ECONOMIC ANNALS-XXI
ISSN 1728-6239 (Online)
ISSN 1728-6220 (Print)
https://doi.org/10.21003/ea
http://ea21journal.world

Volume 211 Issue (9-10)'2024

Citation information: Issatayeva, F., Aubakirova, G., Togaybaeva, L., Shametova, A., Koshmaganbetova, Zh., & Biryukov, V. (2024). Critical mineral resources: the case of Kazakhstan under the global competition shift. Economic Annals-XXI, 211(9-10), 15-28. doi: https://doi.org/10.21003/ea.V211-03

UDC 330.121

Farida Issatayeva
PhD (Geology),
Associate Professor,
Abylkas Saginov Karaganda Technical University
106/4 Ermekov Str., Sq. 44, Karaganda,100009, Republic of Kazakhstan *
isataeva.farida@gmail.com *
ORCID ID: https://orcid.org/0000-0001-6208-3292

Gulnara Aubakirova
D.Sc. (Economics),
Professor,
Abylkas Saginov Karaganda Technical University
11 N. Nazarbayev Ave., Apt. 10, Karaganda, 100008, Republic of Kazakhstan
rendykar@gmail.com *
ORCID ID: https://orcid.org/0000-0003-0337-1539

Lusia Togaybaeva
PhD (Economics),
Abylkas Saginov Karaganda Technical University
106/4 Ermekov Str., Sq. 44, Karaganda,100009, Republic of Kazakhstan
toglusia@mail.ru *
ORCID ID: https://orcid.org/0000-0002-4469-5022

Aigerim Shametova
PhD (Economics),
Associate Professor,
Abylkas Saginov Karaganda Technical University
17/2 N. Nazarbayev Ave., Apt. 1, Karaganda, 100008, Republic of Kazakhstan
ashametova.74@mail.ru *
ORCID ID: https://orcid.org /0000-0002-7200-1921

Zhanar Koshmaganbetova
MA (Economics and Business),
Senior Lecturer,
Abylkas Saginov Karaganda Technical University
17/2 N. Nazarbayev Ave., Apt. 1, Karaganda, 100008, Republic of Kazakhstan
zhanar_kosh@mail.ru *
ORCID ID: https://orcid.org/0000-0002-5433-1070

Valery Biryukov
D.Sc. (Economics),
Associate Professor,
Abylkas Saginov Karaganda Technical University
17/2 N. Nazarbayev Ave., Apt. 1, Karaganda, 100008, Republic of Kazakhstan
_valera@mail.ru *
ORCID ID: https://orcid.org/0000-0003-2712-8840

Critical mineral resources: the case of Kazakhstan under the global competition shift

Abstract. This study presents the authors' perspective on Kazakhstan's position during the shift in global competition from hydrocarbon extraction to the race for critical mineral resources in the context of the global energy transition. Describing the response of Kazakhstan's mining industry to this challenge, the authors offer developing countries a theoretical and practical framework for formulating a new strategy aimed at minimizing environmental impact and finding new ways to create the necessary conditions for the functioning of the rare earth metals industry. This strategy takes into account not only the prerequisites but also the restraining factors for its development against the backdrop of a changing geoeconomic landscape.
The study demonstrates that the growing importance of critical minerals to the global economy, coupled with limited access to them for many countries, could shift Kazakhstan's position. There is an opportunity not only to conduct responsible exploration, extraction, and processing of critical minerals and to establish a full technological cycle to meet domestic demand, but also for the country to carve out a niche as a global

* Corresponding author

player in the high-tech industry. Kazakhstan could integrate into international technological supply chains, thereby strengthening its strategic autonomy and enhancing its perception by the international community as a key region supplying critical minerals to the global market.

In a context where geopolitical factors, including regional conflicts, are increasing the importance of transcontinental routes and strategic raw materials, the authors' proposals may be useful for countries with transitional economies in developing plans to diversify sources of critical mineral supplies. A promising area for future research is the study of the role of junior mining companies as new players in the resource extraction sector, as well as expanding their involvement in critical mineral supply chains to strengthen Kazakhstan's strategic position within the new energy paradigm.

Keywords: Kazakhstan; Investments; Mining Sector; Mining Industry; Critical Minerals; Rare Earth Metals; Lithium; Mining Company; Global Economy; Transitional Economy; Supply Chain; Global Energy Transition

JEL Classifications: JEL: L71; L78; Q56

Acknowledgements and Funding: The authors received no direct funding for this research.

Contribution: The authors contributed equally to this work.

Data Availability Statement: The dataset is available from the authors upon request.

DOI: https://doi.org/10.21003/ea.V211-03

1. Introduction

In the context of the transition to a low-carbon economy, each country has responded in its own way to the challenge of securing mineral supply chains, including rare earth metals (REMs) and rare earth elements (REEs) (Barteková & Kemp, 2016). There is a steady global increase in demand for critical minerals: by 2050, annual nickel supply will need to increase by 208%, and copper by 156% compared to 2020 production levels (World Bank, 2024). The highest growth rates in REE demand during 2024–2029 are projected in the Asia-Pacific region, which is becoming the global hub for electronics manufacturing (Figure 1) (IEA, 2023; International Metallurgical Research Group, 2023; Mordor Intelligence, 2024).

Currently, China holds a dominant position in the global supply market for critical minerals. Significant reserves have also been identified in the United States, Russia, Australia, and Brazil, while limited quantities have been found in Canada, India, South Africa, and Southeast Asia. Since 2017, China has become the world's largest importer and exporter of rare earth elements (REEs), controlling 60% of global REE extraction and 85% of processing. The country is positioned in the upstream and midstream segments of the industrial value chain, possessing all the necessary knowledge, technologies, and production capacities within its national borders. China accounts for over two-thirds of global rare earth metals (REMs) production, as well as 70% of cobalt refining, 58% of lithium, and 35% of nickel (Xu et al., 2024). The growing domestic demand

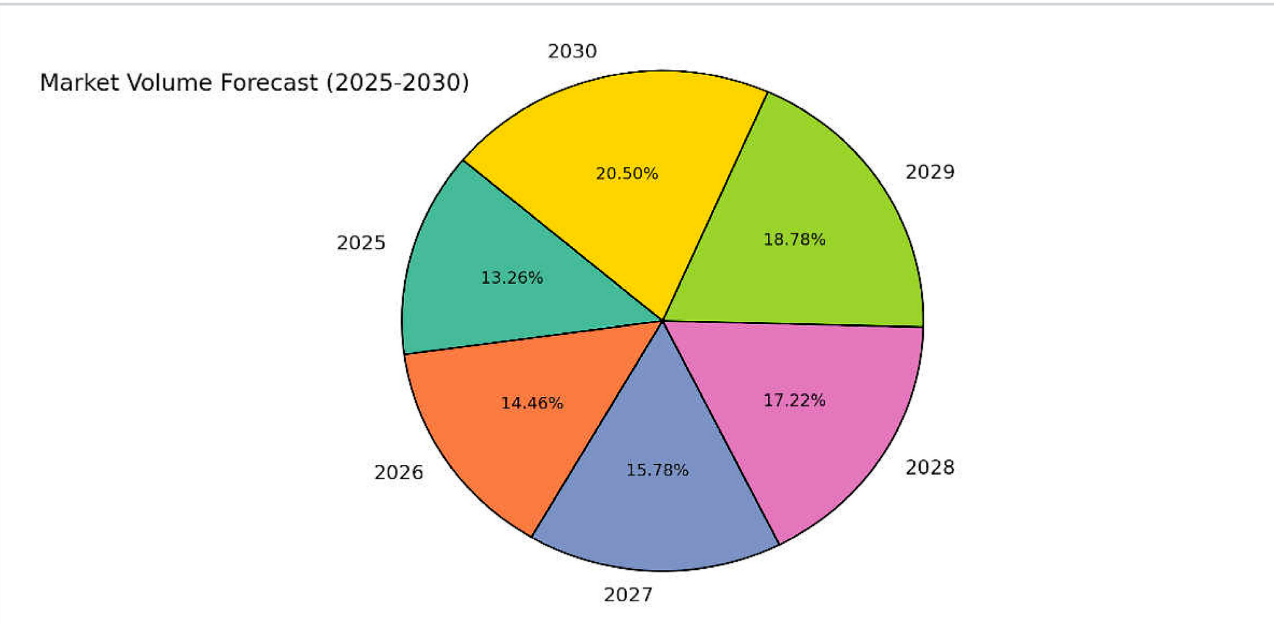

Figure 1:
Projected Growth of the Global REM Market, USD Billion
Source: Based on data of IEA, 2023; IMRG, 2023; Mordor Intelligence, 2024

for cobalt, lithium, and platinum group metals is driven by the country's ambition to maximize its control over value chains in high-demand technology sectors (Going Out: An Overview of China's Outward Foreign Direct Investment, 2011; Shen et al., 2020).

Access to vast rare earth mineral resources in the Asia-Pacific region enables China to increase its imports. To strengthen its strategic position, reinforce monopolistic dominance, and maintain control over key nodes in global supply chains - while also creating barriers to the development of the industry in other countries - China has imposed export restrictions as early as 2008. In 2023, the country introduced new restrictions on the export of gallium and germanium, which are widely used in high-tech manufacturing, as well as on technologies related to the refining, processing, and application of REEs.

This strategic stance by China necessitates adjustments in the management of global REM supply chains for high-tech sectors of national economies. Shifts in global markets driven by the geopolitical concentration of raw material supply in a single country may hinder the global energy transition. The REM sector's sensitivity to supply chain disruptions and price volatility has become a limiting factor for its development and can lead to significant fluctuations in the prices of critical materials.

Moreover, since economically viable REM deposits are concentrated in only a few countries, trade plays a vital role in ensuring access to these resources. As a result, many countries are heavily reliant on a limited number of suppliers. At the same time, the overall mineral supply chain poses challenges for trade flows, adversely affecting importers and end-users of these essential minerals.

Against the backdrop of escalating geopolitical conflicts, the need to enhance the resilience of supply chains is compelling countries to focus more intently on the development of their own production capacities. The EU, the United States, and Japan, while limited in metal extraction and processing capabilities, are actively supporting domestic enterprises and working to form, regulate, and control REM supply chains that are independent of China.

According to forecasts, annual production of REEs from non-Chinese sources is expected to grow from 20,000 tons in 2020 to approximately 70,000 tons by 2030. However, the existing supply chain to sustain this level of demand remains extremely limited, and much of this material will likely still be processed in China (Williams, 2021).

The actions of the United States - through initiatives such as the Economic Resilience Initiative for Central Asia (ERICEN) and the C5+1 Critical Minerals Dialogue - demonstrate a clear intention to reduce dependency on Chinese critical mineral supply, to constrain China's ability to expand access to such resources, and to establish regional cooperation in exploration, extraction, and processing of critical minerals in Central Asia. This region, which ranks among the top twenty global producers of certain critical materials, seeks to assert control over the mineral wealth within its territory.

For the European economy, critical raw materials (CRMs) - of which the EU is significantly import-dependent - hold both economic and strategic importance. The EU is also expanding its cooperation with Central Asia, a region that exports REMs primarily to China, in order to boost the energy efficiency of its economy, regulate strategic metals supply chains, and enhance its security and resilience. This effort is particularly focused on accelerating the deployment of mineral-intensive renewable energy sources as an alternative to Russian gas and coal (Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, 2020).

To ensure unrestricted access to certain raw materials, the European Commission has established a regularly updated list of CRMs - materials deemed essential to the EU economy and associated with a high risk of supply disruption.

Kazakhstan, where the tax rates on the extraction of rare earth minerals (REMs) are the lowest among all minerals, ranging from 1% to 7.8% (gallium - 1, graphite - 3.5, tin - 3.9, vanadium - 5.2, indium - 6, platinum, palladium - 6.5, tellurium - 7, lithium, niobium - 7.7, antimony, bismuth, cobalt, magnesium, and tantalum - 7.8), has significant potential in the field of critical raw materials. Eighteen of the 34 critical raw materials required by the European economy are produced in the country, not just in raw form but as ready-to-use metals.

Among rare metals, tungsten holds a leading position in Kazakhstan, followed by molybdenum, with tantalum, niobium, tin, and REMs, which are mainly sourced from vanadium, phosphate, uranium, molybdenum-tungsten, and titanium-zirconium deposits.

Kazakhstan has identified 124 deposits of rare and rare earth metals, including 15 REM deposits, which are strategically important for electronics and environmentally clean energy technologies, as well as 17 tantalum-containing ore deposits, 13 of which also contain niobium. About 80% of the reserves are composed of rare metal pegmatite deposits located in Eastern and Northern Kazakhstan. One of the world's three full-cycle production facilities for beryllium, scandium, osmium, and four tantalum productions is located in Kazakhstan. Kazakhstan is the only producer and holder of the artificially produced rare earth metal - osmium-187 monoisotope, which is extracted from waste generated during copper ore processing.

Currently, 37 deposits have been explored, and prospecting activities are underway to identify rare and rare earth metal reserves at 12 promising sites, with valuable components found at 9 of them. Among the rare metals, there are 6 lithium oxide deposits and 2 deposits of copper-rich sandstones containing osmium oxide. A special group of rare metals consists of rare scattered elements and REEs, which do not form their own deposits. As trace elements in ores from various deposits, they can be extracted during the complex processing of these ores.

For Kazakhstan, the economic and scientific-technical policies established for the dynamic development of the high-tech industries of the USA and the EU using REEs and REMs are only partially applicable, as they are based on different goals in managing global raw material supply chains. Despite the drive to ensure comprehensive utilization of mineral resources, Kazakhstan's demand for valuable components is relatively low, mainly due to the limited capacity of the domestic market.

At present, Kazakhstan, having gained certain competencies in the production of critical raw materials and strengthened its position as a reliable supplier in the global REM supply chain, aims to restore depleted natural resources, enhance its position in the midstream segment of the global value chain, and create a vertically integrated supply chain (Hirvilammi et al., 2023).

This has defined the goal of the present study - to assess the current state of Kazakhstan's mineral raw materials sector, identify accumulated issues, and outline directions for further development within the context of forming a model to retain the production chain within the country while simultaneously strengthening international positions.

2. Brief Literature Review

To build Kazakhstan's carbon regulation model, aimed at increasing the energy and environmental efficiency of the economy, it is essential to conduct an in-depth study of the accumulated global experience and knowledge on the issue of decarbonization for subsequent adaptation to national conditions. The pressing issues related to the energy transition of the global economy and the formulation of a sustainable development concept are the subject of numerous discussions. Research on the transition to sustainable development in both developed and developing countries is characterized by diversity, systematic approaches, and evolutionary complexity.

The controversial nature of the topic, along with the growing demand for critical minerals, is largely due to their distinctive feature - being integrated into global supply chains (Chen & Zheng, 2019). Moreover, their wide dispersion across the Earth's surface and low concentration in any one region make REEs difficult to access for industrial use.

In the literature, REMs are referred to as the «new oil» (Brennan & Edström, 2011), the term «minor metals» is used to emphasize the limited volumes of their production (Abraham, 2015), and the increasing role of social factors and changes in societal values is highlighted (Kamenopoulos et al., 2016; García-Sánchez et al., 2019).

At the same time, the scope of research is expanding to deepen the understanding of how a circular economy is linked to primary metals and minerals in international supply chains of various goods (copper, iron ore, aluminum, REEs, etc.) (Schulz et al., 2017; Schumacher & Green, 2023). These studies emphasize that the segmentation of raw material markets and changes in the geopolitical situation will increase the costs of the energy transition, reduce investments in renewable energy sources (RES), and that resource price dynamics will significantly affect the cost of decarbonization.

Among experts, debates continue regarding the idea that, over time, fluctuations in demand for raw materials become more significant compared to changes in the supply of raw materials (Jacks & Stuermer, 2020). Measures are being proposed to address potential imbalances between supply and demand, both from the supply side and the end-demand side (Wang et al., 2020;

Känzig, 2021). The continually growing demand for products made using critical raw materials and the limited supply determine the heightened critical importance of these metals, emphasizing the search for factors that influence the competitiveness of REE mining projects. For instance, the authors of the study (Silva & Petter, 2018) highlight the potential value of the raw material source and the quality of infrastructure.

Due to the high share of fossil fuels in global energy trade, increasing attention is being paid to the study of trade relations between countries (Pitron, 2020). In their work (Wang et al., 2022), the authors show that China and Japan had high trade dependence on Turkmenistan, Kazakhstan, and Uzbekistan for natural gas imports. They highlight that China, Australia, the United Kingdom, and Germany could play a leading role in addressing the climate trade dilemma. Countries with a developed mining industry and a commitment to ethical mining, such as Australia, may become preferred suppliers of the components that will underpin the future of clean energy.

Of particular interest are the findings of studies that confirm the potential of critical resources for high-tech industries and the transition to «green energy» (Viebahn et al., 2015; International Energy Agency, 2022). The increasing significance of REEs in the growing green energy market is emphasized, especially as the demand for renewable energy will continuously rise, increasingly impacting the current renewable energy supply chain, as noted in the study (Dutta et al., 2016). Authors (Lukas et al., 2024), recognizing the role of copper, nickel, cobalt, and lithium in the economy, underline their importance specifically for the energy transition.

Many studies have made forecasts regarding the development of the REM industry, taking into account the impact of various factors (Goodenough et al., 2018; Wang et al., 2020). For forecasting rare earth resources, on one hand, the demand from high-tech industries is analyzed, while on the other hand, the current and future production levels of companies extracting and processing these resources are considered (Binnemans & Jones, 2015; Frenzel et al., 2017; Dostal, 2017). In their study, the authors (Zhou et al., 2017) indicate the demand for rare earth elements by clean technologies in 2030, estimated at 51.9 thousand metric tons. More detailed data on the forecast of REE demand under various conditions and factors is also presented in the work (Alonso et al., 2012).

Many studies examine the influence of partners and the pricing factor in rare earth mineral (REE) trade relations. It is discussed how price changes and the presence of a single source of supply become the main reasons for frequent disruptions in global supply chains (Nassar, 2017; Xu-guang et al., 2022).

A particularly noteworthy study is by Guo & Wang (2024), where the authors argue that due to the tendency of the REE trade dependency network to expand, there is a need to integrate production chains aimed at supporting high-tech industries in developed countries.

Several studies emphasize the need to improve institutional conditions for rare earth raw material suppliers, consumers, and governments, which would protect businesses, mitigate various crises, and prevent disruptions in established global production chains. Various tools are suggested for identifying excessive dependence on foreign raw material sources and the degree of vertical integration in supply chains, as well as studying the demand for critical materials and their secondary use process (Federal Register, 2017).

The extraction process of critical resources is very complex and problematic from an environmental perspective due to the use of necessary chemicals. To make extraction economically viable, critical technologies are required, as strategic directions that determine the priorities of innovative development (Fagerberg, 1996).

This confirms the relevance of works dedicated to the search for new approaches and technologies for deep and complex processing of rare earth ores with complex compositions, which cannot be enriched using traditional physical-mechanical methods. The technologies currently proposed for extracting REEs from ash are of particular interest due to the diversity of operations involved in removing components (Pan et al., 2021).

Many countries encourage and stimulate the secondary use of rare earth materials (REMs), which reduces the negative environmental impact. In light of this, the issues of recycling REMs attract the attention of scientists and practitioners, as they contribute to solving the problem of growing demand and limited supply, ensuring stable supplies of critical REMs (Goodenough et al., 2018).

The above confirms the relevance of this study and the objective need for in-depth research into various aspects of the REM industry development in line with the strategic priorities of

Kazakhstan's economy. Studying global experience will allow Kazakhstan to implement a holistic approach to promoting the mineral raw materials industry, making scientifically substantiated management decisions regarding deposits with identified potential for valuable minerals, and achieving synergy between geology, scientific-educational, and industrial communities.

In this study, the authors consider not only the theoretical foundations of the transition to sustainable development in the context of the increasing demand for critical minerals, but also emphasize the practical implications for countries that own them and seek to maintain national security, protect unique ecosystems, and create independent regional supply chains.

3. Research Methods

The study employs a mixed approach to analyzing the issues of the global energy transition, which involves examining them from both a global perspective and specifically within the context of Kazakhstan's accumulated experience. The application of this approach is crucial for selecting the country's development prospects, where national interests must align with global trends.

The methodology of the analytical study includes a review of domestic and foreign literature, and a systemic and comparative analysis, which allowed for the summarization and evaluation of the initial evidence base, which the authors faced limitations with. This is partly due to the fact that reliable data on mineral reserves is considered strategic information by many countries and is often classified. In some cases, mineral deposits are only described using qualitative assessments. For instance, geological surveys have covered only 35% of Kazakhstan's territory, and no major new deposits have been discovered over the past 30 years. About 160,000 reports with reliable historical data from the Soviet era remain undisclosed. Therefore, information on the actual potential of mineral deposits remains open, and data from past geological surveys require adjustments in accordance with current standards, as well as updates on the availability of these resources using new technologies and methods that allow for higher extraction coefficients.

Kazakhstan's critical raw materials market is relatively new, and there is an ongoing process of establishing accurate accounting for ecological-economic, geological, and political factors that influence the extraction and processing of rare earth metals (REM). Objective assessment of demand and supply is hindered by the confidential nature and the lack of accurate statistical data on the demand and supply of critical raw materials. Dealers publish proposals for the supply of specific types of raw materials on the internet, offering them to potential consumers in Kazakhstan; however, the origin of the raw materials (from local producers or foreign sources) is generally not disclosed or published. The secrecy of geological data on the balance reserves of rare earth elements (REEs) and rare metals is one of the main barriers to attracting investors to Kazakhstan.

The authors partially compensated for the identified limitations through the comprehensiveness of the information search, the depth of the presented literature sources, and the references provided, which meet the criteria of quality and relevance.

The informational and analytical basis of the study consisted of legislative and regulatory acts of Kazakhstan, data from the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, JSC «National Geological Service,» the International Financial Center «Astana» (IFCA), the news site mining.com, covering global mining and metallurgy industries, the monitoring agency Energyprom.kz, specializing in research on the current state and development trends of Kazakhstan's energy and industry markets, the international business publication «Kursiv,» the news agency LS, and the Kazakhstan Telegraph Agency KazTAG.

To ensure the reliability of the conclusions, the study also used research results from the World Bank, the International Energy Agency (IEA), the International Metallurgical Research Group, the consulting agency Mordor Intelligence, which studies global trends in the transition to a low-carbon economy.

In the authors' opinion, despite the diversity of global practices concerning the rare metals industry, there are common methodological approaches that Kazakhstan can adopt to develop proactive measures for minimizing potential economic consequences caused by disruptions in the supply of critical raw materials and to adapt the experience of leading countries in the metals market to the specifics of the national economy.

4. Research Results and Discussion

About 20% of investments in Kazakhstan's industry are generated by the mining and metallurgical complex, with nearly a quarter of total industrial production coming from the extraction and processing of metals (Table 1). The growing demand for raw materials increases competition for long-term investments to enable enterprises to participate in a responsible supply chain that adheres to ethical standards.

In Kazakhstan, accounting is carried out for 103 types of mineral resources and more than 8,000 deposits, including 326 hydrocarbon deposits, 920 solid mineral deposits, over 3,000 deposits of common mineral resources, and more than 4,000 groundwater deposits. Despite the discovery of major deposits during the Soviet period, since 1991, 168 hydrocarbon deposits, 99 groundwater deposits, and 221 solid mineral deposits have been placed on the state balance (Figure 2).

There is a relative depletion of high-quality resources and reserves, with increases in reserves of iron, manganese, gold, and zinc being achieved through revaluation and further exploration of previously studied deposits. Metals and metal products are Kazakhstan's second-largest export category after fuel and energy products. According to the Astana International Financial Centre (AIFC), the promising metals include copper (with a low product complexity index), lead (with a medium complexity index), zinc, aluminum, and silver. Zinc and copper, along with metal products, are classified as non-raw materials and account for almost three-quarters of the total processed exports (Figure 3).

In the current export of the aforementioned metals, Kazakhstan demonstrates comparative advantages (Table 2).

Rare earth metals (with a medium product complexity index), as well as lithium (with a medium product complexity index), nickel (with a medium product complexity index), and gold (with

Table 1:
Indicators of the Mining and Metallurgical Complex of Kazakhstan

Indicator	Years										
	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Metallurgical industry:											
- total, billion tons	1772.1	1915.2	2119.3	3360.7	4089.7	4656.0	4885.4	5677.8	7678.0	9018.8	8177.8
- production of basic precious and non-ferrous metals	1131.4	1141.9	1379.1	2227.1	2528.8	2900.0	3217.5	4023.5	4774.6	5824.6	5524.5
Mining of metal ores:											
- total, billion tons	786.2	882.3	700.5	996.3	1211.6	1462.1	1906.0	2188.4	3277.3	3419.2	3786.7
including:											
- non-ferrous metal ore mining	532.1	659.0	563.6	803.5	968.9	1171.7	1492.0	1710.0	2306.7	2734.9	3264.7

Source: Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan (2024)

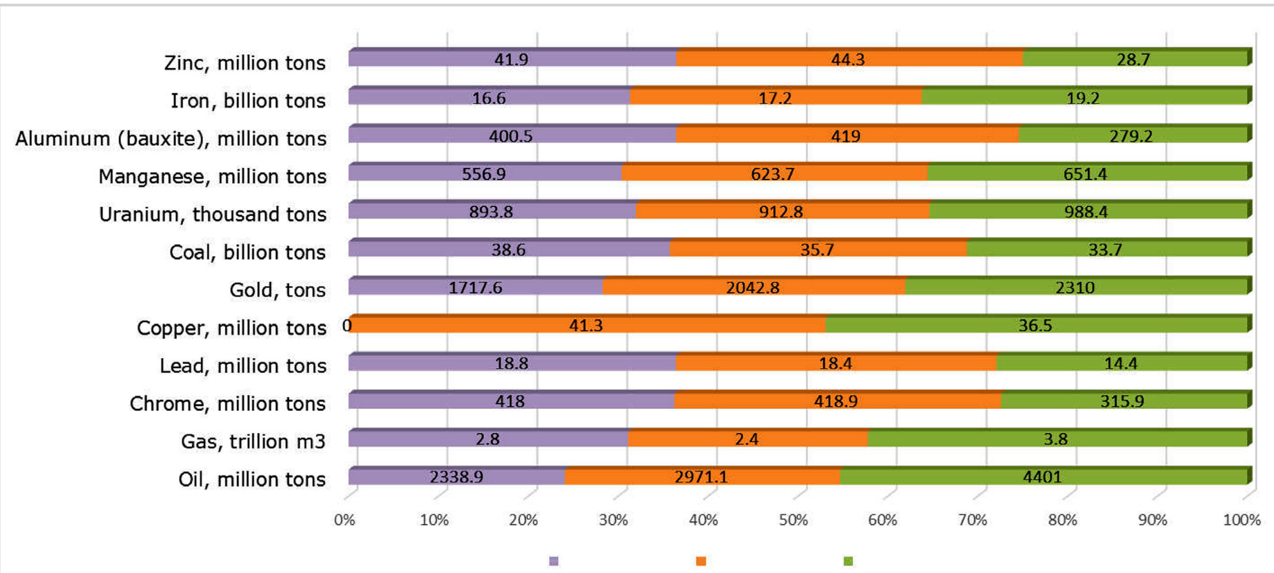

Figure 2:
State Accounting of Mineral Reserves
Source: Mining Industry. Central Asia (2024)

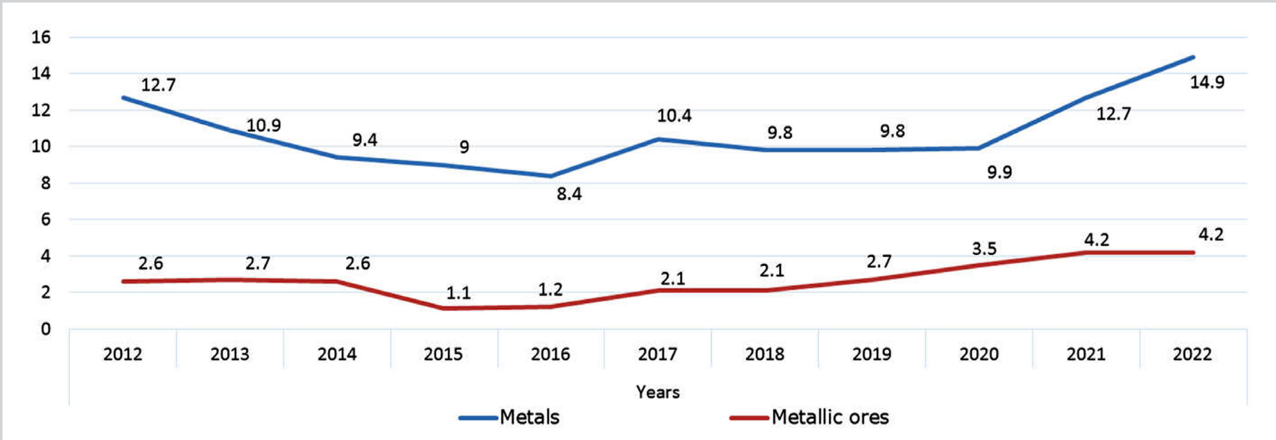

Figure 3:
Dynamics of Metal Exports, Billion USD
Source: Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan (2023)

Table 2:
Dynamics of Production and Export of the Most Promising Export Metals of Kazakhstan

Indicator	Year						
	2017	2018	2019	2020	2021	2022	2023
Zinc (medium complexity index):							
- production, thousand tons	330	304	304	222	194	312	330
- share in world production, %	2.6	2.4	2.4	1.9	1.5	2.5	2.8
- export:							
- thousand tons	300	102	297	294	267	250	201
- million dollars	849	304	731	621	734	834	505
Aluminum (relatively low complexity index):							
- production, million tons	4.8	5.7	5.8	5.0	4.3	4.4	4.3
- share in world production,%	1.6	1.7	1.6	1.3	1.1	1.2	1.1
- export:							
- thousand tons	234	262	273	267	276	230	199
- million dollars	473	572	513	466	682	670	461
Silver (relatively high difficulty index):							
- production, tons	461	369	422	435	450	1053	990
- share in world production, %	1.7	1.4	1.6	1.9	1.9	4.1	3.8
- export:							
- tons	1037	890	916	1058	948	979	874
- million dollars	538	450	436	614	745	660	643

Source: Compiled based on AIFC (2024)

a low product complexity index), are classified as emerging exports. These have the potential to strengthen Kazakhstan's position in the global mineral market and enhance the recognition of the rare earth metals (REM) industry as a strategically important sector for Kazakhstan (Table 3).

Not only due to compliance with OECD standards and Kazakhstan's favorable geostrategic position, but also thanks to market accessibility and a strong resource base, landlocked Kazakhstan is the leader among Central Asian (CA) countries in terms of foreign direct investment (International Business Publication Kursiv, 2017). Kazakhstan holds advantages over other C5 countries - the five Central Asian nations - in the mining industry and infrastructure development.

Efforts by CA countries, which hold 38.6% of global manganese reserves, 30.07% of chromium, 20% of lead, 12.6% of zinc, and 8.7% of titanium, to compete for critical resources - amid growing U.S. and Chinese involvement and rising competition from African and Latin American nations - highlight the strategic importance of the region in the global supply chain for rare earth elements (REEs) and key minerals. Entry of CA countries into the REE market could lead to a decrease in prices and, consequently, profits. However, there is an advantage that could facilitate their advancement up the supply chain: since REEs tend to have lower density in the soil compared to other minerals, transportation costs rise, increasing expenses for delivering raw materials to global markets. This indicates that CA countries do not necessarily need to engage in the full cycle of high-tech product manufacturing; they can focus, for instance, on processing rare earth minerals. In this case, the development of such industries will expand the Trans-Caspian International Transport Route, which would positively impact the economies of these countries despite high transportation costs and long transit times.

Table 3:
SWOT Analysis of the Rare Earth Metals Sector

Strengths	Weaknesses
- proven geological reserves, diversification of energy supplies to world markets, search for alternative routes and new sales markets, Kazakhstan's commitment to combat climate change	- depletion of high-quality reserves, high levels of carbon dioxide emissions, shift of production to hard-to-reach regions, the need for an individual set of components and technical solutions for each field
- completion of the transition to the international CRIRSCO mineral reserves certification system and the implementation of KAZRC, ESG standards for the mining industry, and the transition to the principles of the best available technologies (Best Available Techniques, BAT)	- lack of open access to balance reserves of some REEs; legacy unprofitable deposits and obsolete capacities with a small number of new geological discoveries and deposits ready for development
- stimulating private investment and developing public-private partnerships to attract global exploration and mining companies	- limited demand from the domestic market with high energy intensity and energy deficit
- legal and tax regulation in the mining sector	- lack of production capacity for processing rare earth raw materials within the country with subsequent creation of high added value products
- creation of the National Geological Survey to declassify and provide investors with open access to geological data	- low investment attractiveness of projects for the development of REE extraction technologies
- significant volumes of rare earth reserves and low levels of radioactivity of REE	- low level of use, implementation and transfer of technologies for geological exploration and expansion of the mineral resource base
- state support for research aimed at processing final products for the purpose of extracting REE and revealing the potential for the integrated development of REE deposits	- the lack of a unified information and analytical industry platform and standards for working with mining, geological and economic information for conducting detailed exploration and commercial exploitation of deposits
- compensation and reimbursement of damage caused to private lands by exploration work in regions where a mining enterprise is present	- increasing dependence on foreign software and difficulties in adapting standard software solutions to the needs of a specific enterprise
- technological changes in the industry taking into account the availability and transfer of exploration, extraction and processing technologies; inter-industry cooperation; collaboration with scientific and educational institutions	-increasing labor costs with relatively low productivity
Possibilities	**Threats**
- the state's focus on the use of high technologies in the further exploration of promising and strategically important rare earth metal deposits to ensure independence from foreign supplies	- increasing geopolitical and macroeconomic uncertainty
- attracting foreign investment, including with the participation of junior companies	- depletion of the mineral resource base, non-replenishment of some high-quality reserves, low level of provision with reserves of priority minerals
- development of innovative technologies for the extraction of rare earth metals in order to expand the possibilities of obtaining high added value products	- lack of experience in creating a complete production and technological cycle of REE production, maintaining it within the country
- involvement in the processing and commercial exploitation of man-made mineral formations (MMF) objects	

Source: Developed by the authors

Foreign investment in the exploration and extraction of REEs not only fosters economic growth in CA countries and diversifies global supply chains, expanding the market for component production, but also supports regional integration and sovereignty, countering China's dominance in this sector (International Tax and Investment Center, 2023).

In Kazakhstan, as in Uzbekistan, REE deposits are scattered and rarely found in concentrated forms, often not present in the final product. Deposits in which rare metals (RMs) and REEs occur in their own distinct minerals are easier to extract, whereas those where RMs and REEs appear as trace elements in other ores require more effort and investment, as they demand the extraction of additional elements.

In terms of REE deposits, the level of geological study remains low. Many of these deposits are already being exploited, though the volume of mining and production remains limited - primarily due to the geological characteristics of the deposits and the by-product nature of rare earth components. Some deposits, including large ones, are listed on the state balance sheet based on Soviet-era estimates but have not been updated, which leads to a lag in reserve growth compared to extraction and slows down the discovery of new deposits.

Critical resources are classified into five groups based on the degree of industrial development and utilization. Four of these represent primary resources present in the subsoil (Table 4). Elements in the fifth group, which are not fully extracted during primary beneficiation and metallurgy, are contained in waste dumps of low-grade ores, which are mined and stored in special dumps during open-pit mining operations.

The country has deposits containing 29 critical resources in the form of primary resources out of 30. All 30 types of critical resources have been identified in the form of secondary resources. Of these, 17 are being mined, and 21 products are being produced as finished products, including the largest volumes of the five critical resources (coking coal, phosphate rocks, phosphorus,

Table 4:
Extraction and Production of Critical Resources

Critical Resources	Types of independent deposits	Associated component in different types of complex deposits	Critical Resources	
			products	annual production, tons
Group No. 1. Resources that constitute the main value of the ore and are extracted from own deposits				
Barite	Barite	Barite is a polymetallic	Barite concentrate	Barite
Boron	Boron-potassium	Inderbor	Boron concentrate	Boron
Coking coal	Coal		Coking coal for metallurgy	Coking coal
Fluorite	Quartz-fluorite			Fluorite
Phosphate rocks	Phosphorites			Phosphate rocks
Phosphorites	Phosphorites			Phosphorites
Metallic silicon	Quartz		Silicon metal	Metallic silicon
Vanadium	Vanadium	Iron ore deposits	Concentrate V 2O5	Vanadium
Bauxites	Bauxites			Bauxites
Titanium	Titanium-zirconium placers		Sponge titanium, metallic magnesium	Titanium
Group No. 2. Resources present in the form of impurity elements in complex deposits and extracted during metallurgical processing of the main components of these deposits (copper, lead, zinc, iron, manganese, chromium, uranium, etc.), released in the form of pure metals				
Antimony	No	Polymetallic	Metallic antimony	Antimony
Bismuth	No	Polymetallic	Metallic bismuth	Bismuth
Cobalt	No	Nickel-cobalt, iron ore, copper	Metallic cobalt	Cobalt
Germanium	No	Bauxites, polymetal - Licheskie	Metallic germanium	Germanium
Indium	No	Polymetallic	Metallic indium	Indium
Platinum group	No	Polymetallic		Platinum group
Scandium	Copper		Scandium metal	Scandium
Group No. 3. Resources available in complex deposits of Kazakhstan are produced at metallurgical enterprises from imported raw materials (relevant concentrates) and are not mined due to their low content in the subsoil				
Beryllium	No	Pegmatite tantalum-niobium-beryllium	Products made of beryllium and alloys from imported raw materials	Beryllium
Niobium	Tantalum-niobium-beryllium		Metallic niobium, products	Niobium
Tantalum	Tantalum-niobium-beryllium		Metallic tantalum, products and alloys	Tantalum
Magnesium	Magnesite		Imported raw materials	Magnesium
Group No. 4. Resources that are present, mainly in the form of trace elements in complex deposits, in some cases in independen t deposits, but are not currently mined or released as products. Technologies for extracting elements of this group have been developed in Kazakhstan				
Tungsten	Tungsten-molybdenum	Tin-tungsten	Not mined or produced	Tungsten
Gallium	No	Polymetallic	Not mined or produced	Gallium
Hafnium	No	Titanium-zirconium placers	Not mined or produced	Hafnium
Heavy REM	Weathering crust deposits	Titanium-zirconium placers	not produced	Heavy REM
Light REM	Weathering crust deposits	Titanium-zirconium placers	not produced	Light REM
Graphite	Graphite		Not being developed or produced	Graphite
Lithium	Lithium	Tantalum-niobium-beryllium with lithium	Not mined or produced	Lithium
Strontium	No	Barite	Not produced	Strontium

Source: Report MSME Kazakhstan COVID-19 (2021)

bauxite, and titanium). On the state balance sheet, rare earth metals (REMs) are accounted for across 70 deposits as by-products.

Since the ores of most deposits are complex, containing impurities of REMs, and the ore quality is inferior to foreign deposits, extracting these ores and subsequently extracting metals from them is currently not cost-effective. In addition, the deposits are located in challenging mining and geological conditions, lack quality infrastructure, and the costs of extracting the main components are relatively high. Furthermore, some types of rare metals and REMs are lost in waste dumps, and there is a steady increase in their volumes.

There are not enough deposits ready for development, and further involvement in processing is complicated by technological issues. The specific nature of the deposits containing REMs (complex chemical and mineralogical composition, low metal content) requires special mining, processing, and extraction technologies, taking into account the characteristics of the raw material, increasing energy consumption, and the need for water conservation.

The issues that are being addressed are not only the reduction in the content of valuable components in ores and the decrease in easily accessible deposits but also the need to comply with environmental standards and ESG principles. When mining and producing critical resources, companies face the challenges of labor intensity, technological complexity, and high costs associated with these processes, as well as the use of technologies that do not meet environmental standards, all against the backdrop of low digitalization levels in the sector (Table 5). The implementation of environmentally friendly methods with the lowest carbon footprint should be realized before the start of extraction, so that all additional costs are initially incorporated into the global value-added supply chain.

Table 5:
Indicators of the Metallurgical Industry, Production of Major Precious and Non-Ferrous Metals

Indicator	Years					
	2018	2019	2020	2021	2022	2023
Metallurgical industry						
Labor productivity						
- thousand US dollars/person	76.6	69.9	75.4	99.1	131.9	106.3
Export volume, million dollars	9970.5	9894.2	10001.5	12817.0	15116.6	12434.5
Export volume of goods of medium technological complexity, million dollars	1926.8	1524.9	1508.5	2482.1	2292.1	1995.8
Export volume of goods of high technological complexity, million dollars	1344.8	1549.0	1799.0	1809.7	2696.5	3531.3
Volume of investments in fixed capital, million tenge	269946	320000	372005	449514	605701	542795
Share of large and medium enterprises using digital technologies, %	-	17.3	26.7	28.8	40.0	39.1
Share of innovatively active enterprises, %	25.9	25.0	34.6	27.7	24.7	25.2
Production of basic precious and non-ferrous metals						
Labor productivity						
- thousand US dollars/person	92.1	85.5	97.1	105.2	187.6	190.3
Export volume, million dollars	5903.3	6588.6	6802.2	7983.5	9624.6	8469.5
Export volume of goods of medium technological complexity, million dollars	233.3	254.1	204.4	243.9	283.3	280.7
Export volume of goods of high technological complexity, million dollars	1343.9	1547.7	1799.0	1809.1	2695.4	3530.0
Volume of investments in fixed capital, million tenge	147944	166167	214325	291894	356911	373128
Share of large and medium enterprises using digital technologies, %	-	20.0	33.3	30.3	45.7	42.9
Share of innovatively active enterprises, %	30.8	34.6	36.2	36.5	31.7	25.4

Source: Report MSME Kazakhstan COVID-19 (2021)

Since the development of rare earth raw material sources depends on the creation of new approaches and technologies for deep processing of complex ores, the key value lies not so much in the reserves themselves, but in the speed of extracting valuable components from various sources of rare earth feedstock. However, extraction speed is hindered by uncertainties caused by geological, production, environmental, and economic constraints. These constraints slow the transition from a model based on the export of low-value-added products to a development model centered on high-value-added production chains, ultimately increasing export potential (Issatayeva et al., 2023).

A rapidly growing segment in the extraction of critical resources is the lithium industry, with the most promising reserves found in newly discovered deposits. Lithium deposits in Kazakhstan are of primary origin, meaning the metal forms as a result of geochemical processes in the Earth's crust. As of January 1, 2023, balance reserves of lithium oxide totaled approximately 75.6 thousand tons. Lithium mineralization has already been identified in multiple regions, and reserves are found in tailings and «tailing sands» from processing plants and deposits. In Eastern Kazakhstan alone, six natural deposits and one anthropogenic deposit are listed in the state registry (Mining Industry. Central Asia, 2023; LS Information Agency, 2024).

Mineralized brines in the Aral sedimentary basin - which shares geological similarities with Chile's Salar de Atacama, home to about 30% of the world's lithium reserves - also show high lithium potential. The Chu-Sarysu salt flats, saline lakes of the Pavlodar Irtysh region, and the entire Caspian region are considered promising. At present, the extraction of valuable elements from salt flats in Kazakhstan remains low, but despite limited geological exploration, these areas are regarded as promising.

It is also important to consider that lithium mining, often concentrated in arid regions, requires large volumes of water, which can negatively impact agriculture. For example, a lithium extraction project in Chile consumed up to 65% of the available water in the Atacama Desert, leading to contamination of freshwater sources.

Undoubtedly, Kazakhstan's lithium reserves remain largely unexplored and require comprehensive exploration drilling, mineralogical and technological studies of core samples, and a revision of geological and economic assessments using modern technologies and updates to outdated scientific and technical frameworks. Currently, Kazakhstan is not represented on the global lithium market but is ready to unlock its lithium potential (JSC «National Geological Service», 2023).

The key issue in realizing the potential of critical resources - especially those found as trace elements in the ores of various mineral deposits - lies in the technology for extracting these elements. It is during the processing and refining stages that the greatest value is added to final products. Therefore, secondary processing of waste from mining and metallurgical industries, with the aim of extracting additional volumes of metals, requires the development of new technological methods. This includes conducting dedicated scientific research to design innovative pyrometallurgical and hydrometallurgical approaches for the recovery of various critical resources.

In conclusion, the prospects for increasing production of certain types of critical resources - especially those that have long been mined in large volumes from primary deposits - are quite significant. This particularly applies to resources that are considered primary rather than by-products, such as coking coal, phosphate rock, phosphorus, bauxite, titanium, and barite (International Business Publication Kursiv, 2023).

5. Conclusion

For Kazakhstan, the prospects for developing the rare earth metals (REM) sector lie not so much in increasing extraction and primary production, but rather in the creation of new industries that consume REM products, the expansion of REM applications in various industrial sectors, and the adoption of environmentally friendly extraction methods.

In the future, to benefit from the growing demand for clean energy minerals without exacerbating vulnerability to price fluctuations and global crises, Kazakhstan - like other Central Asian countries - must overcome the prevailing opacity around its natural resources. It needs to enhance the domestic value of its mineral wealth, move up the commodity supply chains, and expand its processing capacities.

According to research, the key issue is not so much the absence of REM production as it is the lack of processing capacity for metal separation and the production of high value-added products. At existing facilities, it is difficult to launch the production of by-product metals due to outdated technologies that are focused solely on extracting base metals. The multi-stage nature of REM metallurgy and the strict purity requirements make the extraction of rare metals from ore particularly complex. In addition to high costs and limited reserves, there is also a shortage of mineralogical research - especially critical given that Kazakhstan's deposits are typically complex. Extracting REM from such ores is expensive and requires new practical approaches to process management with a focus on energy efficiency and environmental sustainability.

In light of this, it is essential for the government to support companies in conducting responsible business practices, independently creating high value-added products, and subsequently developing high-tech sectors. It is also important to involve junior companies in critical resource projects that comply with GRI Standards, ESG principles, the principles of Best Available Technologies (BAT), and the KAZRC standard (Environmental Code of the Republic of Kazakhstan, 2021; Chen et al., 2024). To increase junior companies' participation in critical resource supply chains, special programs are needed to facilitate technological research on extracting resources from secondary sources. This type of subsoil use, supported by preferential financial conditions and access to digital technologies, can incentivize enterprises to develop additional sources of these critical materials.

References

1. Abraham, D. S. (2015). The Elements of Power: Gadgets, Guns, and the Struggle for a Sustainable Future in the Rare Metal Age. Yale University Press.
2. Alonso, E., Sherman, A. M., Wallington, T. J., Everson, M. P., Field, F. R., Roth, R., & Kirchain, R. E. (2012). Evaluating Rare Earth Element Availability: A Case with Revo-lutionary Demand from Clean Technologies. Environmental Science and Technology, 46(6), 3406-3414. https://doi.org/10.1021/es203518d
3. Andersen. A. D, Marìn, A., & Simensen, E. O. (2018). Innovations in Natural Resource-Based Industries: a Pathway to Development? Introduction in Special Issue. Innovation and Development, 8(1), 1-27. https://doi.org/10.1080/2157930X.2018.1439293
4. Barteková, E., & Kemp, R. (2016). National strategies for securing a stable supply of rare earths in different world regions. Resources Policy, 49, 153-164. https://doi.org/10.1016/j.resourpol.2016.05.003
5. Binnemans, K., & Jones, P. T. (2015). Rare Earths and the Balance Problem. Journal of Sustainable Metallurgy, 1, 29-38. https://doi.org/10.1007/s40831-014-0005-1

6. Brennan, E., & Edström, B. (2011). Rare Earth Elements: The Next Oil? Policy Brief, 78, 1-2. https://isdp.eu/wp-content/uploads/publications/2011_brennan-edstrom_rare-earth-elements.pdf
7. Bureau of National Statistics Agency for Strategic Planning and Reforms of the Republic of Kazakhstan. (2024). Official web-site. https://stat.gov.kz/en/
8. Chen, W., Xie, Y., & He, K. (2024). Environmental, social, and governance performance and corporate innovation novelty. International Journal of Innovation Studies, 8(2), 109-131. https://doi.org/10.1016/j.ijis.2024.01.003
9. Chen, Y., & Zheng, B. (2019). What Happens after the Rare Earth Crisis: A Systematic Literature Review. Sustainability, 11(5), 1288. https://doi.org/10.3390/su11051288
10. Code of the Republic of Kazakhstan. (2017, December 27). On subsoil and subsoil use, No. 125-VI (with amendments and additions). https://online.zakon.kz/Document/?doc_id=31764592 (in Russ.)
11. Code of the Republic of Kazakhstan. (2021). Environmental Code of the Republic of Kazakhstan, No. 400-VI ZRK (with amendments and additions). https://online.zakon.kz/Document/?doc_id=39768520 (in Russ.)
12. Dostal, J. (2017). Rare Earth Element Deposits of Alkaline Igneous Rocks. Resources, 6(3), 34. https://doi.org/10.3390/resources6030034
13. Dutta, T., Kim, K.-H., Uchimiya, M., Eilhann, E. K., Jeon, B.-H., Deep, A., & Yun, S.-T. (2016). Global demand for rare earth resources and strategies for green mining. Environmental Research, 150, 182-190. https://doi.org/10.1016/j.envres.2016.05.052
14. Energy Prom. (2024). Lithium: despite a colossal surge in demand, only a quarter of all proven reserves are economically viable to extract. https://energyprom.kz/ru/articles-ru/industries-ru/litij-nesmotrya-na-kolossalnyj-vsplesk-sprosa-ekonomicheski-vygodna-dobycha-lish-chetverti-vseh-razvedannyh-zapasov (in Russ.)
15. European Commission. (2020). Critical Raw Materials Resilience: Charting a Path towards Greater Security and Sustainability. Communication From the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. EU. Brussels. https://ec.europa.eu/docsroom/documents/42849
16. Fagerberg, J. (1996). Technology and competitiveness. Oxford review of economic policy, 12(3), 39-51. https://doi.org/10.1093/oxrep/12.3.39
17. fDi Intelligence news magazine. (2023, December 11). Cambodia carries the strongest FDI momentum into 2024. https://www.fdiintelligence.com/content/News/cambodia-carries-the-strongest-fdi-momentum-into-2024-83236
18. Freiman, G. (2021). The Role of MSMEs in Ensuring Critical Raw Materials Supply during the COVID-19 Recovery Phase in Kazakhstan. Almaty. https://unece.org/sites/default/files/2022-06/Report%20MSME%20Kazakhstan%20COVID-19%20Freiman%20RUS.pdf (in Russ.)
19. Frenzel, M., Kullik, J., Reuter, M. A., & Gutzmer, J. (2017). Raw material «criticality»-sense or nonsense? Journal of Physics D: Applied Physics, 50(12), 123002. https://doi.org/10.1088/1361-6463/aa5b64
20. García-Sánchez, I.-M., Gallego-Alvarez, I., & Zafra-Gomez, J.-L. (2019). Do the ecoinnovation and ecodesign strategies generate value added in munificent environments? Business Strategy and the Environment, 29(3), 1021-1033. https://doi.org/10.1002/bse.2414
21. Goodenough, K. M., Wall, F., & Merriman, D. (2018). The Rare Earth Elements: Demand, Global Resources, and Challenges for Resourcing Future Generations. Natural Resources Research, 27, 201-216. https://doi.org/10.1007/s11053-017-9336-5
22. Guo, Q., & Wang, Y. (2024). Rare earth trade dependence network structure and its impact on trade prices: An industry chain perspective. Resources Policy, 91, 104930. https://doi.org/10.1016/j.resourpol.2024.104930
23. Hirvilammi, T., Häikiö, L., Johansson, H., Koch, M., & Perkiö, J. (2023). Social policy in a climate emergency context: towards an ecosocial research agenda. Journal of Social Policy, 52(1), 1-23, https://doi.org/10.1017/S0047279422000721
24. International Energy Agency. (2022). The Role of Critical Minerals in Clean Energy Transitions. https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf
25. International Energy Agency. (2024). Critical Minerals Market Review 2023. IEA, Paris. https://www.iea.org/reports/critical-minerals-market-review-2023
26. Ishekenova, B. (2024, January 30). In Kazakhstan, they are looking for new oil. LS Aqparat. https://lsm.kz/kazahstan-aktivno-ishet-litij-v-nedrah-podrobnosti (in Russ.)
27. Issatayeva, F. M., Aubakirova, G. M., Maussymbayeva, A. D., Togaibayeva, L. I., Biryukov, V. V., & Vechkinzova, E. (2023). Fuel and Energy Complex of Kazakhstan: Geological and Economic Assessment of Enterprises in the Context of Digital Transformation. Energies, 16(16), 6002. https://doi.org/10.3390/en16166002
28. Jacks, D. S., & Stuermer, M. (2020). What Drives Commodity Price Booms and Busts? Energy Economics, 85, 104035. https://doi.org/10.1016/j.eneco.2018.05.023
29. JSC National Geological Service. (2023). Kazakhstan is ready to unlock lithium potential - Chairman of the Board of JSC National Geological Service. https://geology.kz/en/news/619 (in Russ.)
30. Kamenopoulos, S. N., Shields, D., & Agioutantis, Z. (2016). Sustainable Development Criteria and Indicators for the assessment of Rare Earth Element Mining Projects. In I. B. De Lima, & W. L. Filho (Eds.), Rare Earths Industry (pp. 87-109). Elsevier. https://doi.org/10.1016/B978-0-12-802328-0.00006-1
31. Känzig, D. R. (2021). The Macroeconomic Effects of Oil Supply News: Evidence from OPEC Announcements. American Economic Review, 111(4), 1092-1125. https://doi.org/10.1257/aer.20190964
32. Kazakh Telegraph Agency. (2023, October 30). Kazakhstan recycles only 11% of its annual output of mineral waste. https://kaztag.kz/ru/news/kazakhstan-pererabatyvaet-vsego-11-ot-godovogo-vykhoda-mineralnykh-otkhodov- (in Russ.)
33. Kursiv. (2017). The Republic of Kazakhstan joined the OECD Declaration on International Investment. https://kz.kursiv.media/2017-06-21/rk-prisoedinilas-k-deklaracii-oesr-po-mezhdunarodnym-investiciyam/ (in Russ.)
34. Lukas, B., Pescatori, A., & Stuermer, M. (2024). Energy Transition Metals: Bottleneck for Net-Zero Emissions? Journal of the European Economic Association, 22(1), 200-229. https://doi.org/10.1093/jeea/jvad039
35. Mamyshev, Zh. (2023). The government will allocate 11.8 billion tenge for the development of rare and rare earth metal mining. Kursiv. https://kz.kursiv.media/2023-10-30/zhnb-redmetkzplans (in Russ.)

36. Mejía, J., & Aliakbari, E. (2024). Survey of Mining Companies, 2023. Fraser Institute Annual. https://www.fraserinstitute.org/sites/default/files/2023-annual-survey-of-mining-companies.pdf
37. Metalresearch. (2024). Rare earth metals market (REM market) 2024 (2025). https://www.metalresearch.ru/rare_earth.html (in Russ.)
38. Minexforum. (2023). The search for lithium is being intensified in three regions of Kazakhstan. https://minexforum.com/2023/11/16/the-search-for-lithium-is-being-intensified-in-three-regions-of-kazakhstan (in Russ.)
39. Mining industry: Central Asia. (2023). Lithium exploration to intensify in three regions of Kazakhstan. https://dprom.kz/novosti/v-tryoh-ryegeeonah-rk-akteevezeeruyut-poesk-letea (in Russ.)
40. Mining industry: Central Asia. (2024). National Geological Survey of Kazakhstan: work on replenishing the mineral resource base. https://dprom.kz/geologorazvedka/natsionalnaya-geologicheskaya-sluzhba-kazahstana-rabota-po-vospolneniyu-msb (in Russ.)
41. Mordor Intelligence. (2024). Rare Earth Elements Market Size and Share Analysis - Growth Trends and Forecasts (2024-2029). https://www.mordorintelligence.com/ru/industry-reports/rare-earth-elements-market (in Russ.)
42. Nassar, N. T. (2017). Shifts and Trends in Global Anthropogenic Stocks and Flow of Tantalum. Resources, Conservation and Recycling, 125, 233-250. https://doi.org/10.1016/j.resconrec.2017.06.002
43. Pan, J., Hassas, B. V., Rezaee, M., Zhou, Ch., & Pisupati, S. V. (2021). Recovery of rare earth elements from coal fly ash through sequential chemical roasting, water leaching, and acid leaching processes. Journal of Cleaner Production, 284(15), 124725. https://doi.org/10.1016/j.jclepro.2020.124725
44. Pitron G., (2020). The Rare Metals War: The Dark Side of Clean Energy and Digital Technologies (trans. B. Jacobsohn). Scribe. https://scribepublications.com.au/books-authors/books/the-rare-metals-war-9781925849325
45. Resolution of the Government of the Republic of Kazakhstan. (2023, December 28). On approval of the Comprehensive Plan for the Development of the Rare and Rare Earth Metals Industry for 2024-2028, No. 1221. https://adilet.zan.kz/rus/docs/P2300001221/history (in Russ.)
46. Sanchez, W. A., Cohen, A., & Hill, W. A. (2023, December). Leveraging Central Asia's Rare Earth Elements for Economic Growth. International Tax and Investment Center. https://static1.squarespace.com/static/5a789b2a1f318da5a590af4a/t/65792cb79087211182910e96/1702440120367/Leveraging+Central+Asia%E2%80%99s+Rare+Earth+Elements+for+Economic+Growth.pdf
47. Schulz, K. J., De Young, J. H. Jr., Seal, R. R., & Bradley, D. C. (Eds). (2017). Critical mineral resources of the United States – Economic and environmental geology and prospects for future supply. US Geological Survey. Reston (VA). https://doi.org/10.3133/pp1802
48. Schumacher, K. A., & Green, M. L. (2023). Circular Economy in a High-Tech World. Circular Economy and Sustainability, 3, 619-642. https://doi.org/10.1007/s43615-022-00220-7
49. Shen, Y., Moomy, R., & Eggert, R. G. (2020). China's public policies toward rare earths, 1975-2018. Mineral Economics, 33, 127-151. https://doi.org/10.1007/s13563-019-00214-2
50. Silva, G. A., Petter, C. O., & Albuquerque, N. R. (2018). Factors and competitiveness analysis in rare earth mining, new methodology: case study from Brazil. Heliyon, 4(3), e00570. https://doi.org/10.1016/j.heliyon.2018.e00570
51. Taiganov, N. (2024). Economic Complexity and Diversification: Kazakhstan Report by Harvard Growth Lab. Mining Industry of Kazakhstan. Export-Oriented Metals. Astana International Financial Centre. https://aifc.kz/wp-content/uploads/2024/07/gornodobyvayushhaya-otrasl-kazahstana-eksportoorientirovannye-metally-rus_compressed-1.pdf (in Russ.)
52. The White House. (2017). A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals. Federal Register, 82(246), 60835-60837. https://www.govinfo.gov/content/pkg/FR-2017-12-26/pdf/2017-27899.pdf
53. U.S.-China Economic and Security Review Commission. (2011). Going Out: An Overview of China's Outward Foreign Direct Investment. https://www.uscc.gov/research/going-out-overview-chinas-outward-foreign-direct-investment
54. United Nations. (2023). World Investment Report 2023. https://unctad.org/system/files/official-document/wir2023_overview_ru.pdf (in Russ.)
55. Viebahn, P., Soukup, O., Samadi, S., Teubler, J., Wiesen, K., & Ritthoff, M. (2015). Assessing the need for critical minerals to shift the German energy system towards a high proportion of renewables. Renewable and Sustainable Energy Reviews, 49, 655-671. https://doi.org/10.1016/j.rser.2015.04.070
56. Wang, J., Guo, M., Liu, M., & Wei, X. (2020). Long-term outlook for global rare earth production. Resources Policy, 65, 101569. https://doi.org/10.1016/j.resourpol.2019.101569
57. Wang, W., Fan, L. W., & Zhou, P., (2022). Evolution of global fossil fuel trade dependencies. Energy, 238, 121924. https://doi.org/10.1016/j.energy.2021.121924
58. Williams, C. (2021, February 26). China Continues Dominance of Rare Earths Markets to 2030, says Roskill. Mining Com. https://www.mining.com/china-continues-dominance-of-rare-earths-markets-to-2030-says-roskill
59. World Bank. (2024). Annual Report 2024. Official website. https://www.worldbank.org/en/about/annual-report
60. Xu, J., Li, J., Charles, V., & Zhao, X. (2024). Evolution of the rare earth trade network: A perspective of dependency and competition. Geoscience Frontiers, 15(3), 101653. https://doi.org/10.1016/j.gsf.2023.101653
61. Xu-guang, Z., Xue-hong, Z., & Jin-yu, C. (2022). Trade dependence network structure of tantalum trade goods and its effect on trade prices: An industry chain perspective. Resources Policy, 79, 103065. https://doi.org/10.1016/j.resourpol.2022.103065
62. Zhou, B., Li, Z., & Chen, C. (2017). Global Potential of Rare Earth Resources and Rare Earth Demand from Clean Technologies. Minerals, 7(11), 203. https://doi.org/10.3390/min7110203

Received 22.04.2024
Received in revised form 17.05.2024
Accepted 20.05.2024
Available online 25.10.2024