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Critical Materials and Geopolitics of Rare-Earth in Renewable Sources of Energy

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Abstract

Critical materials-are raw materials for which there are no viable substitutes with current renewable technologies, for which most consumers depend on imports, but the supply is continuously changing (regarding dominant producing countries) with the exception of China which dominates global production of rare earth elements. Critical materials currently used for the production of renewable energy with low carbon emissions are rare earth elements (REE) and other metals, such as cobalt and lithium. Critical materials create geopolitical competition. China is the world leader. It currently produces 63% of the world's REE, holds 36% of the world reserves, provides 98% of the European Union's REE supply and 80% of the US's. Our article represents a syntetic documentary of the international literature in this field being structured on three chapters and conclusions: 1) The role of rare earth elements in current geopolitics; 2) Geopolitical competition over critical materials in the transition to renewable energies and 3) Rare earths from Ukraine: partnership with EU and agreement with USA.

Keywords: Critical Materials, Renewables Technologies, Low Carbon Emission, Competition, Geopolitics.

Introduction

Renewable technologies and batteries require certain minerals for their production, such as cobalt, lithium and rare earth elements. Some fear that countries that are rich in these essential minerals could use them to exert pressure on countries that lack them. This view was given credence in 2008, when China restricted the supply of rare earths to foreign buyers. Markets panicked and international prices rose because China controlled a substantial portion of the global supply of rare earth minerals. In fact, most of the 17 rare earth minerals (lanthanum, cerium, praseodymium, neodymium, prothemium, samarium, europium, gadolinium, terbium, dysprosium, halenium, erbium, thulium, ytterbium, lutetium, scandium and yttrium) are not geologically rare (See Table 1). They are abundant and polluting.

Rare earths have been perceived as rare, partly because, like all commodity markets, rare earth markets are cyclical. When demand increases, supply takes time to respond, as new mining markets have long lead times; the lag causes prices to rise, high prices can cause companies to overinvest, so a boom is followed by a price collapse and a new cycle begins. This is exactly what happened following China's export restrictions: as prices rose, investment flowed into mining projects, leading to a price collapse in 2012. In addition, there are alternatives to the use of rare earths and other critical metals in renewable technologies. Efforts are underway to create cobalt-free batteries and only a small minority of wind turbines (less than 2% in the US) are built with rare earth elements. The minerals can also be recycled, reused and stored, further reducing their perceived scarcity.

Source:www.telework.ro/ro/materialele-critice-si-geopolitica-pamanturilor-rare-in-sursele-regenerabile-de-energie/#

These factors combine to make it unlikely that cartels will emerge to control these critical materials. Cartels are difficult to form and sustain. In the 20th century, oil was the only major

commodity whose price did not fall in real terms, even when cartels were active in tin, coffee, sugar and rubber. International trade rules also prevent cartels. In 2014, the US, Japan and the EU appealed to the WTO and successfully challenged China's decision to restrict the export of rare earths. In conclusion, the energy transformation driven by renewable energy sources will provide fewer instances of "statecraft", the use of energy resources as an instrument of foreign policy. It is unlikely that electricity, biofuels and other materials essential to the new energy system will acquire the geopolitical role and weight of oil and gas.

The Role of Rare Earth Elements in Current Geopolitics

Minerals-including rare earth elements (REEs) and metals needed for renewable technologies-form a key-element of emerging low-carbon supply chains. The main concern is that the low-carbon transition will lead to increasing demand for critical materials such as lithium and cobalt, in turn creating geopolitical competition. An often-cited precedent is China's 2008 decision to restrict the sale of REE to foreign buyers, which led to widespread panic and price increases. To help manage potential risks, the research also made policy recommendations to ensure low-carbon supply chains. As with oil and gas reserves, the geographic concentration of critical material production and reserves can lead to a" Battle for Resources" as countries and companies attempt to control strategic aspects of the supply chain.

Today, China produces 63% of the world's REE and currently holds 36% of the reserves. China provides 98% of the EU's REE supply and 80% of the US's. And China's expanding dominance is overtaking REE. Researchers warn that China's efforts to mitigate its own mineral supply risk through foreign direct investment abroad, such as cobalt mines in the DR Congo, could limit the availability of minerals to other countries, leading to rivalry over access to different types of minerals. There is also growing concern about China's potential control over lithium supply chains, which together with cobalt are currently a key-raw material for electric vehicle batteries. As a result, the US and EU are stepping up efforts to minimize their dependence by creating alternative supply chains and technologies.

A "new resource curse"-associated with the low-carbon supply chain, its ownership and access to critical materials- could emerge. The production and sale of these materials can generate significant rents, which in turn could hinder the development of domestic institutions, similar to that experienced by some fossil fuel-producing economies (Alternatively, some research has focused on how countries that produce and export large amounts of renewable energy are also vulnerable to the resource curse, although this does not seem very likely). Others, however, warn against comparing it to the fight for oil. First, REEs are actually not that rare and are found in many countries. Second, technological innovation for replacing certain materials and recycling can help reduce unilateral dependencies. Tesla has announced that it will begin developing cobalt-free EV batteries.

Geopolitical Competition Over Critical Materials in the Transition to Renewable Energies

The current rapid growth of renewable energy is giving impetus to another phase of geopolitical thinking, this time focusing on the changes in the positions of states in the international system that may arise from the growth of renewable sources.

Source:www.telework.ro/ro/materialele-critice-si-geopolitica-pamanturilor-rare-in-sursele-regenerabile-de-energie/#

Although the geopolitics of renewable energies represents a new direction for geopolitical analysis, some arguments are already repeated with such frequency that they can come to be seen as familiar. They tend to involve the transposition of the geopolitical logic of oil and gas to renewable sources, despite the considerable differences between the types of energy and their associated technologies and infrastructure. While shifting its focus from fossil fuels to renewable resources, geopolitical analysis remains focused on resource-rich locations, key-infrastructure, transportation routes, control over energy supplies and the potential for supply disruption. The underlying assumption continues to be that control over and disposition of resources confers power to states in the international system.

Competition Over Critical Materials

A common claim about the consequences of the energy transition is that there will be increasing geopolitical competition for critical materials for renewable energy technologies. "Critical materials" is a broad term that refers to raw materials for which there are no viable substitutes with current technologies, on which most consumer countries depend on imports and whose supply is dominated by one or a few producers. Much of the concern about critical renewable materials focuses on the 17 rare earth elements and was sparked by an episode in 2010 when China imposed an embargo on rare earths to Japan over a territorial dispute. China dominates global production; Japan depends on Chinese supplies and fears that China could use its increasingly dominant position in global rare earth markets as a foreign policy tool.

However, most rare earth elements are actually geologically abundant in the Earth's crust. For example, cerium is more common than lead. The heavier rare earth elements are less common than the lighter ones, but most of them are still not among the rarest basic elements. Only promethium is truly rare, but it is not used in renewable energy technologies. What is true about REEs is that they are mostly found in dilute concentrations-which in turn makes their extraction expensive-and that there hasn't been much demand until recently and therefore production is limited. The Chinese-with low costs, lax environmental standards and an eye for profit-have captured most of the market.

One of the most relevant rare earth elements forty renewable energy is neodymium, followed by praseodymium and dysprosium, all of which are used in permanent magnets for direct-drive wind turbines. However, the vast majority of wind turbines are built with geared turbine technology that does not require permanent magnets. In the US, less than 2% of wind turbines use permanent magnets. Sometimes, "Rare earth elements" are used as an abbreviation for all materials critical for renewable energy. However, some of the most important materials for renewable energy technologies do not belong to the rare earth element group. For example, lithium and cobalt are essential for lithium-ion battery technology and copper is used in electric turbines and for electricity distribution, but neither of these belong to the rare earth element group. Whether and which critical materials

might be scarce and sought after is a complex question. The energy transition is primarily about technology and innovation.

Sources:www.telework.ro/ro/materialele-critice-si-geopolitica-pamanturilor-rare-in-sursele-regenerabile-de-energie/# www.telework.ro/ro/rolul-elementele-pamanturilor-rare-materiale-critice-litiu-cobalt-in-geopolitica-actuala

It is impossible to estimate with certainty which renewable energy technologies will be developed in the future, but it is very likely that there will be technological improvements and cost reductions in some or the other. One of the main objectives of renewable energy research is the development of new technologies that use cheaper materials and the prospects for success in this endeavour are good. But in recent years, the intensity of neodymium, dysprosium, germanium, tellurium, europium and terbium materials in clean energy technologies has been reduced. The rare earth element conflict between China and Japan in 2010 triggered technological innovations in the following years, weakening China's control over the market.

Another problem with the interest in critical materials is that tends to confuse the economics of commodity cycles with geological scarcity. Commodity markets are typically cyclical, repeating patterns of boom and bust. Mining projects have long lead times, sometimes decades, from an investment in exploration until a processed product reaches the market. When production from many different new mining projects finally reaches the market, prices collapse, initiating a new boom-and bust cycle. The 2010 Chinese supply disruption is a case in point, as it triggered more investment in rare earth mining and processing in other countries, changing the supply picture to some extent.

As renewable energy technologies evolve, it is plausible that prices for some critical materials will be high, that they will generate significant revenues for exporting countries and expenses for importing countries, and that some materials will be securitized. However, this does not mean that a geopolitical race to take control of critical materials is inevitable. EU imports of rare earths fell by almost 30% in 2024-an attempt to reduce dependence on China.

In 2024, a total of 12 900 tonnes of rare earth elements were imported into the EU marking a decrease of 29,3% compared to 2023, according to Eurostat. At the same time, 5500 tonnes of rare earth elements were exported from the EU, a decrease of only 0,8%. Rare earths elements are a group of 17 specialty metals with high supply risk and significant economic importance used in various high-tech applications.

Half of the EU Imports Come from China

In 2024, China was the largest EU partner for rare earth element imports, accounting for 46.3% of the total import weight or 6 000 tons. China was followed by Russia, with 28,4% of imports or 3 700 tons and Malaysia, which contributed 19,9% of the EU imports or 2600 tons.

China Uses Rare Earths as a Weapon

China's new export controls on key-rare earths have raised supply chain concerns for the US technology and defense sectors and beyond. All US allies that can re-export precious metals are targeted. China has imposed new export controls on seven additional rare earth elements, including yttrium, dysprosium and ytterbium, which are essential for modern technology such as jet engines and electric vehicles, according to Reuters. The move comes after US President Donald Trump increased tariffs on Chinese goods. China's inclusion of these items on its dual-use export control list raises concerns about global supply chains. The Dual-Use Export Control List does not guarantee defined export bans, but it allows for increased scrutiny of customers, particularly those linked to US military supply chains. This has already led to the halting of Chinese exports of germanium and gallium to the US, ahead of a complete ban in December 2024. The US Geological Survey estimates that global production of yttrium, one of the rare earths now under export restrictions does not exceed 20 000 tons annually.

Source:www.telework.ro/ro/rolul-elementele-pamanturilor-rare-materiale-critice-litiu-cobalt-in-geopolitica-actuala

Despite small quantities, these metals are ubiquitous in modern technology, highlighting the potential impact of China's export controls. China's control over the rare earths, market remains unchallenged, with the country accounting for approximately 60% of global production. It also dominates rare earth metal rare earth metal refining processes, handling approximately 90% of global production. Western countries are trying to reduce their dependence on Chinese rare earths by developing new mines and recycling projects. However, these initiatives are nowhere near being able to compete with China's production capabilities. The new export controls are expected to cause immediate supply disruptions and could signal a decline in Chinese shipments of rare earths to Western military buyers.

Rare Earths from Ukraine: Partnership with EU and Agreement with USA

The EU has had such a partnership with Kiev since 2021.More recently, President Donald Trump has indicated that he wants to reach a deal with Ukraine to gain access to the country's rare earths as a condition for continued US support for its war against Russia, the Associated Press reports. Speaking to reporters in the Oval Office, Trump complained that the US had sent, Ukraine more military and economic assistance than its European partners, adding, "We are looking so make a deal with Ukraine where they will pay for what we give them, with their rare earths and other things". Trump suggested that he had received word from the Ukrainian government that it would be willing to make a deal too give the US access to the essentials of a modern high-tech economy. Ukraine single, in 2021, immediately after the war began, a Strategic Partnership on Rare Earths with the EU-one of the rare moments when Europe stood up to the US. ''I want to have rare earth security", Trump added. We are" investing hundreds of billions of dollars. They have rare earths. And I want rare earth security and the" are willing to do it." ''We "are made a lot of progress on Russia, Ukraine" peace, Trump said.

Rare Earths in Ukraine Strategic Partnership with the EU, Starting in 2021

In the summer of 2021, Kiev was invited to join the European Batteries and Raw Materials alliance, with a view to developing in Ukraine an entire, value chain of mineral extraction, refining and recycling that would be connected to the EU mar-

ket for electric cars and digital equipment. European Commission Vice-President Maros Sefcovic went to Ukraine, where he signed a Strategic Partnership in the field of raw materials with Prime Minister Denys Shmyhal. The European Commission has seen the opportunity to cooperate with Ukraine in the field of raw materials given that the EU is dependent on imports from China, which supplies it with 98% of the elements extracted from rare earths, essential components for the manufacture of batteries of all types or wind turbines.

From the list of 30 essential materials, 21 of them are found in Ukraine, which extracts 117 of the 120-minerals used globally. We are talking about lithium, cobalt, titanium, rare earths, all of them are found in Ukraine, which can be a very valuable partner for us and which can strengthen the new industrial ecosystem that we are building on EU territory", said Commissioner Sefcovic in 2021. The Commission refused to specific the estimated volume of trade in raw materials under this partnership with Ukraine, Commissioner Sefcovic saying that it depends on the degree of availability of Ukrainian partners, especially regarding compliance with environmental, labour or human rights standards.

Source:www.dcbusiness.ro/acordul-dintre-sua-si-ucraina-bogat-in-simbolistica-dar-sarac-in-minereuri_675750.html

Critics from Russia and Germany

Kremlin spokesman Dmitry Peskov criticized US president Donald Trump's proposal to provide military assistance to Ukraine in exchange for access to the country's valuable minerals, Politico reports. "If we call it what it is, this is a proposal to buy aid-in other words not to provide it unconditionally or for other reasons and specifically to provide it on a commercial basis, Dmitry Peskov commented". "It would be better if the assistance was not provided at all, which would contribute to the end of this conflict", he added.

Germany chancellor Olaf Scholz criticized Trump's suggestion, calling it "very selfish, very self-centred" and pointed out that Ukraine would need its natural resources to finance its post-war reconstruction. Kiev's American security shield: US-Ukraine agreement for access to rare earths (V. Bratu,2025). US Treasury Secretary Scott Bessent said a deal between Kiev and Washington on access to mineral resources would provide Ukraine with a "security shield" after the war and President Volodimir Zelensky said he hoped such a deal could be reached soon, Reuters reports. Bessent, the first cabinet level official from Trump's team to visit Kiev, made the remarks after Zelensky said he was ready to strike a deal to open up access to Ukraine's mineral resources for American investment.

Trump, who wants a quick end to the war with Russian but has not said whether he will continue vital military aid to Kiev, said he wants 500 billion dollars, in rare minerals from Ukraine and that Washington's support must be ''assured". Zelensky told journalists after the meeting with Bessent that the American side presented a first draft of the agreement, which Kiev will study and hopes to conclude at the Munich Security Conference on February 14-16, 2025. ''We had a productive, constructive conversation. For me the issue of security guarantees for Ukraine is very important and we talked about minerals in general", said Zelensky, who is due to meet with US Vice-President JD Vance in Munich.

For his part, Bessent said the minerals deal is part of a "larger peace deal that Trump is considering", adding that his first visit to Ukraine showed that the war is a top priority for the Trump administration. President Trump confirmed in February that he would also send his special envoy, Keith Kellogg, to Ukraine, tasked with preparing a proposal to end the three-year fighting between Ukraine and Russia.

US-Ukraine Agreement, Strong and Weak Points

The mining agreement signed by President Trump with Ukraine is a great symbolic victory for both sides. Ukraine gains a long-term US commitment to invest in a -free, sovereign and secure Ukraine. The US, in turn, gains access to some of the future potential of Ukrainian mineral resources. And Trump is reinforcing his image as the -Great negotiator- as White House spokeswoman Karoline Leavitt pointed out. However, we should not expect an explosion of investment in Ukraine -critical minerals in the near future. Ukrainian Deputy Prime Minister Yulia Svirydenko stated on the X platform that she does not expect the Joint Investment Fund for Reconstruction to pay dividends for the next ten years [1]. The agreement covers all underground resources from oil and gas to a wide range of metals. Ukraine has some earth deposits, but their economic viability is uncertain. The best mapped field, Novopoltavske, was last studied between 1982-1991 and is located in a problematic area-near Cernihiv, in Zaporojie province, beyond the front line.

Sources:www.telework.ro/ro/rolul-elementele-pamanturilor-rare-materiale-critice-litiu-cobalt-in-geopolitica-actualawww.dcbusiness.ro/acordul-dintre-sua-si-ucraina-bogat-in-simbolistica-dar-sarac-in-minereuri_675750.html

The same is true for some of the most promising lithium projects. According to estimates of the think tanks We Build Ukraine and the National Institute for Strategic Studies, approximately 40% of Ukraine's metal resources are under Russian occupation. Without a definitive peace and reconciliation with Russia-which also claims the territory-it will not be possible to fully capitalize on this agreement. Although Ukraine also possesses other essential resources such as uranium, titanium and graphite, the lack of production infrastructure, with many facilities having been closed since the start of the war, means that an entire mining industry will have to be built from scratch.

Metal Processing and Refining, A Major Challenge

The separation of rare earths is complicated and dominated by China, which is why the agreement avoids mentioning them explicitly. Similarly, uranium must be enriched to be used and titanium refined to become useful in aviation. Russia, ironically is a key-player in both processing chains and supplied 27% of the enriched uranium used by the US in 2023. Russia is, however, excluded from any benefits of Ukraine-reconstruction. Another major obstacle is the market price. Although Ukraine's graphite deposits are well positioned and mapped-such as the Balakhivske project currently under feasibility study-the economic profitability is uncertain. There is demand in Europe for the graphite needed for electric car batteries, but China controls 70% of the global supply chain and can manipulate prices by

flooding the market to weaken its competitors.

The West's lithium ambitions are also under pressure due to oversupply in China and very low prices. Under these conditions, Ukraine will quickly understand that private investments will need government support to withstand market fluctuations. The US has already done this-the Department of Defense is a strategic investor in a domestic rare earths processing project led by an Australian company. As the world shifts from a fossil fuel-based economy to one centered on metals, minerals are becoming the new geopolitical currency. In this new world order, China is the dominant leader, and the West is the challenger. The US just made a strategic move in the great global mineral's competition. It won't be the last. Next on the list is the Democratic Republic of Congo, where another deal-minerals for security-is under discussion [1].

Table No 1: Critical Materials and the Geopolitics of Rare Earths in Renewable Energy Sources

Critical materials	Definition	Provenance of REE	Properties REE	Applications REE&other metals	From a geopolitical point of view	Objectives
REE 17:lanthanum,cerium, praseodymium,neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium,thulium, ytterbium, luthetium, scandium, yttrium Other metals: lithium, cobalt, copper	Are raw materials for which there are no viable substitutes with renewable technologies	-From minerals in the earth's crust -From reuse -From used products through recycling	-Produce low-carbon energy -Are cyclical-Repeating patterns of expansion and crisis like any commodity Are polluting -Expensive extraction (diluted state)	-REE significant economic importance, used in various high-tech applications Neodymium (to permanent magnets for direct drive wind turbines) -Praseodymium (to permanent magnets for direct drive wind turbines) -Dysprosyum (to permanent magnets for direct drive wind turbines) -terbium (essential for modern technology-jet engines electric vehicles) yttrium (essential for modern technology-jet engines, electric vehicles) Other metals: -lithium (essential for lithium-ion battery technology) cobalt (essential for lithium-ion battery technology) -copper (to electric turbines&electricity distribution)	-creates competition -seeks to reduce dependence on China -renewable energy represents a new direction centered on: resource-rich locations,key-infrastructure, transportation, routes, supply control The US concluded a contract with Ukraine in May 2025 for the joint exploitation of REE and other metals	-low-carbon energy production -search for cheaper alternatives to REE, with prospects of success -innovative technologies as renewable energy sources

Source: Author, based on data from reference materials

Conclusions

Rare Earth Elements (REEs) along with lithium and cobalt are critical materials used in renewable technologies for low-carbon energy production. Exploiting REEs is expensive, because they are found in the Earth's crust in a diluted state, there is not much demand and they are polluting. The issue of critical materials for renewable technologies has led to geopolitical competition. China is the world leader and sets prices, causing concern. From a geopolitical point of view, the US and the European Union are pursuing a policy of minimizing their dependence on China, by creating new supply chains and alternative technologies. Technological innovation for replacing critical materials with new ones and recycling can lead to a decrease in unilateral dependence.

Geopolitical analysis focuses on resource-rich locations, key-infrastructure, transportation routes, control over energy supplies and the potential for supply disruption. Examples of REEs and their use. Neodymium, praseodymium and dysprosium are used in permanent magnets for direct-drive wind turbines. Terbium and yttrium are essential for modern technology (jet engines, electric vehicles). Modern renewable technologies must use cheap critical materials with promising prospects that will diminish China's control of the market. We know that REEs have significant economic importance, used in various high-tech applications [2-5].

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