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IMPORTANCE OF USING SOME CRITICAL MINERALS IN GREEN ENERGY TRANSITIONS IN CHINA- A REVIEW

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ABSTRACT: This review examines the essential function of critical minerals, including lithium, cobalt, nickel, graphite, rare earth elements, copper and platinum group metals, in facilitating China's transition to clean energy. As the nation intensifies its move towards renewable energy sources such as solar, wind, hydropower, and biomass, these minerals are vital for manufacturing renewable energy technologies and electric vehicles (EVs), especially in lithium-ion batteries utilized for energy storage. The review highlights China's leading position in the global supply chain for these critical minerals, emphasizing the country's strategic oversight of mineral extraction, refining, and processing, which establishes it as a key player in the worldwide energy transition. It also investigates the geopolitical ramifications of China's mineral supply and the potential vulnerabilities linked to its dependence on foreign critical mineral sources, alongside its initiatives to secure domestic resources. Additionally, the environmental consequences of mineral extraction and processing in China are addressed, focusing onsustainability challenges related to mining practices, such as water usage, land degradation, and pollution. Ethical considerations, including labor conditions in mineral-rich areas, are also discussed. The review assesses the policies and subsidies that China has enacted to bolster the development of its clean energy sector, encompassing initiatives for renewable energy implementation, electric vehicle manufacturing, and critical mineral procurement. China's governmental strategies, such as the "Made in China 2025" initiative, are analyzed in relation to their influence on the future of clean energy and mineral extraction within the country. Moreover, the review explores technological advancements that may lessen reliance on critical minerals, including innovations in battery chemistries and recycling methods. The review also explores the possibility of replacing rare minerals with more readily available substitutes, as well as the associated challenges and opportunities that these innovations present. In summary, it offers an in-depth analysis of the relationship between essential minerals and the transition to clean energy in China. It highlights the necessity of ensuring a sustainable and ethically sourced supply of these minerals while promoting technological advancements and supportive policies to propel China's green energy transformation. The results emphasize the importance of international cooperation and a balanced strategy regarding mineral extraction, environmental sustainability, and economic development in the quest for a low-carbon future

Key words: energy transition, critical minerals, low-carbon and China

INTRODUCTION

The transition to green energy signifies a major transformation in the methods of energy generation and consumption. This shift is currently focused on mitigating climate change by enhancing the share of energy derived from renewable sources, including hydropower, geothermal, wind, solar, and biomass (IEA, 2020a, b). Key factors driving this transition include: 1) a decrease in environmental impact; 2) the growing affordability of renewable energy; and 3) increased policy support and financial incentives. As of 2021, it is important

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to note that fossil fuels account for 82% of the world's primary energy production **(BP, 2022)**. In an effort to curb emissions and thus combat climate change, 195 countries have committed to the Paris Agreement **(UN, 2015).**

The prevailing agreement on renewable energy is not fully established, as its implementation varies based on national capabilities. This is evident from the polarization seen in certain countries, such as the United States, Iran, Libya, and Yemen, which have either withdrawn from or failed to ratify the agreement, while others have set ambitious targets to achieve 'net zero' emissions in the near future. This indicates a shift in national economies aimed at offsetting or eliminating emissions **(see IEA, 2023b).** In 2023, the United Nations Secretary-General emphasized the urgent need for all countries and sectors to significantly accelerate their climate initiatives **(UN, 2023).** Since the Paris Agreement, there has been a global movement advocating for rapid structural changes in energy production and consumption **(IPCC, 2021; IEA, 2021, 2023c; IRENA, 2023).** Nevertheless, the transition to green energy is a complex issue, characterized by substantial social, infrastructural, economic, and political challenges **(Rubin et al., 2021; Ali et al., 2022; Owen et al., 2023)**. Specifically, within the mineral value chain, key challenges include: 1) the availability of energy; 2) rigid supply chain dynamics; and 3) escalating geopolitical tensions.

The expected rapid expansion of zero-emission transportation will necessitate substantial amounts of minerals, particularly metals, for vehicle production. Key materials such as lithium, graphite, rare earth elements, cobalt, nickel, copper, and platinum group metals are typically categorized as critical minerals. These minerals hold significant economic value, and any instability in their supply could impede the advancement and adoption of innovative technologies. Therefore, the effective implementation of clean technologies in future transportation will depend on further advancements in understanding the properties of these materials, which will facilitate better alignment with their applications, allow for potential substitutions, and optimize their utilization through sustainable resource exploration and a circular economy. This report outlines the essential aspects of critical minerals, their significance in zero-emission transportation, and evaluates the current global challenges in meeting the demands of automotive supply chains while addressing environmental concerns **(Czerwinski, 2022)**.

The shift towards a low-carbon energy system holds the promise of significant advantages for both society and the environment. Key renewable energy technologies, such as solar photovoltaic (PVs), wind turbines, and lithium-ion batteries, play a pivotal role in this energy transition. These technologies depend on "critical minerals" or "critical materials," which are vital for economic and national security and have supply chains that are susceptible to disruptions. Consequently, ensuring a sufficient global supply of materials necessary for the development of renewable technologies has become a primary concern for businesses, governments, researchers, and various stakeholders **(Calderon et al., 2024)**.

The essential nature of rare earth elements (REs) in emerging technologies stems from their distinct physical and chemical characteristics. These exceptional properties have rendered REs increasingly vital across various domains. Initially, REs found extensive use in traditional industries such as metallurgy, petroleum, textiles, and agriculture. However, as knowledge and technology have advanced, a wide array of applications leveraging their chemical, catalytic, electrical, magnetic, and optical attributes has rapidly developed, particularly in high-tech sectors. Notable examples include hybrid vehicles, wind turbines, compact fluorescent lamps, flat-screen televisions, mobile devices, disc drives, and defense technologies, as illustrated in Table 1. Moreover, their role in clean energy technologies and defense systems has garnered significant global interest in REs. Given the growing economic significance and ongoing strategic relevance of these sectors, ensuring continuous access to these resources is crucial for both developing and developed nations. Nevertheless, the global distribution of REs is uneven, as depicted in Figure 1.

Table 1. Applications of rare earths (REs)

Field		Function	Main Productions	REEs
Traditional applications	Metallurgy, Machinery	Alter chemical and physical properties, improve performance	Superalloys, steel aluminum magnets	La, Ce, Pr,Nd,Y
	Petrochemical industry	Catalyst	Petroleum refining, catalytic converts	La, Ce, Pr, Nd
	Glass, Ceramic	Polishing, decoloration, additive, colorant	Capacitors, sensors, colorants, scintillators, refractories	La, Ce, Pr, Nd,Y, Eu, Gd, Lu,Dy
New applications	Clean energy	Improve performance and property	Motors, wind Turbines, NiMH batteries	Nd, Pr, Tb, Dy
	Nuclear	Improve performance	Water treatment	Eu, Gd, Ce, Y

Sources: **(Calderon *et al*., 2024).**

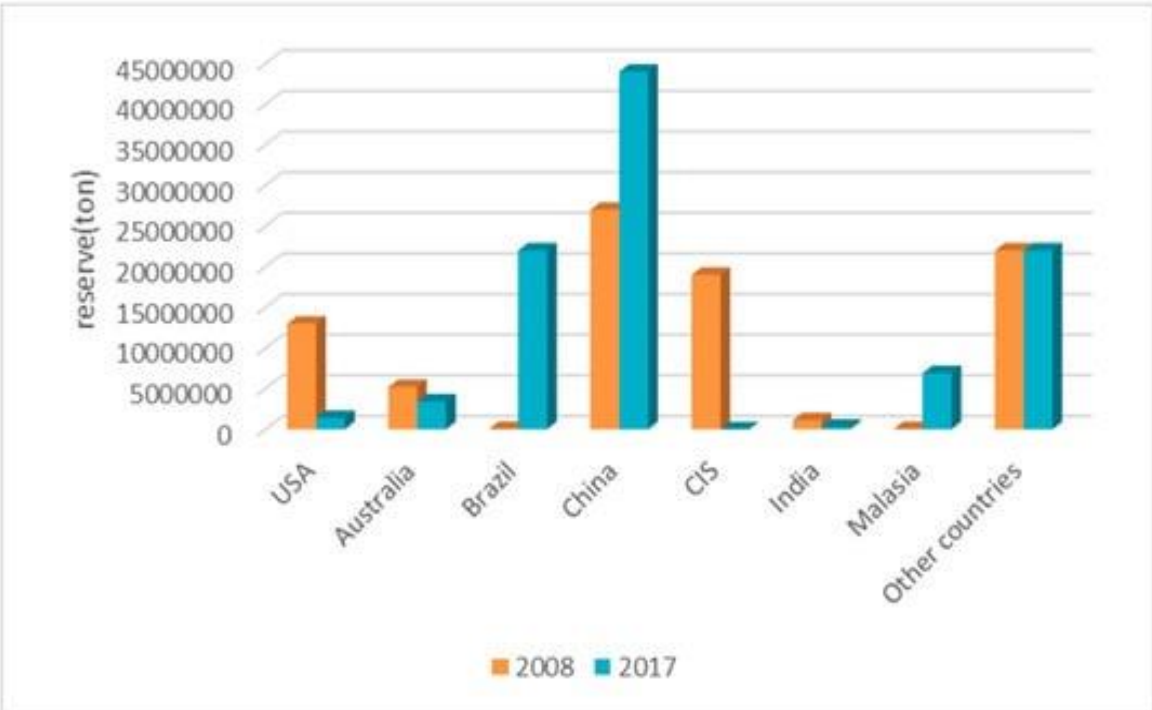

Fig.1. Main reserve of rare earth in different countries (source: U.S. Geological Survey). **(Calderon *et al*., 2024)**

China is widely recognized as having the largest proven reserves of rare earth elements (REs). At the same time, it stands as the foremost exporter and consumer of these materials globally. Holding around 23% of the world's total rare earth reserves, China has met over 90% of global demand for many years. This heavy reliance on China's REs has raised concerns among other nations, including the United States, Japan, and the European Union, regarding the stability of supply given China's dominant role in the rare earth market. Notably, in 2010, China implemented a strict export policy, which led to a significant increase in the prices of rare earth products.

Research Objectives

The main aim of this review is to explore the role of critical minerals in China's clean energy transition, focusing on their significance in renewable energy technologies, electric vehicles (EVs), and energy storage systems. The specific research objectives include:

1. To Analyze the Role of Critical Minerals in China’s Clean Energy Transition:

a. Investigate how minerals like lithium, cobalt, nickel, graphite, rare earth elements, and copper and platinum group metals are essential for China’s deployment of renewable energy technologies, including solar photovoltaics (PVs), wind turbines, and energy storage solutions.

b. Examine the contribution of critical minerals to the production of electric vehicles and their role in reducing emissions in the transportation sector.

2. To Assess the Geopolitical and Economic Impacts of China’s Control Over Critical Mineral Resources:

a. Evaluate China's dominance in the global critical mineral supply chain and its implications for global energy markets.

b. Assess the economic and geopolitical risks China faces by being a central player in the extraction, processing, and supply of critical minerals.

3. To Explore the Environmental and Ethical Concerns Linked to the Mining and Processing of Critical Minerals:

a. Examine the environmental degradation associated with mining and processing critical minerals in China, including water use, pollution, and land degradation.

b. Investigate the ethical concerns related to the mining of critical minerals, such as labor conditions, human rights, and child labor in certain regions of mineral extraction.

4. To Investigate the Policy Framework Supporting Critical Mineral Sourcing and Clean Energy Transition in China:

a. Explore China’s government policies, including the “Made in China 2025” initiative and the 14th Five-Year Plan, and their impact on the critical minerals sector and the clean energy transition.

b. Analyze China’s efforts to reduce dependency on foreign sources of critical minerals, focusing on domestic mining, recycling, and international collaborations.

5. To Assess Technological Innovations and Alternatives in Reducing Dependency on Critical Minerals:

a. Investigate the latest advancements in renewable energy technologies and energy storage systems that could reduce dependence on critical minerals.

b. Explore the development of alternative materials and innovative battery chemistries (e.g., solid-state batteries, sodium-ion batteries) that might alleviate mineral supply pressures.

Research Problems

1. Limited Availability and Accessibility of Critical Mineral Reserves:

a. Despite China’s dominance in the supply chain, global reserves of critical minerals are finite. There is growing concern about the sustainability of mineral resources, particularly as demand rises in the clean energy and electric vehicle sectors.

b. How can China address potential shortages of critical minerals while continuing its rapid expansion of renewable energy and electric mobility?

2. Geopolitical Tensions and Mineral Supply Risks:

a. The global supply chain for critical minerals is highly concentrated in a few countries. China's role as the primary processor and refiner of critical minerals places it at the center of geopolitical risks, such as trade restrictions, supply chain disruptions, and international competition for resources.

b. How can China mitigate risks associated with supply chain disruptions and maintain a stable supply of critical minerals?

3. Environmental and Social Impacts of Mineral Extraction:

a. The mining and processing of critical minerals are often linked to severe environmental damage, including deforestation, water contamination, and the release of toxic chemicals. Additionally, there are concerns over the social and ethical impacts of mining, such as child labor and poor working conditions.

b. What strategies can be implemented in China to ensure that the extraction of critical minerals for clean energy technologies is environmentally responsible and ethically sound?

4. Technology and Market Uncertainties:

a.The rapid evolution of clean energy technologies and battery chemistries could change the demand for specific critical minerals. For instance, advancements in recycling, the development of new energy storage systems, or alternative materials may reduce dependency on certain minerals.

b.How can China anticipate future technological trends and adjust its strategies to address changing demands for critical minerals?

5. Policy Challenges and Implementation:

a. While China has implemented numerous policies to support the clean energy transition and secure critical mineral supply, there are still challenges in balancing environmental sustainability, economic growth, and geopolitical interests.

b. What policy frameworks can China adopt to better manage the extraction and utilization of critical minerals, while ensuring that its energy transition goals are met in a sustainable and socially responsible manner?

6. Global Competition and Market Dynamics:

a. The competition for critical minerals is intensifying, as many countries are focusing on securing their own supplies to ensure a smooth transition to green energy.

b. How can China maintain its competitive advantage in securing critical mineral resources, and what role can it play in global cooperation on sustainable mineral sourcing and clean energy development?

Research Methods

This study commenced with a systematic review of academic literature to compare models of mineral demand. We identified peer-reviewed articles through Web of Science searches utilizing keywords such as "energy transition," "low-carbon," "renewable energy," "demand," "material flow analysis," "scenario," "availability," and "outlook." Additionally, we incorporated material-specific terms like "critical," "mineral," "metal," "material," "metal demand," "metal constraints," "bottleneck," "metal requirements," "mineral demand," and "mineral requirements," along with renewable energy-related terms such as "wind," "solar," "electricity," "renewable," "electric vehicle," and "batteries." This comprehensive search yielded over 2,500 publications across various research domains. The articles were subsequently screened based on specific selection criteria to ensure the studies were comparable: each proposal had to focus on a renewable energy-driven scenario, address material demand on a global scale, and forecast future mineral and metal demand **(Calderon *et al*., 2024).**

This investigation was expanded on by including relevant gray literature due to the importance of studies by government and non-governmental organizations, such as the International Energy Agency **(IEA, 2021**) and the **(World Bank, 2020**).

The Green Energy Transition and Its Global Impact

In the framework of the transition to green energy, GEMMs play a crucial role in the generation and storage of electrical energy. As a result, GEMMs are expected to progressively replace fossil fuels as the energy supply shifts towards a more electrical focus. The dynamics of supply and demand for fossil fuels have significantly influenced global power relations, with geopolitics being partially driven by energy requirements. The increasing significance of GEMMs has the potential to alter the geopolitical landscape, as control over any segment of the GEMM value chain represents a form of geopolitical influence, and acknowledgment of this emerging power will likely lead to its strategic application.

A likely consequence of the ongoing energy transition is the redistribution of power from nations that supply fossil fuels to those that provide green energy mineral materials (GEMM). This shift may have intricate effects, potentially influencing both the energy transition itself and international diplomatic relations **(Chishti *et al*., 2023).** As a result, the transition is expected to significantly affect the economic and political dynamics among countries (Jacobsen, 2019; Sattich *et al*., 2021 and Dall-Orsoletta *et al*., 2022). The International Energy Agency reports that the proportion of oil in the global energy mix is projected to decrease from approximately 32% today to 20% by 2040 (IEA, 2020b). Consequently, the green energy transition is likely to diminish the significance of oil-exporting nations. For instance, countries that rely heavily on oil exports, such as Saudi Arabia and Russia, may experience a reduction in their geopolitical clout, particularly in developed countries with advanced electrification (Costa *et al*., 2022). Overall, this suggests that relationships built on traditional energy trade may become unstable or diminish. Specifically, the deep connections between the financial sector and the oil market, driven by financialization, indicate that fluctuations in oil prices could lead to considerable global financial instability (Gkillas *et al*., 2021 and references therein).

Countries that are leaders in green energy production and technology, including China, the United States, Canada, and Germany, are likely to see an increase in their global influence. These nations are expected to hold a considerable advantage in the burgeoning green energy market, projected to reach trillions of dollars in the upcoming decades (see Fig. 3 and Fig. 4). The International Renewable Energy Agency has indicated that by 2050, renewable energy could account for as much as three-quarters of the overall energy mix **(IRENA, 2019 and 2021).** This transition to renewable energy is anticipated to generate new geopolitical opportunities for countries at the forefront of this sector, allowing them to assume a more prominent role on the world stage .

China, in particular, is a leading supplier of renewable energy minerals and technologies (see Fig. 5; USGS, 2023 and Miller, 2023). Its growing geopolitical influence is exemplified by its successful mediation of a peace agreement between Saudi Arabia and Iran, a remarkable achievement. Beyond economic ramifications, the shift towards green energy will also reshape political dynamics among nations. Countries rich in green energy minerals and metals (GEMMs) such as lithium, cobalt, and rare earth elements (REEs) may gain increased strategic significance **(Collier and Venables, 2017 and Cabigiosu, 2022**). For instance, Chile has recognized the strategic value of battery metals and has recently nationalized its lithium sector **(Villegas and Scheyder, 2023).** The supply of GEMMs is largely controlled by a select few nations, with China being a dominant source of REEs (see Fig. 5; USGS, 2023), raising concerns regarding supply chain security. Efforts to safeguard national interests through strategic maneuvers reflect a form of geopolitical action, as the negotiating power associated with scarce and valuable natural resources is inherently tied to state authority.

Mineral Demand for Green Energy Technologies

Green energy technologies depend on a variety of GEMMs (as shown in Table 2), which can be categorized into energy and battery minerals or metals based on their primary function in electricity generation or storage. GEMMs constitute a significant portion of numerous critical raw material (CRM) lists, which aim to inform resource policy (e.g., European Commission, 2011, 2014, 2017a, 2020b, 2023b; Appelgate, 2022; Government of Canada, 2022). Notably, they account for 50% of the 2023 EU CRMs list, 73% of the Canadian critical minerals list, and 68% of the US strategic minerals list. For the EU's CRM lists from 2011 to 2023, all prior lists, except for the 2023 edition, explicitly stated that the promotion of clean energy technologies was a driving factor in alignment with EU climate goals. The 2023 list introduces a new category termed ‘strategic raw materials,’ which was first comprehensively addressed in 2020 in relation to the EU's military requirements (European Commission, 2020a). A fundamental assumption across these lists is that demand will remain robust and continue to rise due to climate objectives. As a result, supply risk is consistently employed as a criterion (or more accurately, an indicator or metric) for ranking raw materials based on their criticality. In this context, current GEMMs significantly overlap with various classifications of strategic raw materials or CRMs, making it challenging to draw a clear distinction, as all identified GEMMs serve ‘dual-use’ purposes (both civilian and military). Consequently, competition for GEMMs can escalate military demand, and vice versa.

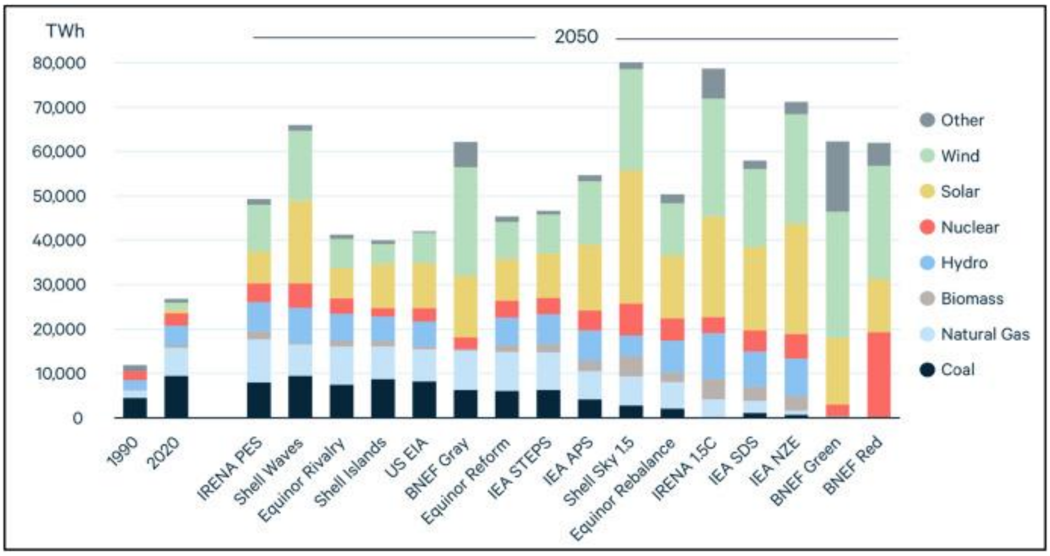

Fig.2. Global energy demand and energy mix scenarios, Terawatt hours (TWh), (Global Energy Outlook, Resources for the Future, 2022) . **(Calderon *et al*., 2024).**

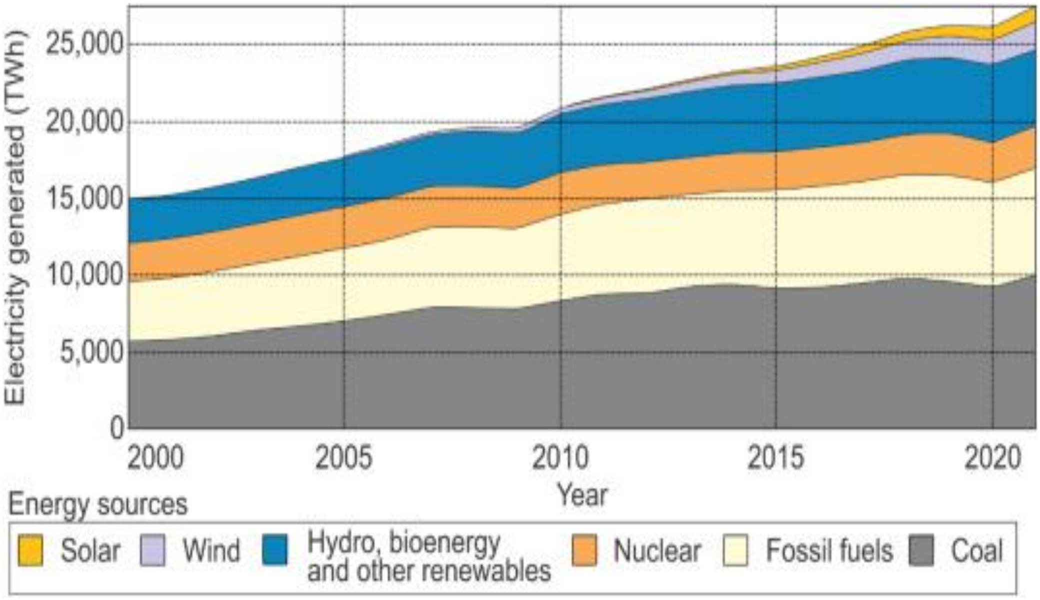

Fig.3. Global electricity production by source. Notice the increase in the adoption of green energy technologies for the past 22 years. Data from **(Ember, 2022) and (BP, 2022)**.

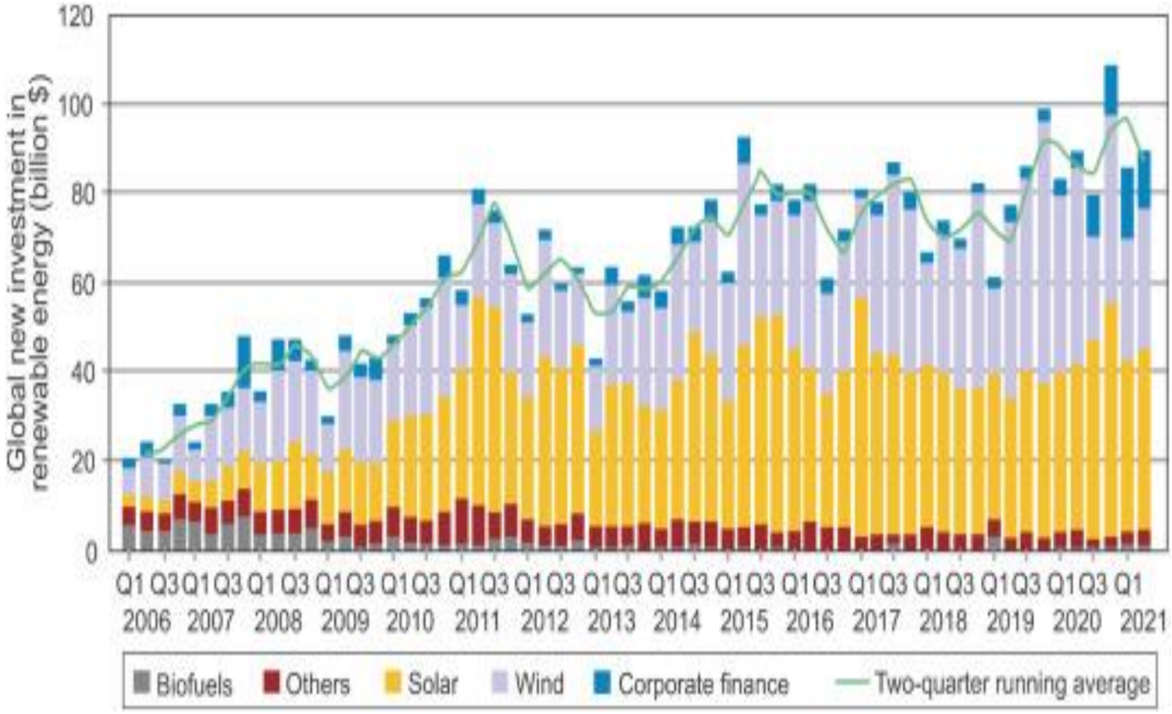

Fig. 4. Global investments in green energy technologies. Figure modified from **(Bloomberg, 2021).**

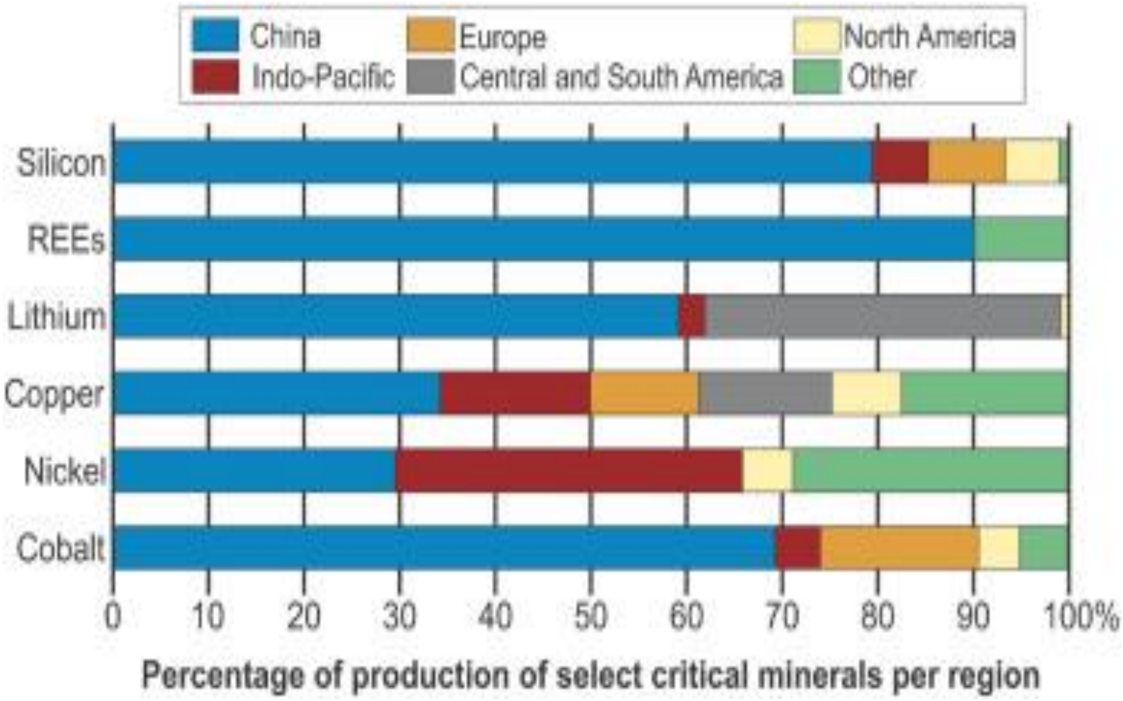

Fig.5. Location and percentage of extraction for select critical minerals. Data from the (**IEA, 2023a)**.

Table2. Minerals and metals that are required for green energy technologies.

Minerals	Solar	Wind	Storage/EVs
Aluminium	✓	✓	✓
Cadmium	✓		
Chromium		✓	
Cobalt		✓	✓
Copper	✓	✓	✓
Gallium	✓		
Germanium	✓		
Graphite			✓
Indium	✓		
Iron	✓	✓	✓
Lead	✓	✓	✓
Lithium			✓
Manganese		✓	✓
Molybdenum		✓	
Nickel	✓		✓
Rare earths		✓	✓
Selenium	✓		
Silicon	✓		✓
Silver	✓		
Tellurium	✓		
Tin	✓		
Titanium			✓
Zinc	✓	✓	

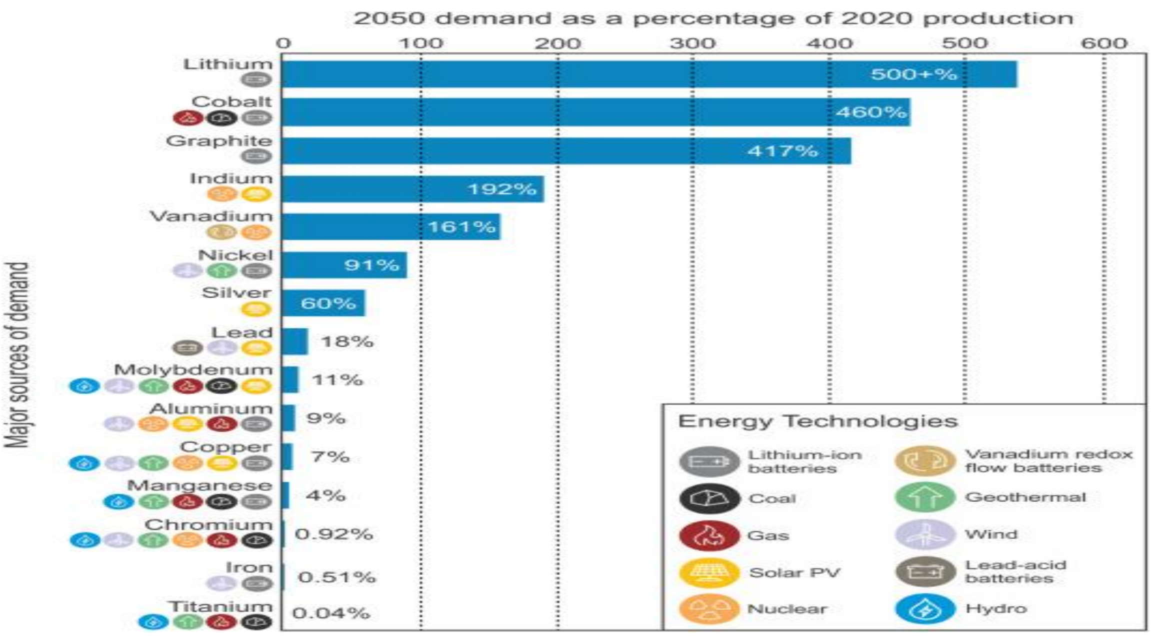

Fig. 6. Metal demand for green energy technologies in 2050 as a percentage of 2020 production. Figure modified from **(Bhutada, 2021)**. Note that the demand for a specific metal, especially lithium, may vary greatly, depending on the study.

Energy Minerals

Energy critical elements (ECEs) represent a specific subset of green energy minerals and materials (GEMMs) that are crucial for the production of clean energy technologies, including wind turbines, solar panels, and electric storage systems (see Fig. 6). Table 3 outlines the categories and descriptions of several important ECEs. These elements and minerals are deemed 'critical' due to their essential role in advancing green energy technologies, with their availability and cost potentially influencing the speed and extent of the transition to sustainable energy.

To reduce the impact of China's supremacy in the rare earths (REs) market, various countries have initiated mining projects beyond China's borders. Reports indicate that approximately 200 REs exploration projects are currently in the stages of preparation and development. However, these mining ventures necessitate substantial financial investment, and many have encountered failure when REs prices declined. Therefore, accurately predicting REs prices holds significant importance for both investors and policymakers, prompting a focused area of research on price forecasting for REs.

Rare Earth (RE) elements are extensively utilized in clean energy technologies, including hybrid electric vehicles (HEVs), wind energy systems, and high-efficiency lighting, due to their distinctive magnetic, optical, and catalytic characteristics. The incorporation of Lanthanum (La) and Cerium (Ce) in automotive catalysts and fluid catalytic cracking processes facilitates the conversion of heavy molecules into lighter compounds, enhances gasoline production, and minimizes emissions. Dysprosium (Dy) contributes to the performance of Neodymium Iron Boron (Nd Fe B) magnets, which are crucial for wind turbines and all-electric vehicles, by improving their intrinsic coercivity and resistance to demagnetization, thereby enabling their operation at elevated temperatures. Yttrium primarily finds application in phosphors, which is significant due to the high demand for compact fluorescent lighting. Table 5 illustrates the various applications of different RE elements in clean energy and their associated levels of criticality.

The initial value for all models depicted in Fig. 7 for the year 2020 is based on the actual demand for copper from renewable technologies, as reported by the IEA, which stands at 5,715 kilotons. Notably, 87% of this copper demand, amounting to 4,975 kilotons, originated from electricity networks, encompassing transmission, distribution, and transformers. However, analyses conducted by organizations such as the World Bank (2020) often exclude infrastructure from their evaluations, thereby overlooking 87% of the copper demand that renewables are expected to generate from 2020 to 2050. Consequently, their demand model suggests a decline in future demand compared to current levels, as the figure of 4,975 kilotons exceeds their future projections. By disregarding infrastructure, the World Bank estimates that a mere 7% of future annual copper production will be allocated to renewable technologies, whereas the IEA forecasts that renewables will represent 40% of total copper demand in the coming decades, primarily driven by infrastructure needs. Indeed, among all demand forecasts, the IEA's estimate for copper demand is the most substantial, as it encompasses a wide range of technologies and is one of the few studies to factor in transmission, distribution, and transformers in its analysis.

China: The variations in criticality assessments within China arise from the consideration of supply risk factors. Given China's significant presence in the critical minerals sector, certain raw materials are deemed "strategic" for reasons that extend beyond supply risk, as they are plentiful in the country. In 2016, the Ministry of Land and Resources established China's first official policy and catalog of "strategic minerals." This list was updated in 2018 to categorize metallic minerals into four subgroups: (1) noble metals including Li, Be, Rb, Cs, Nb, Ta, Zr, Hf, and W; (2) rare earth metals such as La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Sc, and Y; (3) companion metals comprising Ga, Ge, Se, Cd, In, Te, Re, and Tl; and (4) precious metals including PGMs, Cr, and Co **(Czerwinski, 2022).**

Table 3. Categories and descriptions of some of the key energy critical elements (ECEs)

Key ECE categories	Known reserves	2022 mine production	Brief description
Rare Earth Elements	118,000,000	272,000	Crucial elements for green energy: Neodymium, dysprosium, terbium—part of a 17-element group used in turbines, motors, and green energy technologies.
Lithium	24,000,000	118,000	A lightweight metal used in rechargeable batteries for EVs and energy storage systems.
Cobalt	7,500,000	170,000	A metal used in the production of rechargeable batteries for EVs, as well as in gas turbines, jet engines and other high-performance applications.
Platinum Group Elements	63,500,000	360,000[a]	A group of six elements, including platinum, palladium and rhodium, which are used as catalysts in fuel cells for hydrogen-powered vehicles. Also used in catalytic converters.
Graphite	300,000,000	1,200,000	Mineral used as anode material: Vital for energy storage and EVs.
Tellurium	32,000,000	640,000[b]	Enhancing solar efficiency: Tellurium in thin-film solar cells.
Copper	7,500,000	170,000	A metal used in electrical wiring, wind turbines and other green energy technologies.
Nickel	>100,000,000	3,000,000	A metal used in the production of rechargeable batteries for EVs and energy storage systems.

A: Only includes Palladium and Platinum.
B: Refinery production.
Data for known reserves and supply rates (both in metric tonnes, rounded) are from (**USGS, 2023**).

Table4. Price increase during rare earths crisis between the rest of the world and China

2009–2011 REE oxide (FOB price)	Average Price Increase		Price Increase Difference
	Rest of World	China	
Lanthanum oxide	2133.20%	531.37%	401.45%
Cerium oxide	2628.87%	919.25%	285.98%
Neodymium oxide	1225.94%	1132.59%	108.24%
Praseodymium oxide	1094.29%	919.16%	119.05%
Samarium oxide	3041.18%	578.05%	526.11%
Dysprosium oxide	1253.39%	1239.19%	101.15%
Europium oxide	576.75%	575.69%	100.18%
Terbium oxide	645.39%	629.66%	102.50%

Sources: **(Chen and Zheng, 2019)**

Table5. Rare earth elements widely used in clean energy and their criticality

Rare Earth Element	Main Criticality (Large Volume) Applications at Present	Level (2014)
Neodymium (Nd)	Nd–Fe–B permanent magnets	High
Europium (Eu)	Y2O3: Eu^{3+}lamp phosphor	High
Terbium (Tb)	Green lamp phosphor LaPO4: Ce^{3+}, Tb^{3+} (LAP))	Very high
Dysprosium (Dy)	Additive in Nd–Fe–B permanent magnets	Highest
Yttrium (Y)	Red lamp phosphor Y2O3: Eu^{3+}, yttria-stabilized zirconia (YSZ), and ceramics	High

Source: **(Chen and Zheng, 2019)**

Table 6. Lithium demand estimates from studies using the same energy scenario

Author	Geographic Scope	Mineral	year	kt/year	Percent of 2020 Lithium Demand	Climate Scenario
World Bank (2020)	World	Lithium	2050	415	1923.64 %	IEA Beyond 2 Degrees (2017)
Watari (2019b)	World	Lithium	2050	660	3059.28 %	IEA Beyond 2 Degrees (2017)
Månberger (2018)	World	Lithium	2050	1470	6813.86 %	IEA Beyond 2 Degrees (2017)
Junne (2020)	World	Lithium	2050	2630	12190.78 %	IEA Beyond 2 Degrees (2017)

Source: **(Calderon *et al.*, 2024)**

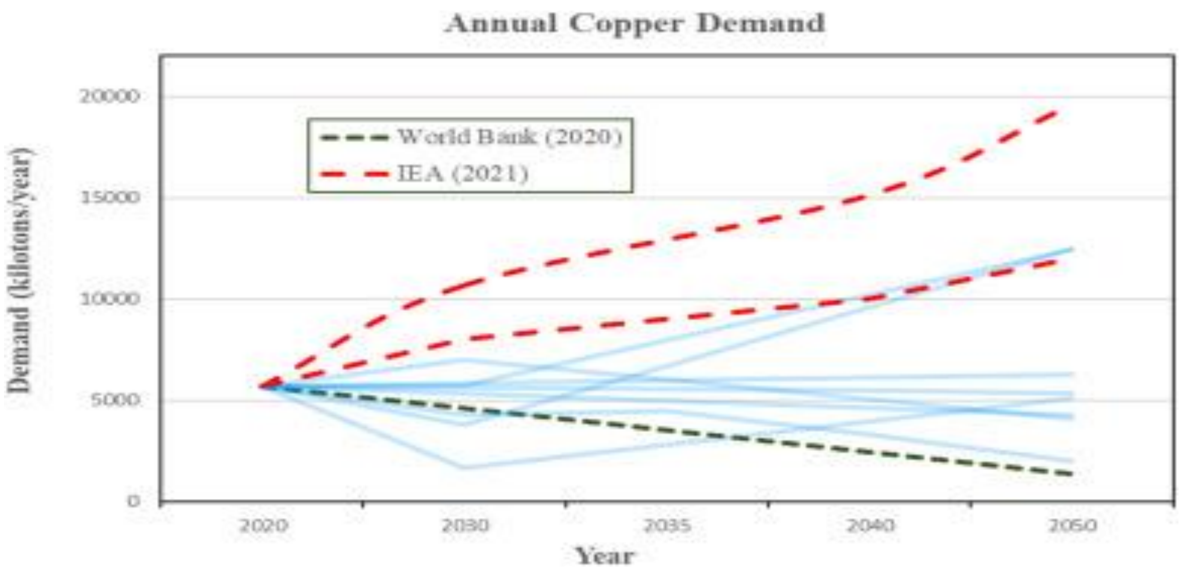

Fig. 7. Annual copper demand through 2050.
Source: **(Calderon *et al.*, 2024)**
An example of critical minerals supply for the European Union is shown in Figure 8.

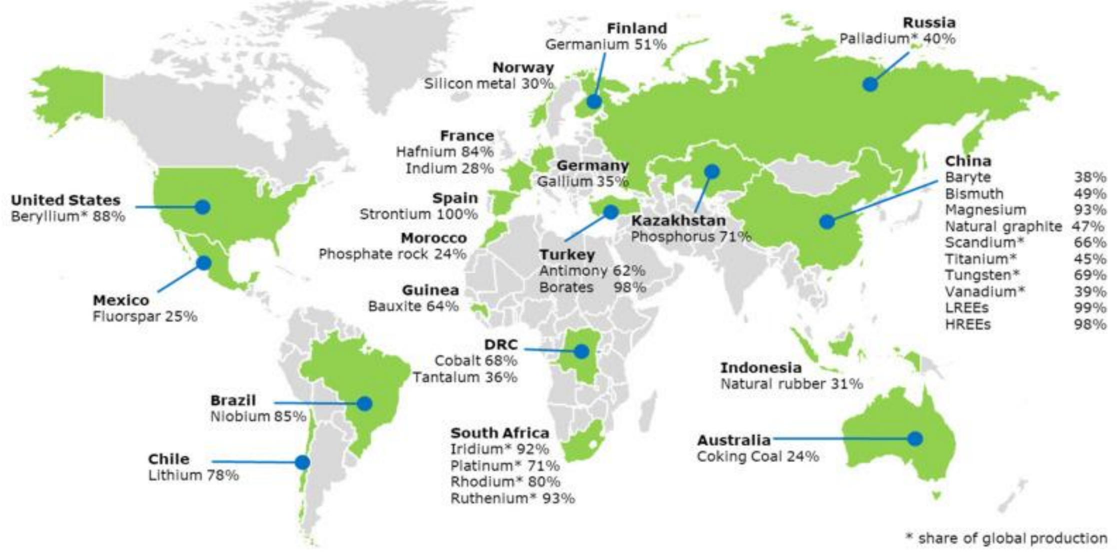

Fig. 8. Global location of critical minerals with specified major supplier countries to the European Union, e.g., China provides 98% of rare earth elements (REE), Turkey provides 98% of borates and South Africa provides 71% of the platinum (2020) (**Czerwinski, 2022**).

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اهمية استخدام بعض المعادن الحرجة في تحولات الطاقة الخضراء فى الصين

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يستكشف هذا الاستعراض الدور الحاسم الذي تلعبه المعادن الأساسية، مثل الليثيوم والكوبالت والنيكل والجرافيت والعناصر الأرضية النادرة والنحاس ومعادن مجموعة البلاتين، في انتقال الصين إلى الطاقة النظيفة. ومع تسارع وتيرة تحول البلاد نحو مصادر الطاقة المتجددة، بما في ذلك الطاقة الشمسية وطاقة الرياح والطاقة الكهرومائية والكتلة الحيوية، تُعدّ هذه المعادن أساسية لإنتاج تقنيات الطاقة المتجددة والمركبات الكهربائية، وخاصةً بطاريات أيونات الليثيوم المستخدمة لتخزين الطاقة.

يتناول الاستعراض هيمنة الصين على سلسلة التوريد العالمية لهذه المعادن الأساسية، مُسلّطًا الضوء على سيطرتها الاستراتيجية على استخراج المعادن وتكريرها ومعالجتها، مما يجعلها لاعبًا محوريًا في التحول العالمي للطاقة. كما يتناول الآثار الجيوسياسية لإمدادات الصين من المعادن والمخاطر المحتملة المرتبطة باعتمادها على مصادر أجنبية للمعادن الأساسية، بالإضافة إلى جهودها لتأمين الموارد المحلية. بالإضافة إلى ذلك، يُناقش التقرير الأثر البيئي لاستخراج المعادن ومعالجتها في الصين، مع التركيز على تحديات الاستدامة المرتبطة بممارسات التعدين، بما في ذلك استهلاك المياه، وتدهور الأراضي، والتلوث. كما يُناقش قضايا أخلاقية، مثل ظروف العمل في المناطق الغنية بالمعادن. يُقيّم التقرير السياسات والإعانات التي طبقتها الصين لدعم نمو قطاع الطاقة النظيفة، بما في ذلك مبادرات نشر الطاقة المتجددة، وإنتاج المركبات الكهربائية، وتوفير المعادن الأساسية. كما يُستكشف استراتيجيات الحكومة الصينية، مثل خطة "صنع في الصين 2025"، في سياق كيفية تشكيلها لمستقبل الطاقة النظيفة واستخراج المعادن في البلاد. علاوة على ذلك، يُحلل التقرير الابتكارات التكنولوجية التي من شأنها تقليل الاعتماد على المعادن الأساسية، بما في ذلك التطورات في كيمياء البطاريات وتقنيات إعادة التدوير. كما يُناقش إمكانية استبدال المعادن النادرة ببدائل أكثر وفرة، إلى جانب التحديات والفرص التي تُمثلها هذه الابتكارات. وفي الختام، يُقدم التقرير نظرة شاملة على التفاعل بين المعادن الأساسية والتحولات نحو الطاقة النظيفة في الصين. ويؤكد التقرير على أهمية تأمين إمدادات مستدامة وأخلاقية من هذه المعادن، مع تعزيز الابتكارات التكنولوجية والسياسات الداعمة لدفع عجلة ثورة الطاقة الخضراء في الصين. وتؤكد النتائج على ضرورة التعاون العالمي واتباع نهج متوازن في استخراج المعادن، والاستدامة البيئية، والنمو الاقتصادي، سعياً إلى مستقبل منخفض الكربون.

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