A GEOSTRATEGIC ROLE OF CRITICAL MINERAL RAW MATERIALS IN THE ENERGY TRANSITION

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Abstract: *At the end of the second decade of the 21st century, humanity is at a turning point: either it will find effective answers to the global challenge of preventing the devastating changes caused by the sources of greenhouse gases emissions, resulting from human activity, or the world, as we know it today, will disappear. In this context, and starting from long-term trends of using the geostrategic resources and mineral raw materials, it is noticeable that the world is going through an inevitable transition - an energy transition, a thorough transformation of the global energy and economic sectors. A demand for certain mineral raw materials, metals and minerals such as cobalt, lithium, magnesium, aluminium is growing fast. Digitalization, industry and energy transition are transforming and increasing the demand for raw materials. In this context, critical mineral raw materials and their circular use are of significant importance in the economy because mineral raw materials form the basis of the economy and are essential for maintaining and improving the quality of life. There is no doubt that it will not be possible to implement the European Green Plan - strategy without the usage of critical raw materials. Namely, less than 5 % of the world's critical resources are extracted in the EU, while EU industry accounts for about 20 % of the world's consumption of these resources, and in this context, strengthening the European supply of critical raw materials is extremely important for the Green Plan and the resilience of the key industry.*
Keywords: *critical mineral raw materials, EU Green Plan, energy transition, research projects, hydrogen*

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1. INTRODUCTION

Mining has been rapidly developing worldwide in recent years, following the global trend of economic growth. The future trajectory of mining will depend on factors such as population growth, energy and mineral demand, economic development, environmental conditions, and assessments of existing ore reserves. The International Energy Agency (IEA) indicates that global energy demand will continue to rise as the human population increases. The current energy transition[1] is unprecedented in scope and speed, with climate targets requiring net-zero emissions by 2050, essentially meaning the complete phase-out of fossil fuels in less than 30 years, accompanied by a significant increase in renewable energy production. We are currently active participants in the early stages of the fourth energy transition, a generational process of decarbonizing the global economy and combating global climate change. Energy resources have always been an integral part of human life, and historical periods characterized by specific energy sources have correspondingly experienced growth rates in both population and gross domestic product. In the past 20 years, more energy has been consumed than in the entire preceding historical period. **Figure 1** illustrates the population growth and energy consumption growth from 2010 to 2019. It is evident that population growth was 11%, while energy consumption increased by 15%, with energy consumption per capita rising from 20.18 to 20.94 MWh. It should be emphasized that the share of renewable sources in total electricity consumption increased from 3.53% in the period of 2010-2019 to 10.33%. In other words, energy production from renewable sources increased by a factor of 4.13. Woetzel et al. (2009) note that the increasing urban population and prosperity in China, Russia, India, and Brazil have led these countries to utilize mineral resources in unimaginable quantities compared to 20 years ago. Numerous authors, such as Cohen (2007) and Ragnarsdóttir (2008), have predicted forthcoming scarcity and even depletion of mineral resources.

[1] *The term "energetska tranzicija" is the translation of the German term "Energiewende." The term "Energiewende" was first used in 1980 in a publication by the Institute for Applied Ecology in Germany titled "Growth and prosperity without oil and uranium." It gained international recognition in the early 2010s after the Fukushima Daiichi nuclear disaster and has since become a reference for one of the most ambitious projects for decarbonizing the energy sector. The concept of "energetska tranzicija" or "Energiewende" encompasses the transition from fossil fuel-based energy systems to low-carbon, renewable energy sources, along with increased energy efficiency and sustainable energy policies. It represents a comprehensive transformation of the energy sector with the goal of achieving a more sustainable, climate-friendly, and secure energy future.*

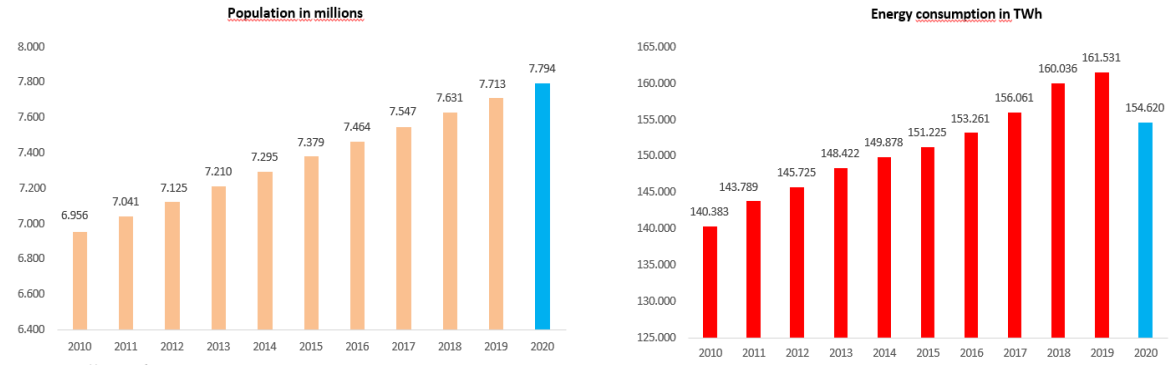

Figure 1 *Population growth and energy consumption 2010-2019 (Data source: economics/statistical-review/bp-stats-review-2021, www.worldometers.info, UN Population Division, 2022.)*

The energy transition is accelerating the factor of mineral supply security, making it an increasingly important aspect in discussions about energy security. As the energy sector becomes the leading consumer, clean energy technologies are becoming the fastest-growing segment of demand. This shift towards clean energy sources, such as renewables, electric vehicles, and energy storage systems, requires a steady and reliable supply of minerals and raw materials.

2. MATERIALS AND METHODS

Critical raw materials in the time trajectory of the foundations of the future development of the EU with reference to the ecological and social aspect.

The new European industrial strategy aims to strengthen European autonomy to prevent the current dependence on fossil fuels such as oil and gas from being replaced by geopolitical dependence on critical mineral resources. In the future, global demand for critical mineral resources could dramatically increase due to the development of new technologies and energy systems. This increased demand could lead to even greater dependence of the EU on the import of these resources, creating new supply risks and opening up space for new geopolitical dependencies. The EU relies on critical raw materials from various third countries, and dependence on the import of critical raw materials can pose a risk as supply can be subject to changes due to political, economic, or trade factors in exporting countries. Dependence on the import of critical raw materials can result in supply risks, price increases of critical raw materials, and negative social consequences, which have a detrimental impact on economic growth. The EU has recognized the need to develop policies for critical raw materials to reduce import dependence, diversify supply, promote innovation and technological progress, and ensure sustainable supply of critical raw materials. This includes promoting domestic production of critical raw materials, developing new technologies for recycling and circular economy, strengthening international cooperation and partnerships, and promoting transparency and accountability in the supply chain of critical raw materials. The EU boasts the largest network of trade agreements globally. Recent agreements with Mexico, the United Kingdom, New Zealand, and Chile feature dedicated chapters addressing energy and raw materials. Furthermore, negotiations are presently taking place with Australia and Indonesia, countries that hold substantial reserves of vital raw materials for the energy transition, including metals and nickel. When examining the concept of critical raw materials, it becomes apparent that the United States' 2020 Energy law provides an intriguing definition. In this law, the term "critical minerals" refers to strategic raw materials that hold considerable importance for both economic and national security. These minerals are characterized by their criticality and are essential for various industries and sectors, including technology, defense, renewable energy, and manufacturing. One defining aspect of critical minerals is the vulnerability of their supply chains. The supply chains for these minerals are susceptible to disruptions and risks that can have significant implications. Geopolitical risks, such as trade restrictions, political instability, and regional conflicts, can greatly affect the availability and accessibility of these minerals. Additionally, fluctuations in global demand, driven by advancements in technology and energy systems, further contribute to the challenges surrounding their supply. The terms "critical raw materials" and "critical mineral raw materials" are often used interchangeably in the literature. This is primarily because minerals comprise the majority of critical raw materials due to their abundance and high production volume. Consequently, the extraction, processing, and utilization of minerals play a crucial role in addressing the criticality of raw materials. The European Commission Communication (2014, 2011) and the study by Blenginia et al. (2017) consider ensuring reliable and sustainable access to mineral raw materials and their circular use to be highly important in the economy within the EU and globally. Mineral raw materials form the foundation of the European economy, providing jobs, enhancing competitiveness, and playing a crucial role in maintaining and improving the quality of life. To address this challenge, the European Commission has developed a list of critical raw materials for the EU, which undergoes regular review and updating. Insufficient availability

of certain raw materials in the market can result from inadequate domestic production and dependence on imports from distant markets, as well as supply disruptions caused by economic, natural, and geopolitical factors. These factors contribute to frequent fluctuations in raw material prices, which, in turn, affect production planning, the pricing of final products, and may disrupt production if the speed of price changes jeopardizes planned production and development goals. Ultimately, these factors can impact the competitiveness of certain industries in the market. For instance, the critical raw materials lithium, cobalt, and graphite are essential for the production of lithium-ion batteries used in electric vehicles and energy storage systems. The scarcity or instability of their supply can significantly impact the development and sustainability of renewable energy in the EU. Tantalum, tin, tungsten, and gold are crucial raw materials for manufacturing microchips, memories, and other electronic components. Disruptions in the supply chain of these raw materials can lead to disruptions in the availability, production, and pricing of electronic devices that are widely used in everyday life, such as smartphones, tablets, computers, televisions, and other electronic components.

It is evident that emerging products and technologies like electromobility, digitalization, industrial advancements, and energy transition are driving the demand for raw materials. This trend highlights the importance of critical raw materials for the successful implementation of the EU's green plan. Numerous key industries in Europe, particularly those involved in innovative technologies, heavily rely on critical raw materials, the majority of which are sourced from non-EU countries. **Figure 2** illustrates the EU's dependence on critical raw materials from various third countries.

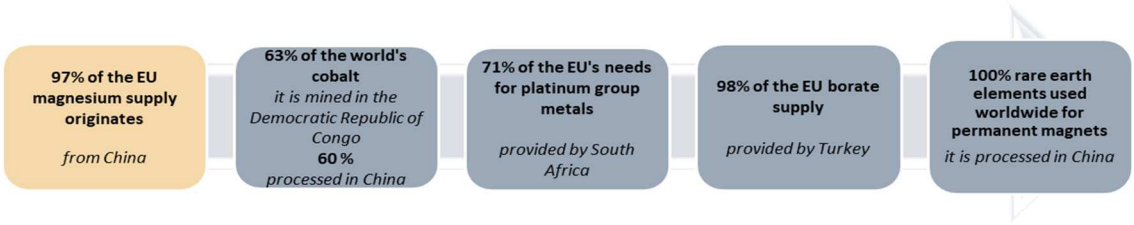

Figure 2 *EU's dependence on critical raw materials from various third countries (Source: EU)*

The European Commission defined the first list of critical raw materials in 2011, which included 14 critical materials. The list of critical raw materials was established as a priority measure of the EU Raw Materials Initiative in 2008. The Commission committed to updating the list at least every three years to take into account developments in production, markets, and technology. The classification was based on criteria that identified the supply of raw materials as highly risky in terms of possible shortages in the next 10 years and highlighted the extreme importance of critical raw materials in the value chains of goods and products (European Commission Communication 2011). After the initial list, revised versions were published in 2014 (with 20 critical raw materials), 2017 (with 27 critical raw materials), and 2020 (with 30 critical raw materials) (Tomašić 2021). The most recent update of this list considered the aforementioned criteria for a five-year period for EU members (EU 27, excluding the United Kingdom), and a total of 83 raw materials were examined. Bauxite, lithium, titanium, and strontium were added to the list for the first time. In terms of supply concentration, helium still raises concerns but was removed from the critical list in 2020 due to its declining economic significance. The list of critical raw materials helps identify areas that require investments and research activities, as well as innovations within the EU programs (Horizon 2020) and national programs, particularly in terms of new mining technologies, substitution, and recycling. The environmental and social aspects of critical raw materials in the EU are now significant aspects of the sustainability and resource management debate in modern society, considering that their extraction, production, and use have significant environmental and social impacts at both local and global levels. The EU has recognized the need for a more sustainable approach to the management of critical raw materials and has adopted a series of initiatives and policies aimed at reducing dependency on the import of critical raw materials, promoting sustainable use and management of raw materials, and incorporating stricter environmental standards and regulations. This includes the promotion of responsible waste management, reduction of greenhouse gas emissions, and the encouragement of innovations in technologies that reduce the ecological footprint of raw material exploitation. In March 2023, the European Commission introduced a proposal for a new Law on Critical Raw Materials. This legislation is part of a comprehensive set of laws aimed at achieving the objectives outlined in the European Green Deal and attaining net-zero greenhouse gas emissions by 2050. The proposed law aligns with the broader objectives of the European Green Deal, which seeks to transform Europe into a climate-neutral and environmentally sustainable continent. By reducing the emissions of greenhouse gases and transitioning towards cleaner energy sources, Europe aims to mitigate climate change and promote a more sustainable future. **Figure 3** shows the objectives of the aforementioned law.

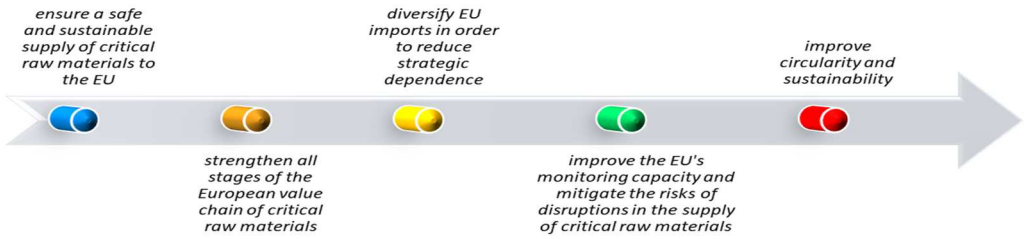

Figure 3 *Objectives of the proposal of the European law on critical raw materials (Resource: EU)*

2.1. Sustainable development in the management of mineral resources in EU countries

The concept of sustainable development is widely used in various fields related to human life. It emerged in response to the excessive and uncontrolled use of natural resources during the dynamic economic growth observed globally in the latter half of the 20th century (Dubiński 2013). In the mining industry, sustainable development can be achieved by adhering to principles, with rational and economical use of mineral resources being the leading principle (Dubiński and Drzęźla 2005). Environmental challenges pose significant issues for the mining industry and constitute the second pillar of sustainable development, encompassing elements such as soil, water, air, waste, seismic activity, and noise (Dubiński and Turek 2006). Conflicts arise from competing interests and activities related to economic requirements, environmental protection, cultural heritage, and regulations. Mining plays a dual role, being essential for industrial production and regional development while also causing substantial landscape and environmental changes (De Vos et al. 2005; Wirth et al. 2012). The economic effects of mining extend to the national, regional, and local levels, with direct environmental and societal impacts concentrated in the proximity of mining sites (Kumpula et al. 2011; Meyfroidt et al. 2013; Schaffartzik et al. 2016; Schilling et al. 2018). Mining activities and associated infrastructure significantly alter landscapes, affect local environments, ecosystems, land use, and human lives. These impacts can persist long after mine closure, both within and beyond the mining areas (Dudka and Adriano 1997; Wirth et al. 2012; Kivinen 2017; Salom and Kivinen 2019). The new European action plan for mineral raw materials adopted in 2020 entitled "Resilience of critical raw materials: charting the path towards greater security and sustainability" includes 10 action points (**Table 1**, Source: European Commission Communication, 2020) that should be implemented:

Table 1 *European action plan for raw materials for the period 2020-2027. years*

EUROPEAN ACTION PLAN FOR RAW MATERIALS FOR THE PERIOD 2020-2027.	
ACTION POINTS	**DATE OF EXECUTION**
Establish a European Raw Materials Alliance, initially to build resilience and open strategic autonomy for the rare earths and magnets value chain, before expanding to other raw materials areas	**2020-2027**
Develop sustainable financing criteria for the mining, extractive and processing sector by the end of 2021	**2021**
Launch critical raw materials research and innovation in 2021 on waste processing, advanced materials and substitutes	**2021-2027**
Map the potential of secondary critical raw materials from stocks and waste in the EU to identify sustainable recovery projects by 2022	**2022**
Identify mining and processing projects and investment needs and related funding opportunities for critical raw materials in the EU that could be operational by 2025, with priority for coal-mining regions	**2025**
Develop the knowledge and skills needed for mining, extractive and processing processes from 2022 onwards	**2021-2027**
Implementation of Earth observation and remote sensing programs for resource exploration, operations and post-closure environmental management (Commission, industry)	**2021-2027**
Develop Horizon Europe R&I projects on processes for exploitation and processing of critical raw materials to reduce environmental impact starting in 2021	**2021-2027**
Develop strategic international partnerships and related financing to ensure a diverse and sustainable supply of critical raw materials, including undistorted terms of trade and investment, starting with pilot partnerships with Canada, interested countries in Africa and the EU neighborhood in 2021	**2021-2027**
Promote responsible mining practices for critical raw materials through the EU regulatory framework (2020-2021 proposals) and relevant international cooperation 32 (Commission, Member States, industry, civil society organizations)	**2020-2027**

Sustainable production of minerals and metals represents a prerequisite for the supply of the industrial supply chain, and the success of the action plan will be conditioned by clear and well-defined economic priorities across industrial sectors. According to Christmann (2021), the development of the Battery Alliance (involving around 400 partners from the entire EU) is the first response to a strategic question of vital importance for the Union's future. Policies related to minerals and metals largely depend on the Chinese government and its companies that directly or indirectly control the banking system and have their own sectoral policies (energy, environment, research, and trade policies) (Reichl and Schatz 2020).

3. RESULTS AND DISCUSSION

Litium[2] is an alkali metal, a relatively rare element that is mainly found in the form of minerals in soil, rocks, and saltwater. It has a very low density, high reactivity with water and acids, and is often used in batteries for its ability to release electrons when oxidized. Lithium-ion batteries are highly efficient, lightweight, and have a long lifespan, making them ideal for use in mobile devices and electric vehicles. The largest sources of lithium in the EU are found in the Czech Republic, Portugal, and Sweden, but EU countries have limited lithium reserves that are insufficient to meet the growing demand for lithium in Europe. Therefore, the EU depends on lithium imports to meet its needs (the EU imports nearly 100% of its lithium requirements, with the largest suppliers being Chile, Australia, and Argentina), while the largest lithium deposits globally are found in South America, Australia, and some countries in Asia. It is predicted that batteries powering electric vehicles will increase the demand for lithium 11-fold by 2030 and 17-fold by 2050. Lithium is a critical and key mineral resource in the context of energy transition for the following key reasons: Lithium-ion batteries have become a fundamental element in global efforts to reduce greenhouse gas emissions, increase the share of renewable energy in the energy mix, and achieve a more sustainable and low-emission energy system; global demand for lithium is rapidly increasing due to the increased use of electric vehicles and renewable energy sources (which can lead to supply instability and high prices); it is geographically concentrated in a few countries (creating geopolitical risks and dependence on specific supply sources) and the process of extracting lithium can have negative environmental and social impacts related to mining activities, water, and local communities. **Figure 4** shows some of the potentially negative environmental impacts that may result from lithium mining.

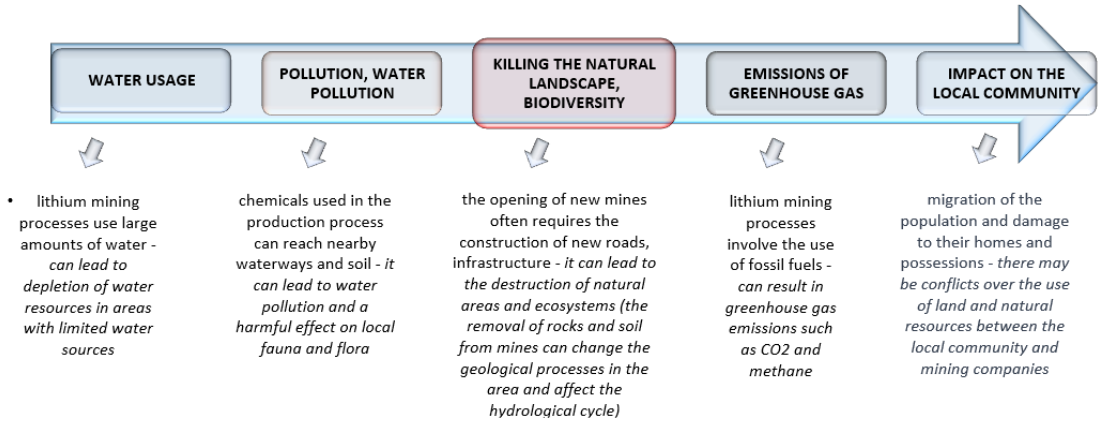

Figure 4 *Some of the key environmental concerns related to lithium mining*

To ensure a sustainable supply of lithium and reduce negative impacts, it is important to invest efforts in developing innovative technologies for lithium extraction and recycling, and to promote transparency, accountability and social sustainability in the lithium supply chain.

4. CONCLUSION

The problem of increasing demand for mineral resources today has a much wider dimension, and more and more often the world talks about the general problem of the safety of mineral raw materials. This security becomes especially important in relation to strategic raw materials that are crucial for the development of many new technologies. In this context of the temporal energy trajectory transition to clean energy and the application of an increasing number of technologies that rely on key mineral raw materials (copper, lithium, cobalt, nickel), it can be concluded that today's supply and investment plans for many critical minerals are far below what is needed to support accelerated development. The sustainable supply of critical raw materials is extremely important for global

[2] *first discovered in 1817 by Swedish chemist Johan August Arfvedson, in the same year British chemist William Thomas Brande also isolated lithium from petalite and named it "lithium" from the Greek word "lithos", meaning stone, (Li) is a chemical element found in the periodic table of elements under the number 3 and the symbol Li*

economic development and technological progress and is faced with growing risks and challenges. Lithium plays a key role in the energy transition and achieving a more sustainable energy system. As more and more countries and industries turn to renewable energy sources and electric mobility, it is important to find a balance between the need for lithium and the protection of the environment and the social aspects associated with its production and use. Geopolitical instability, environmental impacts and social injustices associated with the supply of critical raw materials require coordinated efforts at global and local levels to ensure sustainable supply and minimize negative impacts on the environment, communities and society. In this context, the energy transition represents an energy trajectory in which lithium is considered a critical mineral raw material and a necessary resource in achieving sustainable energy goals and reducing greenhouse gas emissions in the energy sector. It is important to emphasize that it should be taken into account that it takes 15 to 20 years for mining projects to move from the discovery phase to the first production phase and that if deficits are waiting to appear before new projects are developed, there may be a period of market tightness and high price volatility, which means that critical mineral raw materials, as key factors in the transition to clean energy, must not become the "Achilles heel" of the process of energy transition and application of clean energy.

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