processing capacities exhibit a highly asymmetric structure. Beyond possessing approximately one-third of global reserves, China controls the vast majority of the world's rare earth refining and separation capacity. This position has transformed China from a mere supplier of raw materials into a critical intermediary actor within global defense and high-technology supply chains (USGS, 2024; Humphries, 2024).

While the United States, Australia, and several European countries possess significant reserve potential, they face substantial difficulties in establishing processing infrastructures capable of competing with China. Environmental regulations, high capital investment requirements, and technological gaps have constrained the development of alternative refining and separation capacities. This situation has created a strategic dilemma that may be summarized as "resources at home, processing power abroad" (European Commission, 2023; Humphries, 2024).

Within this context, China's periodic use of rare earth elements as a foreign policy instrument—through export restrictions, quotas, and regulatory controls—demonstrates that REEs have evolved into a geopolitical leverage mechanism rather than a neutral commodity. Such practices have heightened concerns over supply security and strategic dependency, particularly in defense and advanced technology sectors, reinforcing the perception of rare earth elements as instruments of structural power in global competition (Nakano, 2024; World Bank, 2023).

Table 1. Comparison of Global Rare Earth Element Reserves, Production, and Processing Capacity

Country / Region	Estimated Reserves (REO, million tons)	Share of Global Reserves (%)	Share of Global Production (%)	Refining / Separation Capacity (%)	Strategic Position
China	~44	~34	70–75	85–90	Hegemonic Actor
Brazil	~21	~16	<2	<1	Reserves Available, No Processing Capacity
Vietnam	~22	~16	<1	<1	High Potential, Investment Deficit
Russia	~12	~9	~2	<1	Geopolitically Constrained
United States	~1.9	~1.5	~12	5–10	Technological Power
Australia	~5.7	~4	~6	<5	Processing Dependent on China
Türkiye (Beylikova)	~694 million tons (ore)	High	Pilot-scale	Pilot-scale	Emerging Strategic Actor

Source: Humphries (2024); Republic of Türkiye Ministry of Energy and Natural Resources (2023); USGS (2024)

The Beylikova deposit does not directly consist of REO; rather, it contains a high-grade complex ore, which—following separation and processing—corresponds to a REO equivalent that ranks second globally.

3.1. The Processing Challenge and the Strategic Bottleneck

Unlike conventional minerals, rare earth elements are chemically very similar to one another, which renders separation and refining processes extremely complex, capital-intensive, and environmentally sensitive. China's global dominance in rare earth elements emerges primarily at this critical stage of the value chain.

In Western countries, processing facilities have remained limited due to:

- Stringent environmental regulations,
- High capital investment requirements,
- Lengthy permitting and licensing procedures.

By contrast, since the 1990s China has established a state-supported, vertically integrated rare earth ecosystem, in which environmental costs were largely deprioritized in favor of strategic and industrial objectives (Humphries, 2024).

4. Geopolitical Arenas of Competition: The United States, Greenland, Venezuela, and the Middle East

Global power competition has generated new geographical focal points centered on rare earth elements (REEs). In an effort to reduce its strategic dependence on China, the United States has intensified its initiatives targeting reserves in Greenland, Australia, and Latin America, seeking to diversify supply chains and secure access to critical minerals (Humphries, 2024; USGS, 2024). Despite its significant reserve potential, Greenland has not yet evolved into an effective production hub due to environmental sensitivities, local political resistance, and infrastructural deficiencies (Nakano, 2024).

Countries such as Venezuela, on the other hand, have become arenas of economic and political influence struggles among major powers, driven by their natural resource endowments. In these contexts, critical minerals—including rare earth elements—are increasingly embedded within broader geopolitical bargaining processes (Gül, 2023; World Bank, 2023).

In the Middle East, direct rare earth element production remains limited. Nevertheless, the region's strategic logistical position and its influence over energy and mineral supply routes confer indirect significance in the global trade of rare earth elements. Control over transportation corridors, maritime chokepoints, and energy–mineral interdependencies amplifies the region's geoeconomic relevance despite the absence of substantial domestic REE extraction (IEA, 2023).

Taken together, these developments demonstrate that rare earth elements have evolved beyond a purely technical or industrial concern and have become one of the central components of geoeconomic and geopolitical competition. Consistent with Diamond's historical perspective on material foundations of power, contemporary global rivalries increasingly hinge on access to, control over, and processing of strategic materials rather than solely on conventional military assets (Diamond, 2018; European Commission, 2023).

4.1. Defense and Aerospace Industry

The defense and aerospace industry ranks among the sectors in which rare earth elements (REEs) are used most intensively, most strategically, and with the highest value added. As modern military systems rely on capabilities such as precision sensing, rapid data processing, dominance of the electromagnetic spectrum, and high maneuverability, a substantial portion of these systems is dependent on the unique magnetic and electronic properties provided by REEs (Gül, 2023; Humphries, 2024).

Within the scope of fifth-generation fighter aircraft, including platforms such as the F-35 and similar systems (including KAAN), REE-based components play a critical role in radar systems, flight control surfaces, electromagnetic signature management, and power transmission mechanisms. Likewise, NdFeB (Neodymium–Iron–Boron) permanent magnets used in missile and precision-guided munition systems, along with yttrium- and erbium-doped laser guidance systems, constitute key factors determining targeting accuracy and response time (Humphries, 2024).

In electronic warfare systems, high-frequency filters, radar sensors, and radar cooling systems cannot achieve the required performance levels without materials incorporating REEs. Similarly, quiet electric propulsion systems and advanced sonar technologies used in submarine platforms rely heavily on the magnetic and acoustic advantages provided by these elements. According to data reported in the literature, approximately 400–420 kg of rare earth elements are used in a single F-35 fighter aircraft, while nearly 4 tons are required for a nuclear-powered submarine (Gül, 2023).

4.2. Energy and Renewable Technologies

The accelerating global energy transition has become one of the primary factors dramatically increasing demand for rare earth elements (REEs). A significant portion of the technologies developed to promote the deployment of renewable and low-carbon energy systems requires high-performance magnetic and electronic components, positioning REEs as strategic assets for energy security (International Energy Agency [IEA], 2023).

In wind energy technologies, particularly in direct-drive turbine generators, permanent magnets based on neodymium and dysprosium enable systems to operate with higher efficiency, more compact designs, and reduced maintenance costs. According to data from the International Energy Agency, the quantity of REEs used in wind turbines is substantially higher than in conventional energy generation systems, thereby intensifying demand pressure and supply-related risks (IEA, 2023).

In the field of nuclear energy, the use of REEs is prominent in control rods, radiation sensors, and high-temperature-resistant structural components. In particular, next-generation small modular reactors (SMRs) and advanced reactor designs increase dependence on REEs due to their heightened requirements for precision measurement, monitoring, and control (World Bank, 2023). In energy storage systems, battery management systems, thermal management infrastructures, and power electronics components rely heavily on materials doped with lanthanum, yttrium, and other rare earth elements (Humphries, 2024).

4.3. Electric Vehicles and the Automotive Industry

Electric vehicle (EV) technologies represent another critical sector in which demand for rare earth elements (REEs) has been increasing rapidly. The high-efficiency permanent magnets used in electric vehicle motors are directly dependent on REEs in terms of energy density and performance. Studies indicate that the amount of rare earth elements used in an electric vehicle is approximately five to seven times higher than that used in internal combustion engine vehicles (IEA, 2023).

This dynamic creates a resource-based competition for demand among the defense industry, the energy sector, and transportation technologies. In particular, the defense industry's requirement for uninterrupted and secure supply makes strategic planning imperative, as the expanding use of REEs in the automotive and energy sectors intensifies pressure on availability and supply chains (European Commission, 2023).

4.4. Electronics, Digital Technologies, and Artificial Intelligence

Rare earth elements (REEs) constitute one of the fundamental inputs of digitalization and artificial intelligence–based technologies. Components such as speakers, vibration motors, and display elements used in smartphones, computers, and advanced electronic devices rely heavily on REE-containing materials. In addition, elements such as yttrium, erbium, and lanthanum play a critical role in semiconductor manufacturing processes, laser systems, and fiber-optic infrastructures (Humphries, 2024).

High-performance data-processing hardware and sensor systems employed in artificial intelligence applications benefit from the magnetic and optical advantages provided by REEs, enabling faster and more precise operation. In this context, rare earth elements have become one of the cornerstones of the digital economy's infrastructure, underpinning advanced computing, connectivity, and intelligent systems (European Commission, 2023).

4.5. Healthcare, Optics, and Advanced Materials

Healthcare technologies and advanced materials applications are significant in illustrating the non-defense yet high-technology uses of rare earth elements (REEs). Magnetic resonance imaging (MRI) systems, advanced medical sensors, and laser-based surgical applications are made possible through the use of REE-doped magnets and optical components (World Bank, 2023).

In addition, high–refractive-index optical glasses, ceramic coatings, and composite materials are widely utilized across aerospace, space, and non-defense industrial sectors. These application areas demonstrate that rare earth elements constitute not merely a military input, but a multi-sectoral and strategically critical technological resource underpinning a broad range of advanced industries (Humphries, 2024).

5. Türkiye and Beylikova: From a Strategic Resource to Strategic Autonomy

The high rare earth element (REE) reserve identified in Eskişehir–Beylikova places Türkiye in a privileged position at the global level. With an estimated reserve size of approximately 694 million tons, Türkiye has emerged as one of the world's second-largest potential reserve holders after China.

The significance of this reserve is not merely quantitative. Pilot facilities established under the leadership of Eti Maden and the development of indigenous separation and processing technologies concretize Türkiye's objective of end-to-end localization across the REE value chain. The utilization of domestically sourced critical components in defense platforms such as KAAN, KIZILELMA, and HİSAR demonstrates the potential to structurally reduce external dependency in strategic defense capabilities.

In this respect, the Beylikova model represents not merely a mining project, but a strategic power instrument capable of delivering strategic autonomy for Türkiye across defense industry development, economic resilience, and foreign policy positioning.

Beyond the sheer scale of its reserves, the Beylikova site stands out due to its potential to support an integrated production model, encompassing extraction, separation, refining, and downstream industrial utilization.T

Table 2. Comparative Analysis of Rare Earth Element (REE) Capabilities: Türkiye – China – United States

Criterion	China	United States	Türkiye
Reserve Size	High	Medium	Very High
Processing Capacity	Very High	Medium	Pilot-scale
Defense Industry Demand	Very High	Very High	High
Localization Potential	Saturated	Limited	Very High
Geopolitical Flexibility	Low	Medium	High

Source: USGS (2024); Republic of Türkiye Ministry of Energy and Natural Resources (2023)

The integration of the Beylikova deposit with the defense industry offers Türkiye not only a raw material advantage, but also the potential to achieve strategic autonomy, economic resilience, and enhanced export capacity.

Conclusion

Rare earth elements (REEs) have become not merely complementary inputs to advanced technologies in the twenty-first-century defense industry, but decisive determinants of technological superiority, economic power, and strategic autonomy. While traditional conceptions of warfare were grounded in steel and gunpowder, contemporary defense paradigms are built upon electronic warfare, precision guidance, sensor systems, and data-processing capabilities. The material foundation of this transformation is formed by rare earth elements.

Framed through Jared Diamond's historical perspective, just as societies that were able to process steel and convert it into mass production achieved military and political superiority in the past, today countries that can separate, refine, and integrate rare earth elements into advanced technological products gain a decisive advantage in global power competition. In this sense, rare earth elements should be regarded as the "strategic raw materials" of the modern world.

China's hegemonic position at the global level clearly demonstrates that it is not merely the existence of these resources, but rather their processing capacity, technological transformation, and control over supply chains that determines strategic power. The Chinese case illustrates that rare earth elements can function not only as economic instruments, but also as effective tools of geopolitical leverage and foreign policy pressure. This reality creates a structural vulnerability, particularly for countries pursuing high-technology production dependent on the defense industry.

Türkiye's rare earth element strategy, developed around the Eskişehir–Beylikova deposit, represents a distinctive and strategic position within this global landscape. The high reserve potential identified at Beylikova provides Türkiye not only with raw material abundance, but also with opportunities to reduce external dependency in the defense industry, support the energy transition, and expand high value-added production capacity. In this context, the Beylikova initiative goes beyond a conventional mining investment and constitutes a comprehensive national security project that simultaneously influences defense industry development, economic resilience, and foreign policy.

In conclusion, policies concerning rare earth elements should be approached not through short-term economic gains, but through long-term strategic planning, environmental sustainability, and technological development objectives. For Türkiye, the success of this process depends not only on the exploitation of reserves, but also on the localization of separation and refining technologies, integration with the defense industry, and positioning as a reliable actor within global supply chains. If these conditions are met, rare earth elements will function as a genuine strategic shield, enabling full independence in the defense industry and long-term economic resilience for Türkiye in the twenty-first century.

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