

THE EUROPEAN UNION'S STRATEGIC AUTONOMY IN RAW MATERIALS

THE GLOBAL RACE FOR METALS AND MINERALS, POSITION AND CHALLENGES FOR EUROPE

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SET SECURITY ENERGY TECHNOLOGY

ECR GROUP EUROPEAN CONSERVATIVES AND REFORMISTS

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Foreword

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Chairman of the Program Council SET Foundation

The economic reality of the 21st century is changing rapidly, forcing countries and regions to adopt new approaches to their raw materials strategies. Global competition for access to metals and minerals essential for technological and ecological transformation poses one of the most serious challenges in the history of the European Union, both economically and geopolitically. This report provides an in-depth analysis of Europe's current position and presents recommendations for key actions to build raw material independence.

The importance of critical raw materials—such as lithium, cobalt, rare earth metals, copper, and nickel—goes far beyond industrial and technological development. It also concerns fundamental issues of economic stability and national security. According to European Commission data, China is currently the largest supplier of 34 out of 51 critical raw materials, meeting the total global demand for 10 heavy rare earth elements (HREE), used in the automotive, aerospace, and defense industries, as well as in renewable energy and electronics. Europe also remains heavily dependent on imports for other raw materials, such as lithium, which is essential for battery production. This dependence poses a real risk, especially in view of growing geopolitical tensions, price fluctuations, and export barriers imposed by non-EU countries.

The report discusses the development of EU raw materials policy from 2008 to the present, with a particular focus on the current solutions contained in *the Critical Raw Materials Act*. The complexity of the challenges requires coherent action at Community level. The key objectives are to increase domestic production, diversify supplies, develop substitute technologies, and intensify recycling. By 2030, the EU plans to cover at least 10% of its demand from internal sources, 40% through processing, and 25% through recycling. It is worth noting that many of the current assumptions have their origins in documents from over a decade ago, which demonstrates the durability and relevance of many early diagnoses.

Particular attention is paid to the dominant position of China, which consistently uses its raw material advantage to strengthen its global position. In order to respond effectively, Europe must overcome internal barriers such as complex administrative procedures, limited financial instruments for risky investments, and low public acceptance of mining projects.

The report also analyzes external supply options, including resources in the Arctic, Greenland, and Ukraine. Despite its difficult political and military situation, Ukraine has around 20,000 deposits covering 117 different raw materials, 22 of which are considered critical by the EU. These include one of Europe's largest lithium deposits, estimated at 500,000 tons. The Arctic and Greenland also offer significant potential, although investment in these regions involves environmental and political risks.

Poland, thanks to its copper, silver, and coking coal resources, can play an important role in ensuring Europe's raw material independence. It has a strong mining base, experience, skilled personnel, and actively participates in ocean floor exploration, where promising strategic deposits are located.

The report is not limited to diagnosis – it contains specific proposals for measures that can ensure Europe's long-term economic security. One of the key proposals is the idea of establishing a European Raw Materials Fund, inspired by Japan's JOGMEC and Korea's KOMIR, which could effectively support strategic investments in raw materials.

I hope that this report will provide impetus for decisive political and economic action at the EU level. Europe's future position in the global balance of power, as well as the security and prosperity of future generations, depend on our effectiveness. The time to build European raw material autonomy is now.

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Abstract

With technological progress, the global race for access to rare earth elements and metallic elements such as lithium, cobalt, nickel, copper, and others is intensifying. Without them, it would be impossible to produce solar panels, batteries, wind turbines, electric vehicles, and other key components of digital and energy infrastructure needed for the transition to a "green economy." Dependence on their supply is a feature of virtually every innovative sector of the economy, including optical technologies, aviation, medicine, and the arms industry.

The EU is heavily dependent on imports or sourcing from outside its borders for critical raw materials needed for the energy transition, and their extraction and processing are often concentrated in third countries. Geopolitical changes and tensions in global economic policy, combined with competition for access to essential raw materials, may lead to various types of conflicts in resource-rich regions. All these factors may and will likely change the rules of the game in the future, but already today, control over strategic raw materials is becoming a fundamental element of national security and a prerequisite for the success of the energy transition, which is one of the European Union's strategic objectives. Countries that fail to secure access to these key resources risk marginalization in the new balance of power and falling behind in the fight for economic competitiveness. Just as the 20th century was the century of oil, the 21st century is becoming the century of strategic raw materials, and whoever controls access to them controls the future of the global economy and politics.

The report we are presenting to you is an attempt to comprehensively diagnose the European Union's position in the global race for raw materials and to identify specific measures that need to be taken to increase raw material security.

It presents and discusses all the most important issues related to the EU's legislative and legal framework for defining and securing the needs of European economies for raw materials classified as critical and strategic (*Critical Raw Materials Act*) and the evolution of this concept over time, together with specific initiatives (e.g., *EIT RawMaterials* and *the European Raw Materials Alliance)*.

The strategic role and importance of raw materials was also emphasized, not only for the European Union, but also for the US and NATO countries, particularly in the context of the need to secure stable access to them and the actions and solutions, including policies, applied in this area by various countries, such as the US, Japan, South Korea, Canada, and Australia. Key mechanisms certainly include building one's own supply security instruments in advance to guarantee stable access to critical raw materials and ensure processing capabilities. The report also outlines the dominant position of China, which is systematically and expansively exploiting and developing its raw material potential.

The report also refers to Mario Draghi's analysis and the instruments proposed therein to strengthen the position of the European Union and its Member States in terms of access to critical raw materials, as well as the objectives *of The Clean Industrial Deal* announced by the EU in 2025, with particular emphasis on the role of critical raw materials in the new EU competitiveness model. It therefore also refers to key internal barriers that slow down the development of European extraction, processing, and recycling projects, pointing, among other things, to overly lengthy administrative procedures, legislative inconsistencies, the lack of dedicated high-risk financial instruments, and a deficit of public support for mining investments.

The report also discusses selected mining projects in Europe, along with the problems associated with them and ways to solve them. At the same time, it provides guidelines for defining "good practices" for future mining projects, helping to ensure that they do not end in failure, as has been the case in some instances.

With regard to the development of the EU's raw material potential, the report presents the raw material potential of areas of greatest interest in this respect, including globally, namely the Arctic, Greenland, and Ukraine. These are important directions for European "external" raw material investments, and their prospects are outlined with reference to possible investment risks and the geopolitical situation.

A separate section is devoted to Poland's potential as one of the EU countries with its own raw material base, industrial capacity and strategic location, which could make our country an important player in the EU's raw material autonomy. Most raw material resources in Poland belong to the group of critical and strategic resources (both for the EU and Poland) with significant extraction potential (copper, silver, coking coal). Other raw materials with lower potential due to both low concentration and the occurrence of deposits at great depths were also discussed. Attention was drawn to the significant potential of the ocean floor in both the Atlantic and Pacific, where Poland has concessions and is conducting research. The significant raw material resources of these areas may soon become the target of industrial-scale exploitation. The first such attempts are already being made by some countries in their maritime areas.

The report also refers to other raw materials, mainly energy resources, pointing to their potential and possibilities of use, taking into account so-called clean technologies (CO_2capture and storage) and the use of these raw materials until they are replaced by other stable energy sources.

An important area highlighted is the development of Poland's geothermal potential, which should be taken into account in the implementation of the European Green Deal.

The authors' intention was not only to diagnose the current state of affairs, but also to propose realistic and feasible solutions, including the creation of a European Raw Materials Fund (EFS), which could play a role similar to that of Japan's JOGMEC or Korea's KOMIR, providing financing, coordination, and support for projects of strategic importance to the EU.

In addition to these solutions, the recommendations identify areas where clarification and prioritization are needed to achieve the goal of securing permanent and stable access to critical raw materials and renewable energy sources in the long term.

In the face of global transformation and intensifying competition for access to natural resources, the question is no longer "should Europe act," but "how quickly and effectively can it build a system" that will secure its interests and future.

We hope that this report will be an important voice in this debate.

Introduction

The growing importance of critical and strategic raw materials in the global economy is one of the key factors defining the new geopolitical and industrial order of the 21st century. The energy transition, the development of digital technologies, electromobility, the automation of production, and the modernization of the defense sector—all these processes require stable and predictable access to specific groups of raw materials that play a fundamental role in modern value chains.

At the center of this dynamic environment is the European Union – a highly developed, technologically advanced economy, but at the same time heavily dependent on imports of key raw materials. A low share of domestic production, limited capacity to exploit primary and secondary resources, low public acceptance of mining investments, and extensive environmental regulations make the EU particularly vulnerable to external shocks and protectionist measures taken by third countries. The widening gap between growing demand and supply shortages could, in the coming decades, lead to a decline in the competitiveness of the European economy and a loss of its ability to achieve its strategic objectives, including in the areas of digitalization, defense, and energy.

In this context, there is growing talk of the need to build strategic raw material autonomy for the EU – understood not as complete self-sufficiency, but as the ability to manage supply risks independently, resiliently and in line with the interests of the community. This autonomy should be based on four pillars: the development of national and European raw material projects, the diversification of imports from partner countries, the development of substitution technologies and recycling, and the strengthening of the EU's negotiating position on the international stage. However, achieving these objectives requires profound institutional changes, new financial instruments, and political courage in defining and implementing raw material priorities.

Purpose of the report

The purpose of this report is to:

- to diagnose the European Union's position in the global race for critical and strategic raw materials;
- to identify the main barriers to the development of European raw material projects;
- to present international best practices and raw material policy instruments of other countries;
- to formulate specific recommendations for the development of an effective and shock-resistant EU raw materials policy;
- presenting the concept of a European Raw Materials Fund as a central tool for supporting investment in the raw materials sector; and
- highlighting the potential of the European Union and its Member States, including Poland in particular, in the context of building a common European raw materials sovereignty.

The report is addressed to policy makers, representatives of public administration, the raw materials sector, and financial and research institutions. It aims to stimulate debate on the role of raw materials in Europe's economic transformation and to identify concrete and feasible measures necessary to ensure the EU's long-term raw materials security.

Critical raw materials in European Union strategy and legislation

2.1. Definition and criteria for classifying raw materials as critical and strategic in the EU

For more than a decade, the European Union has been diagnosing the challenges related to access to key non-energy raw materials and outlining action plans to ensure the security and stability of their supply.

The analysis must begin with a definition of what constitutes raw materials according to European strategy and law. According to the definitions contained in *the Critical Raw Materials Act* (CRMA)[1], "raw material" means a substance in a processed or unprocessed state used as an input material for the production of intermediate or final products, excluding substances used primarily as food, feed, or fuel for combustion engines." (Article 2(1)). The definition focuses on the function of the raw material in the production chain – it is understood as an "input material" used in the production of intermediate or final goods. This means that **the main criterion is not the origin or physical state of the substance, but its role in the industrial process.** At the same time, by excluding substances used primarily as food, feed or fuel for combustion engines, the CRMA focuses on raw materials of industrial and technological importance, rather than energy (traditional) or agricultural importance. The term "unprocessed or processed" means that the concept covers both primary raw materials (extracted directly from deposits) and secondary materials (derived from processing). **Processing** also has a legal definition under the CRMA, where, according to Article 2(8), it means "all physical, chemical, and biological processes involved in converting raw materials from ores, minerals, plant products, or waste into pure metals, alloys or other forms suitable for economic use, including enrichment, separation, smelting and refining, but excluding the processing of metals and further transformation into intermediate and final goods".**The definition is based on the principle of technological neutrality and openness.** It covers all physical, chemical, and biological processes that transform primary and secondary materials into usable forms, such as physical processes such as crushing or grinding, chemical processes such as leaching, hydrometallurgy, and chemical extraction, and biological processes such as *bioleaching.* A key element of the definition is the transformation into a form that is "economically viable." This is a dynamic criterion, dependent on the market, technological, and geographical context, which determines the practical end of the processing process, i.e., the achievement of a form that allows for effective use or sale. It is very important to clearly exclude from the definition of processing "the treatment of metals and further transformation into intermediate and final goods." This means that processing ends at the stage of obtaining pure metals, alloys, etc., while further stages (e.g., rolling, production of batteries, electronic components) are not covered by the CRMA regulations as "processing."

The definition of critical *raw materials* (*CRM*) and strategic *raw materials (SRM)* is somewhat more complicated**.** There are no comprehensive legal definitions in Article 2 of the CRMA, but according to Articles 3 and 4 of the CRMA, they are defined by reference to the relevant lists annexed to the CRMA.

Thus, according to Article 3(1), "Strategic raw materials are raw materials, including those in unprocessed form, obtained at any stage of processing and as a by-product of other extraction, processing or recycling processes, listed in the list set out in the Annex and Section 1." Similarly, pursuant to Article 4(1), "Critical raw materials are raw materials, including those in unprocessed form, obtained at any stage of processing and as a by-product of other extraction, processing or recycling processes, listed in the list set out in Annex II, Section 1." Firstly, in both cases**, there is no complete abstract definition** indicating the essential elements for classifying a raw material, and the characteristics are based on **a reference to a list.** Secondly, the broad functional approach **focuses on the strategic value of a given raw material**, depending not only on its state of processing, but also on its function in the economy and the possibility of obtaining it from various sources (including those defined in the CRMA as extraction processes (Article 2(4)) and recycling (Article 2(10)).[1]

In addition to referring to the list, Article 3(2) and (3) of the CRMA also establishes a mechanism for updating the list and, importantly, the criteria to be used when determining whether raw materials are strategic. Thus, pursuant to Article 3(2), the European Commission is granted delegated powers to update the list of strategic raw materials based on three criteria:

– strategic importance–relating to the role of the raw material in the implementation of EU policies,
– forecast growth in demand – crucial for economic transformation (e.g., raw materials for renewable energy sources, batteries),
– difficulties in increasing production–taking into account geological, technological, regulatory, and geopolitical barriers.

These criteria are further specified in Annex I, Section 2, which establishes a methodology for selecting strategic raw materials based on three pillars:

1) strategic importance determined on the basis of the importance of the raw material for the ecological and digital transformation, as well as for defense, aerospace, and space applications, taking into account the number of strategic technologies using the raw material as a feedstock, the amount of raw material needed to produce the relevant strategic technologies, and the expected global demand for the relevant strategic technologies;
2) the projected increase in demand calculated taking into account the global annual forecast for demand for the raw material and its production,
3) difficulties in increasing production, assessed taking into account, inter alia, the current global annual scale of production, the ratio of resources to the quantity of raw material produced, based on known economically recoverable geological resources and current global annual production, as well as reliable data on the time frame for the implementation of new projects to increase supply potential.

The CRMA establishes in Article 3(3) a cyclical review to be carried out every three years, with the first review to be completed by May 24, 2027. At the same time, it introduces a rapid response mechanism – the review may be initiated at any time if necessary.

Similarly, with regard to critical raw materials, Article 4(2) of the CRMA delegates to the European Commission (in accordance with Article 38 of the CRMA) the power to update the list. To this end, objective and measurable classification thresholds are established:

– economic importance – threshold ≥ 2.8,
– supply risk – threshold ≥ 1.0.

These are quantitative indicators, the calculation methodology for which is also set out in Annex II, Section 2, which lists six basic principles for calculation:

1) economic importance, taking into account the individual sectors of the NACE economy[2],
2) substitutability index of the assessed raw material related to its economic importance,
3) risk to raw material supply,
4) dependence on imports of raw materials,
5) the Herfindahl-Hirschmann Index (an economic measure of market concentration used to assess the level of competition in a given sector of the economy, the dominance of individual suppliers or producers, and the risk of dependence on a small number of sources),
6) substitutability index of the assessed raw material linked to supply risk.

It is also pointed out that if structural or statistical changes affect the assessment of all raw materials, the

values should be adjusted accordingly to ensure comparability. Calculations should be based on averages over the last five years, taking into account the quality and availability of data.

Despite the lack of an abstract definition of strategic and critical raw materials, the technocratic and transparent approach described above increases the regulatory legitimacy of the published lists.

It is worth noting that, in accordance with Article 4(2) of the CRMA, the list of critical raw materials also includes all strategic raw materials listed in Annex I, Section 1**,** which means that **"strategic importance" is treated as a subset of "criticality."** Furthermore, as in the case of the list of strategic raw materials, the first review and, if necessary, update of the list of critical raw materials is to take place by May 24, 2027, and then at least every three years (Article 4(3)).

When defining critical and strategic raw materials, it is worth referring back to the results of the comprehensive analysis *"Study on the Critical Raw Materials for the EU 2023 – Final* Report"[3] (CRMS), which became the basis for identifying critical and strategic raw materials, drawing up lists of such materials, and proposing regulations for establishing the CRMA. According to the glossary contained therein, critical *raw materials* (*CRMs)* are defined as "raw materials of high importance for the EU economy, the supply of which is subject to high risks. Two main parameters, *Economic Importance* (EI) and *Supply Risk* (SR), are used to determine the criticality of a material for the EU. The CRM list is based on raw materials that meet or exceed the thresholds for both parameters." Strategic *raw materials* (*Strategic Raw Materials)* are those raw materials that are important for technologies supporting the green and digital transition and for defense and aviation objectives.

The current lists of strategic raw materials and critical raw materials, as set out in Annexes I and II to the CRMA, **include**:

1) **critical raw materials – 34 items**: antimony, arsenic, bauxite/aluminum oxide/aluminum, barite, beryllium, bismuth, boron, cobalt, coke, copper, feldspar, fluorite, gallium, germanium, hafnium, helium, heavy rare earth metals, light rare earth metals, lithium, magnesium, manganese, graphite, nickel – in the standard required for batteries, niobium, phosphorite, phosphorus, platinum group metals[4] , scandium, metallic silicon, strontium, tantalum, metallic titanium, tungsten and vanadium;
2) **strategic raw materials – 17 items**: bauxite/aluminum oxide/aluminum, bismuth, boron – metallurgical grade, cobalt, copper, gallium, germanium, lithium – in the standard required for batteries, metallic magnesium, manganese – in the standard required for batteries, graphite – in the standard required for batteries, nickel – in the standard required for batteries, platinum metals, rare earth metals for the production of magnets (Nd, Pr, Tb, Dy, Gd, Sm and Ce), metallic silicon, metallic titanium and tungsten.

What **rare earth metals** are still needs to be explained. Generally, including in the aforementioned CRMS study, it is assumed that the term rare earth metals – *Rare Earth Elements (*REE) refers to a group of 17 chemical elements, including 15 lanthanides (lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium) as well as scandium and yttrium.

Within rare earth metals**,** two main subgroups are distinguished: ***light rare earth elements*** **(LREE)**, which, according to the above-mentioned study, include 5 elements: cerium, lanthanum, neodymium, praseodymium and samarium**,** and **heavy *rare earth elements (HREE)*, (HREE),** which, according to the same study, include 10 elements: dysprosium, erbium, europium, gadolinium, holmium, lutetium, terbium, thulium, ytterbium, and yttrium. This division is based on differences in ionic radius, difficulty of separation, and varying industrial importance and occurrence in nature. It is worth noting that, from a European perspective, from a chemical and geological point of view, both yttrium and scandium cannot be clearly assigned to the lanthanide series, but their physicochemical properties, similar ionic radius and natural co-occurrence with REEs in ore deposits (especially in the case of yttrium) justify their inclusion in this category in raw material analyses. The CRMS definition states that yttrium should be treated as a rare earth element, which is supported by its chemical properties and its co-occurrence with lanthanides in deposits. Scandium, on the other hand, has been excluded from this classification due to its different physicochemical properties and the lack of clear functional analogies, both in terms of electronic structure and technological application.

From the perspective of the raw materials economy, HREE are much rarer and more difficult to extract, which makes them particularly important for the security of supply and technological independence of the European Union. Rare earth metals are one of the most important groups of raw materials for the modern high-tech economy. They have unique magnetic (REE used in permanent magnets include neodymium, praseodymium, terbium, dysprosium, samarium, gadolinium, and cerium), catalytic, and optical properties, which determine their key importance for a wide range of strategic sectors. They are used, among others, in the automotive industry (strong permanent NdFeB magnets), aerospace, defense (guidance systems, sensors), as well as in renewable energy (wind turbine magnets), telecommunications (antennas, fiber optics) and consumer electronics (LED screens, batteries, exhaust catalysts). The scale of their application and limited availability (including geographical concentration of production, especially in China) make REEs both critical and strategic raw materials within the meaning of EU raw materials policy.

It is also worth noting that, in accordance with Article 3(3) of the CRMA, as part of the first update of the list of strategic raw materials, the Commission will specifically assess whether synthetic graphite should remain on the list of strategic raw materials. This is important because the inclusion of synthetic graphite on the list may be considered debatable, as it is not a material extracted from deposits but an industrial product, albeit with strategic applications (e.g., in lithium-ion batteries).

2.2. The European Union's raw materials policy

2.2.1. The raw materials initiative

The first strategic document that comprehensively diagnosed the challenges related to access to key non-energy raw materials and formulated the main directions for the European Union's action was the European Commission Communication COM (2008) 699 of 4 November 2008 entitled "*The raw materials initiative — meeting our critical needs for growth and jobs in Europe*" [5] . The Commission correctly assessed that, although the EU is self-sufficient in some raw materials, such as construction aggregates, it is heavily dependent on imports for many metals, especially those used in advanced technologies. **As early as 2008, it was pointed out that technological progress and economic development are expanding the range of applications for raw materials such as cobalt, platinum, rare earth metals, titanium, lithium and rhenium superalloys, while at the same time growing demand for raw materials on global markets and protectionist measures by some raw material-exporting countries are exacerbating the challenges of ensuring stable supplies.** In this context, reference was made to the tantalum supply crisis of 2000, when a sharp increase in demand for this metal, mined mainly in Central Africa, primarily in the Democratic Republic of Congo, caused by the dynamic development of the mobile phone and consumer electronics market, led to market shortages and a several-fold increase in prices. It was predicted that such situations would recur in the future. **Seventeen years ago, it was also correctly pointed out that the main suppliers of raw materials essential for new technologies are China, Africa, South America, Russia and Australia, and the fact that "some sources of important raw materials are located in parts of the world where there is no market economy or which are politically or economically unstable" should be treated as a risk.**

The European Union's strategic response to these challenges was based on three pillars:

1) **Ensuring access to raw materials on international markets on the same terms as other industrial competitors** – through an active trade policy and raw materials diplomacy aimed at eliminating export barriers such as customs duties, or quantitative restrictions applied by third countries. To this end, active measures were planned, varying in nature depending on the type of stakeholder. From today's perspective, it is noteworthy that with **Russia and China, described as rapidly developing economies, the strategic objective was to "strengthen dialogue, inter alia, with a view to removing measures causing market distortions."** It was also planned to use various formats of cooperation, such as the G8 and the OECD, and to ensure that key stakeholders fulfilled their international multilateral and bilateral commitments, including through the use of World Trade Organization (WTO) instruments, bilateral agreements, and dispute settlement mechanisms. In order to ensure stable

access to raw materials, which often come from developing countries, mainly in Africa, the European Union intended to: (1) strengthen countries, including by supporting the rule of law and transparency in governance in a number of areas, including raw materials, infrastructure development and the economy, through financial assistance, among other means; (2) promote a healthy investment climate, including by creating transparent and fair conditions for business, including in the mining sector, equal rules for all players, fair tax systems, and support for investment (e.g., loans from the European Investment Bank), (3) promoting sustainable resource management by assisting partner countries in raising standards in the field of social policy and environmental protection, improving the human rights situation and combating child labor.

2) **Increasing the supply of raw materials from European sources**–it was pointed out that in order to create favorable conditions for the extractive industry**,** it is necessary**,** among other things, **to ensure easier access to land, simplify administrative procedures, improve spatial planning, including its integration with raw materials policy, and cooperate in geological research**. Other objectives include **supporting research into new extraction technologies,** particularly from deep deposits and the seabed, **raising public awareness** of raw materials, improving worker qualifications, and promoting safe working conditions in the mining sector. Attention was also drawn to the need to make better use of the potential of recycling and secondary raw materials, as well as to reconcile exploitation with environmental protection (Natura 2000).
3) **Reducing the consumption of primary raw materials in the EUs** – the aim here is to reduce dependence on imports, protect the environment and develop a circular economy , among other things by promoting resource efficiency, recycling, substitutes and renewable raw materials.

2.2.2. Critical Raw Materials Act – framework and objectives of the regulation

The CRMA Regulation[1]establishes a harmonized legal framework for developing secure supply chains for critical and strategic raw materials in the European Union. Its essence is to strengthen the EU's raw material autonomy in light of the green, digital, and industrial transitions and to ensure access to resilient and sustainable supplies of critical raw materials, including through the use of sustainable instruments, promoting efficiency, and promoting a circular economy throughout the value chain. The measures through which the EU intends to act are primarily the identification and support of strategic projects that will contribute to reducing dependence on critical raw materials, as well as promoting technological progress and resource efficiency, and monitoring and reducing risks related to the supply of critical raw materials.

These measures are intended to achieve the following targets **by 2030**:

- the Union's extraction capacity to extract ores, minerals or concentrates needed to produce at least 10% of its annual consumption of strategic raw materials, to the extent possible given the Union's resources;
- the Union's processing capacity to cover at least 40% of its annual consumption of strategic raw materials;
- the Union's recycling capacity to cover at least 25% of the annual consumption of strategic raw materials, while allowing for the recycling of significantly increasing amounts of each strategic raw material from waste;
- diversification of imports of strategic raw materials into the Union, ensuring that no third country supplies more than 65% of the Union's annual consumption of strategic raw materials.

An important element of the CRMA is the establishment of a category **of strategic projects**, which may concern the start or expansion of extraction, processing or recycling of strategic raw materials or the production and increase of materials that can replace strategic raw materials necessary in strategic technologies. These projects must meet specific criteria, including contributing significantly to the achievement of the CRMA objectives, meeting high environmental and social standards, being technically feasible within a reasonable timeframe with an estimable production dimension, and bringing benefits to the EU beyond a single country. By obtaining strategic

status, they benefit from **accelerated administrative procedures** – a maximum of 27 months for extraction projects and 15 months for processing and recycling projects, and for projects for which the permit granting procedure was started before they were designated as strategic projects, 24 and 12 months respectively[1] and **coordination support** from Member States.

Member States have also been required to draw up, by May 24, 2025, at the latest, national plans for general exploration work focused on critical raw materials and associated minerals. These plans are to be reviewed at least every five years and updated as necessary.

Monitoring obligations have also been established, whereby the European Commission is required to **monitor the risks related to the supply of critical raw materials**, in particular those that pose a risk of disrupting competition or fragmenting the internal market, while large companies that extract or depend on strategic raw materials are required to carry out regular risk assessments in their supply chains. The Commission is also establishing an early warning mechanism to prevent supply crises. Furthermore, as already mentioned, the Commission will review the lists of strategic and critical raw materials and the effectiveness of the implementation of benchmarks every three years.

The CRMA also promotes **recycling, eco-design, and the circular economy**, among other things, through the mandatory collection of certain types of waste containing critical raw materials, measures to increase the recovery of raw materials from scrap and electronic equipment, and support for the design of products with recycling in mind (*eco-design*). Firstly, Member States are required to develop national programs promoting the circular economy. These programs are intended, among other things, to increase waste collection, and processing, promote reuse and repair, and support the development of recycling technologies. Financial and regulatory incentives (e.g., in public procurement) are provided for the use of recycled materials. This obligation must be fulfilled within two years of the adoption of the relevant implementing acts. Secondly, operators of mining waste facilities will have to submit preliminary assessments of the potential for recovering critical raw materials, and Member States are required to create databases of closed facilities containing potential deposits of secondary raw materials. This is intended to lay the groundwork for future recycling and revitalization of historic mining waste dumps. Thirdly, permanent magnets containing rare earth metals are an important focus of the CRMA. The CRMA introduces a requirement to label products containing such magnets and to provide detailed information on their chemical composition, location in the product, and disassembly options. There is also a requirement to publicly disclose information on the content of recycled metals and, in the future, to establish minimum thresholds for their share.

A permanent governance framework has been established in the form of the **European Critical Raw Materials Board**, composed of representatives from all Member States and the Commission, as an advisory body to support the Commission in updating the lists, assessing strategic projects, and monitoring the market. The development of international partnerships with third countries is also envisaged in order to diversify sources and promote sustainable extraction.

The CRMA also lays the foundations for a system for coordinating strategic stocks of critical raw materials in the European Union. A central element of the regulation in this regard is the obligation for the Commission to submit data on the level of EU strategic stocks to the European Critical Raw Materials Board every two years, starting on May 24, 2026. This shall be accompanied by a draft reference indicator to determine the so-called safe level of reserves for each strategic raw material. This indicator is operational in nature: it is expressed as the number of days for which stocks should be sufficient in the event of a disruption of supply and is proportional to the supply risk and the importance of the raw material concerned. Although the CRMA does not impose a direct obligation to build up stocks, the Commission may issue opinions to Member States recommending that they increase their stocks or better coordinate procedures for their release and distribution. An important role has also been assigned to the private sector: the regulation stipulates that it is companies that should be encouraged to build their own raw material buffers, with public instruments supporting rather than replacing this trend.

One of the EU's instruments for responding to challenges and threats is **the legal framework for joint procurement of strategic raw materials** established in the CRMA. The mechanism is based on aggregating demand from companies based in the EU and jointly soliciting offers from suppliers of critical raw materials. The system is designed not only to improve trading conditions for EU entities, especially small and

medium-sized enterprises, but also to reduce the risk of shortages by increasing the efficiency and resilience of the supply system. The European Commission, after analyzing the impact of this mechanism on competition and the internal market, has the power to decide which raw materials to include in joint purchases and at what stage of processing. Importantly, joint purchase negotiations (including prices) are allowed, provided they are transparent and comply with EU competition law. The CRMA thus creates an exception to the general rules prohibiting coordination of trading conditions between independent entities. At the same time, it introduces exemptions - entities subject to EU sanctions, among others, are excluded from participation in the system.

2.2.3. First European list of critical raw materials (2011)

At the European level, the first list of critical raw materials (Table 1) was published in the European Commission Communication COM (2011) 25 of February 2, 2011, entitled "Facing challenges in commodity markets and raw materials"[6] .

In addition to a broad overview of the measures taken under the above-mentioned "Raw Materials Initiative," the document also presents the characteristics and conditions of the global raw materials market, including their classification, trading mechanisms, and factors affecting supply, demand, and price stability.

According to the typology presented by the Commission, raw materials include metallic minerals (containing, for example, copper and aluminum), industrial minerals, construction materials, and raw materials of biological origin, such as wood and natural rubber. It was emphasized that trade in raw materials is global in nature, which means that their prices and availability are shaped by market mechanisms that go beyond the borders of a single country or region. From the point of view of trading mechanisms**, two main categories of raw materials** were distinguished**:**

- exchange-traded, which include base metals such as aluminum, copper, zinc, lead, nickel, and tin. An example of a major trading center of this type is the London Metal Exchange (LME), which is the leading wholesale market for industrial metals;
- not listed on stock exchanges (over-the-counter markets), including a number of raw materials that are key to the EU economy, such as cobalt, gallium, indium and REEs. These markets are characterized by lower transparency, limited availability of trade data, and lower liquidity, which makes it difficult to assess their condition and plan strategic purchasing activities.

Even then, the European Commission recognized the cyclical nature of market processes, their susceptibility to price fluctuations depending on supply and demand dynamics, and predicted steady growth in demand driven by economic growth in developing countries (including China, India, and Brazil) and the global development of technologies key to the energy and digital transition (e.g., the production of batteries, solar panels, and wind turbines). In this context, **14 years ago, the Commission expressed concerns about the increasing use by some countries of export-restrictive measures, including export duties, quotas, licenses, or total export bans, aimed at ensuring priority access to raw materials for domestic industries.** In the Commission's assessment at the time, this in turn inevitably led to serious distortions of competition in the international market and increased uncertainty of supply. Such practices were described as discriminatory and were found to be potentially in breach of World Trade Organization (WTO) rules. It was recognized that, in response to these mechanisms, companies were taking various protective measures that could further restrict the supply available on the open market and thus increase price pressure. These included:

- stockpiling,
- concluding long-term contracts with suppliers,
- the use of financial instruments in the form of forward contracts (hedging).

Taking the above into account, the European Commission, in cooperation with Member States and stakeholders, has drawn up **a list of fourteen raw materials considered critical at EU level**. The Commission also presented a methodological approach to determining what "critical importance" means for a raw material in the context of raw materials policy. According to the adopted methodology, critical raw materials (currently CRMs) are those that:

- present a high risk of supply disruption in the next decade,

– play an important role in European value chains and industrial sectors of strategic importance (including energy, automotive, ICT, and defense).

The risk of shortages is most often due to:

– geographical concentration of extraction (production often concentrated in one or a few countries),
– political and economic instability in raw material-supplying countries,
– limited substitutability of the material in question, and
– the lack of effective recycling technologies.

The document emphasized that many raw materials considered critical are essential for the achievement of climate policy objectives and the EU's technological transformation, e.g., **rare earth elements**, which are necessary for the production of, among other things, high-efficiency permanent magnets (used in wind turbines and electric vehicle motors), automotive catalysts, and electronic components (printed circuits, optical fibers, high-temperature superconductors). In **2011, it was found that the EU is fully dependent on imports of these raw materials, with China accounting for a dominant share, representing as much as 97% of global production** of rare earth elements **in 2009**. As highlighted, **there are no viable technologies for recycling or substituting them,** which exacerbates dependence and risk.

As the Commission pointed out, the process of identifying critical raw materials has highlighted gaps in data and market knowledge, pointing to the need to:

– systematic updating of the list of key raw materials, based on changing market realities and the development of new technologies (e.g. related to the use of lithium, hafnium, nickel),
– taking into account the impact of raw materials on the environment, and
– extending the scope of raw materials policy to include materials which, although not formally classified as critical, are of strategic importance in the context of sustainable development and the competitiveness of EU industry.

1: List of CRMs 2011[6]

Raw materials	Main producers (2008, 2009)	Main sources of imports into the EU (2007 or 2006)	Level of import dependency	Substitutability	Recycling rate
Antimony	China 91	Bolivia 77%	100%	0.64	11%
	Bolivia 2%	China			
	Russia 2%	Peru 6%			
	South Africa 2%				
Beryl	USA 85%	USA, Canada, China, Brazil (*)	100%		
	China 14%				
	Mozambique 1%				
Cobalt	Democratic Republic of the Congo 41%	Democratic Republic of the Congo 71%	100%	0.9	16%
	Canada 11	Russia			
	Zambia 9%	Tanzania 5%			
Fluorite	China 59%	China 27%	69%	0.9	0%
	Mexico 18	South Africa 25			
	Mongolia 6%	Mexico 24%			

Gal	n/a	USA, Russia (*)	(*)	0.74	0%
German	China 72%	China 72	100%	0.8	0%
	Russia 4%	USA			
	USA 3%	Hong Kong 7%			
Graphite	China 72%	China 75%	95%	0.5	0%
	India 13	Brazil			n/a
	Brazil 7%	Madagascar 3%			
		Canada 3%			
India	China 58%	China 81%	100%	0.9	0.30%
	Japan 11	Hong Kong 4			
	South Korea 9%	USA 4%			
	Canada 9%	Singapore 4%			
Magnesium	China 56%	China 82%	100%	0.82	14%
	Turkey	Israel			
	Russia 7%	Norway 3%			
		Russia 3%			
Niobium	Brazil 92%	Brazil 84%	100%	0.7	11%
	Canada 7	Canada 16			
Platinum	South Africa 79%	RPA 60%	100%	0.75	35%
Metals	Russia 11%	Russia 32%			
	Zimbabwe 3%	Norway 4%			
Rare earth elements	China 97%	China 90%	100%	0.87	1%
	India	Russia 9%			
	Brazil 1%	Kazakhstan 1%			
Tantalum	Australia 48%	China 46%	100	0.4	4%
	Brazil	Japan 40			
	Rwanda 9%	Kazakhstan 14%			
	Democratic Republic of the Congo 9%				
Tungsten	China 78% (6.1)	Russia 76%	73	0.77	37%
	Russia 5% (6.5)	Bolivia 7			
	Canada 4%	Rwanda 13%			

(*) subject to strong fluctuations

2.2.4. Evolution of the European list of critical raw materials

The first review of the CRM list resulted in **the European Commission Communication COM (2014) 297 of May 26, 2014,[7] on the review of the list of critical raw materials for the EU and the implementation of the raw materials initiative.**

In a study conducted in 2013 in accordance with the methodology described in the 2011 Communication, 54 raw materials other than energy and food products were analyzed (41 were analyzed in 2010), expanding the research panel with seven new abiotic raw materials and three biotic raw materials (gum, paper pulp, and softwood lumber). As a result of the review, tantalum was removed from the list (due to reduced risk of supply shortages) and six new raw materials were added: borates, chromium, coke, magnesite, nd phosphorite, and metallic silicon. In addition, rare earth elements were divided into light and heavy elements and treated as separate items. **The new list thus included a total of 20 critical raw materials.**

[8]The third assessment and classification of raw materials resulted in **the European Commission Communication COM (2017) 490 final of September 13, 2017, on the list of critical raw materials for the EU in 2017**.

This time, the assessment of the criticality of raw materials was carried out on the basis of an updated and improved methodology developed by the European Commission, ensuring consistency and comparability with previous methodological editions (from 2011 and 2014). The analytical basis continued to be two key indicators: the economic importance of a given raw material and the risk associated with its supply. However, the new version of the methodology introduced modifications consisting of:

- taking into account import dependence and export restrictions in the assessment of supply risk,
- the introduction of a substitution indicator, which adjusts both the assessment of economic importance and vulnerability to supply disruptions, and
- assigning raw materials to specific industrial uses in order to determine their economic role in the value chain more reliably.

It was also emphasized that raw materials that have not been formally classified as critical may also play an important role in the functioning of the EU economy, as they are the initial link in sectoral value chains. Their availability may change rapidly as a result of global changes in international trade or revisions of third countries' trade policies. For this reason, it was considered necessary to maintain strategic diversification of raw material sources and increase their recycling rate in order to reduce the EU economy's vulnerability to external supply shocks.

As part of the 2017 update, 78 raw materials were assessed, which represented an extension of the scope of the 2014 analysis. As a result, nine new items were added to the list of critical raw materials. At the same time, three raw materials (chromium, coking coal and magnesite) were removed from the list due to a decrease in their criticality. **The status of raw materials critical to the European Union was assigned to 27 raw materials characterized by both a high risk of supply disruption and significant economic consequences exceeding those of most other raw materials.** The data showed that there is a certain level of domestic production of selected critical raw materials in the EU, such as hafnium. However, as was emphasized, **China plays a dominant role as a global supplier of, among others, rare earth elements, magnesium, tungsten, antimony, gallium, and germanium.** It was also noted that many other raw materials are also characterized by strong geographical concentration: **Brazil as the main producer of niobium and the United States in the supply of beryllium and helium.** It was also pointed out that **platinum group metals (PGMs),** such as palladium, iridium, platinum, rhodium, and ruthenium, **come mainly from Russia and South Africa.** It was diagnosed that the risks associated with the geographical concentration of raw material extraction are further exacerbated by their low substitution potential and limited recycling possibilities, which makes the EU industry particularly vulnerable to disruptions in supply chains.

Another **European Commission Communication COM (2020) 474 final of September 3, 2020,**[9], presented an updated European Union strategy on raw materials security. The aim was to identify raw materials that are critical to the EU economy and to define policy tools to reduce the risk of disruptions in their supply, particularly in the context of the Green Deal and the digital transformation.

In 2020**, the European Commission reassessed that the EU is highly dependent on imports of critical raw**

materials, citing again that "China provides 98% of the EU's rare earth supplies, Turkey provides 98% of the EU's boron supplies, and South Africa 71% of the EU's demand for platinum and an even larger share of its demand for platinum group metals – iridium, rhodium and ruthenium." At the same time, the European Commission presents data illustrating the scale of future needs in key sectors of the low-carbon and digital economy.

According to the projections cited in the document, it is forecast that:

The EU will need up to **18 times more lithium and 5 times more cobalt in 2030,** and almost **60 times more lithium and 15 times more cobalt in 2050**, compared to current supplies for the entire EU economy.

The demand **for REEs, used in the production of permanent magnets, is expected to increase tenfold by 2050** due to the expansion of wind turbines and electric motors.

The Commission also pointed out that **Europe has deposits of critical raw materials** (Fig. 1), including those directly related to the development of the battery manufacturing sector, such as lithium, nickel, cobalt, graphite, and manganese.

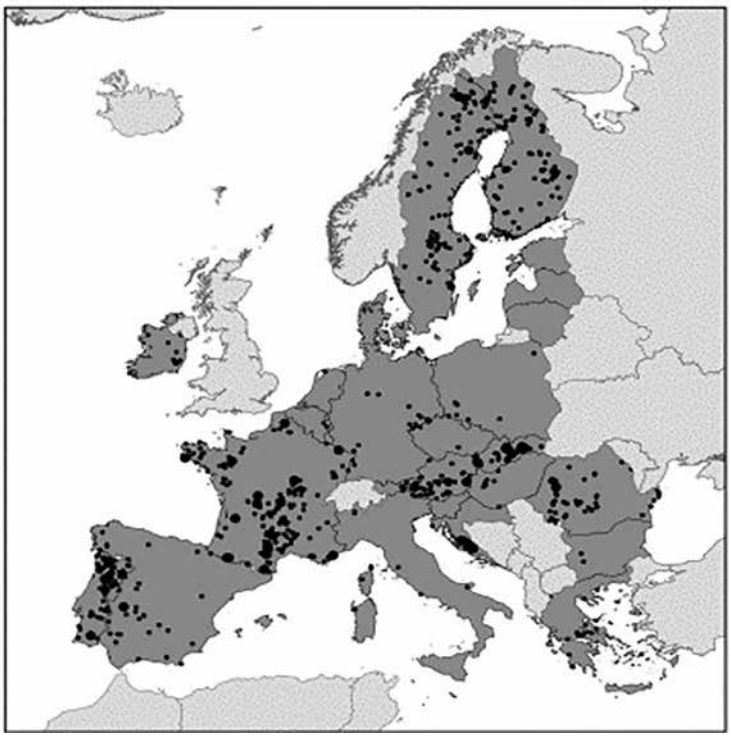


Fig. 1. Critical raw material resources in the EU. (according to EuroGeoSurveys)[10]

It has been noted that despite its abundance of certain base metals, such as copper and zinc, and despite its rich mining tradition, **Europe has not been successful in developing projects** aimed at supplying critical raw materials. The reasons for this have been identified as:

- a lack of investment in exploration and extraction,
- diverse and lengthy national licensing procedures, and
- low level of public acceptance.

According to the Commission, the difficulties in developing projects to the exploitation stage also stem from the significant risks and costs of new projects, the lack of incentives for exploration and financing, and the lengthy national permit granting procedures.

The Communication also points out that many of the raw materials necessary for battery production in the European Union (Fig. 2) are located in areas that are highly dependent on the coal industry or other sectors with high greenhouse gas emissions. Given that these regions are also the planned locations for battery production facilities, the EC considered that this would create synergies in the context of economic transformation.

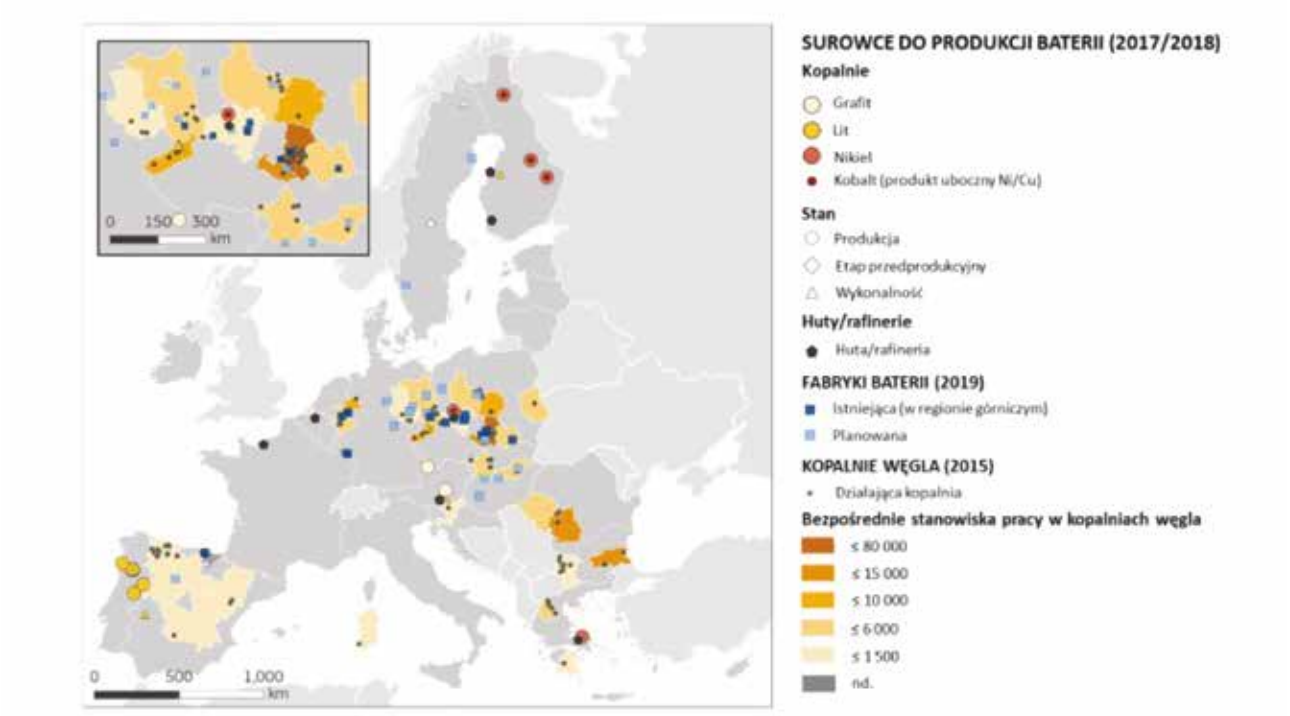


Fig. 2. Mines for battery raw materials, battery factories, and coal mines[10]

The European Commission's response to the challenges identified was to formulate an action plan to ensure the EU's raw material resilience and support strategic industrial value chains, which includes ten specific initiatives set out in the form of integrated actions ***(Action Plan on Critical Raw Materials)***:

1) Launching **a** European industry-led **alliance for raw materials** in the third quarter of 2020, initially to build resilience and open strategic autonomy in the rare earths and magnets value chain, and then expanding it to other raw material-related areas.
2) Develop **criteria for sustainable financing of the mining, extraction, and processing sectors** in delegated acts on the taxonomy by the end of 2021.
3) Launching **research and innovation** in 2021 on critical raw materials for waste processing, advanced materials and substitution, using the Horizon Europe program, the European Regional Development Fund, and national research and innovation programs.
4) Identify opportunities for sourcing **secondary critical raw materials** from EU stocks and waste and identify promising projects for raw material recovery by 2022.
5) Identify **mining and processing projects and investment needs** and related financing opportunities for critical raw materials in the EU that can be launched by 2025, giving priority to coal mining regions.
6) **Develop expertise and skills** in mining, extraction and processing technologies as part of a sustainable transition strategy in regions undergoing transition from 2022 onwards.
7) Use Earth observation and remote sensing programs for **resource exploration, exploitation, and environmental management** after exploitation.
8) Develop research and innovation projects under the Horizon Europe program on the extraction and processing of critical raw materials to **reduce environmental impact** from 2021.
9) Develop **strategic international partnerships** and related financing to ensure diversified and sustainable supplies of critical raw materials, including through unhindered trade and investment conditions, starting with pilot partnerships with Canada, interested countries in Africa and countries neighboring the EU in 2021.
10) Promote **responsible mining practices** for critical raw materials through an EU regulatory framework (proposals in 2020-2021) and through relevant cooperation.

As regards **the list of critical raw materials** itself, in 2020 (Table 2), after analyzing the assessment of 83 raw materials, it was **extended to 30 items**, compared to 14 in 2011, 20 in 2014 and 27 in 2017. Compared to the 2017 list, 26 raw materials remained on the list, while helium was removed due to its declining economic importance. Bauxite, lithium, titanium, and strontium were added to the list for the first time.

Table 2. 2020 CRM list[10]

Critical raw materials in 2020 (differences from the 2017 list are indicated in bold)		
Antimony	Hafnium	Phosphorus
Barium	Heavy rare earth metals	Scandium
Beryllium	Light rare earth metals	Metallic silicon
Bismuth	Indium	Tantalum
Boron	Magnesium	Tungsten
Cobalt	Natural graphite	Vanadium
Coke	Natural rubber	**Bauxite**
Fluorite	Niobium	**Lithium**
Gallium	Platinum group metals	**Titanium**
Germanium	Phosphorite	**Strontium**

In 2020, for the first time, the Communication was supplemented with Annex 2, which is **a matrix defining the "Significance of critical raw materials for industrial ecosystems,"** covering 14 sectors, from aerospace and defense, through electronics and the digital sector, renewable energy and energy-intensive sectors, to tourism, health, and the creative/cultural sector.

2.2.5. Current list of critical raw materials (2023)

The fifth list of critical raw materials was formulated in **the regulatory proposal COM (2023) 160 final of March 16, 2023, based on the analysis "*Study on the Critical Raw Materials for the EU 2023 – Final* Report"** [3].

In an extensive study that formed the basis for the list, a total of 87 raw materials were analyzed, including 67 individual raw materials and three groups: ten heavy (HREE) and five light (LREE) rare earth elements and five platinum group metals (PGM). As a result, it was proposed to distinguish not only a group *of critical raw* materials (CRM), but also *strategic raw materials* (SRM), which, as already mentioned, should be considered important for technologies that support the green and digital transition and defense and aviation objectives.

Compared to the list of 30 CRMs in 2020 (Table 3), **six new critical raw materials have been added** (arsenic, feldspar, helium, and manganese, as well as copper and nickel, defined as strategic raw materials), and two raw materials have been removed from the list (indium and natural rubber).

Table 3: CRMs 2023[3]

2023 CRMs vs. 2020 CRMs			
aluminium/bauxite	gallium	phosphate rock	vanadium
antimony	germanium	phosphorus	arsenic
baryte	hafnium	PGM	feldspar
beryllium	HREE	scandium	helium
bismuth	lithium	silicon metal	manganese
borate	LREE	strontium	copper
cobalt	magnesium	tantalum	nickel
coking coal	natural graphite	titanium metal	~~indium~~
fluorspar	niobium	tungsten	~~natural rubber~~

Legend:
Black: CRMs in 2023 and 2020
Red: CRMs in 2023, non-CRMs in 2020
~~Strike:~~ Non-CRMs in 2023 that were critical in 2020

In contrast, **the list of strategic raw materials** contained in the annex to the regulatory proposal COM (2023) 160 includes **16 items**: bismuth, boron – metallurgical grade, cobalt, copper, gallium, germanium, lithium – in the standard required for batteries, metallic magnesium, manganese – in the standard required for batteries, natural graphite – in the standard required for batteries, nickel – in the standard required for batteries, platinum group metals, rare earth metals for magnet production (Nd, Pr, Tb, Dy, Gd, Sm, and Ce), metallic silicon, metallic titanium, and tungsten. **Three criteria** have been adopted for their identification**:**

- **strategic importance** is determined on the basis of the importance of the raw material from the point of view of ecological and digital transformation, as well as defense and space applications,
- **forecast growth in demand**, and
- **difficulties in increasing production,** taking into account the current scale of production and the ratio of resources to raw material production.

2.2.6. Cooperation formulas for raw material security

Two key European Union initiatives aimed at strengthening Europe's raw material security and supporting innovation in the mineral raw materials sector are EIT RawMaterials and the European Raw Materials Alliance (ERMA). Although they are closely linked, they have separate functions and different organizational structures.

EIT RawMaterials was established in 2015 as one of the Knowledge and Innovation Communities (KICs) within the European Institute of Innovation and Technology (EIT), an EU agency established in 2008. It is the world's largest innovation network in the raw materials sector, bringing together over 300 partners from industry, academia, research and investment institutions from more than 20 EU countries. EIT RawMaterials' mission is to transform raw materials into a key asset for Europe by increasing the competitiveness and attractiveness of the mineral raw materials sector. It aims to ensure a sustainable supply of raw materials by supporting innovation, education, and entrepreneurship throughout the raw materials value chain. Its activities focus on:

- financing innovative projects in the exploration, extraction, processing, recycling, and substitution of raw materials,
- supporting start-ups and SMEs through acceleration and investment programs,
- running educational programs at various levels, from schools to doctoral studies, to train future specialists in the field of raw materials, and
- creating regional innovation centers *(Co-Location Centers)* that bring together industry, research, and education.

The European Raw Materials Alliance (*ERMA*) was launched by the European Commission on September 3, 2020, as part of the aforementioned *Action Plan on Critical Raw Materials*. Officially launched on September 29,

2020, ERMA is an industry alliance managed by EIT RawMaterials, bringing together over 750 members, including companies, research institutions, non-governmental organizations, and financial institutions. ERMA's goal is to increase Europe's economic resilience by diversifying raw material supply chains, creating jobs, attracting investment in the raw material value chain, supporting innovation, training young talent, and contributing to the creation of the best possible environment for raw materials and strengthening the circular economy. ERMA's activities include:

- identifying barriers and investment opportunities in the raw materials value chain,
- supporting the creation of innovative and sustainable solutions and infrastructure,
- implementing a circular economy to support the production of complex products such as electric vehicles, clean energy technologies, and hydrogen equipment,
- supporting the capacity of the raw materials industry in Europe to extract, design, produce, and recycle materials,
- promoting innovation, strategic investment, and industrial production in specific value chains.

Both initiatives (EIT RawMaterials and ERMA) are complementary and work together to strengthen Europe's raw materials security and support innovation in the raw materials sector. EIT RawMaterials focuses on supporting innovation, education, and entrepreneurship across the entire raw materials value chain, while ERMA focuses on building economic resilience through supply chain diversification and attracting investment in strategic areas.

2.3. Diagnosis of the economic importance and dependence on critical raw materials

2.3.1. USA

On March 20, 2025, US President Donald J. Trump signed an executive order to increase domestic production of mineral resources, including critical resources, in response to growing technological demand and national security threats arising from import dependence. The demand for critical raw materials has been described by the White House as the "gold rush of the 21st century" due to their importance for the development of new technologies[11]. [12]**"It is essential to our national security that** the **United States take immediate action to maximise domestic production of minerals**," said US President Donald J. Trump when signing the aforementioned executive order in March 2025, aimed at increasing domestic production of critical raw materials.

The US administration emphasizes that **the United States is 100% dependent on imports of at least 15 critical raw materials, and imports of non-fuel mineral raw materials account for more than half of domestic consumption**. The production capacity of the metal mining industry in the US has been declining for years, while China, Iran, and Russia control large deposits of critical raw materials for the US, with 70% of US imports of rare earth metals coming from China. According to the White House, this poses a threat to national security, as critical raw materials are essential for US military readiness, being key components of fighter jets, satellites, submarines, smart bombs, and missile guidance systems. A strong domestic industry for the production of key raw materials would ensure that US companies remain competitive in the global market without excessive reliance on foreign supply chains. The regulation covers raw materials such as uranium, copper, and gold, as well as any other elements, compounds, or materials specified by the chair *of the National Energy Dominance Council.* It requires a number of federal agencies and offices to take steps to accelerate projects related to the production of critical raw materials, give them priority over other activities on federal lands, provide financial and investment support, including through the use of *the Defense Production Act (*DPA) and the creation of a dedicated critical raw materials fund in cooperation with the Department of Defense[11].

2.3.2. NATO

The actions of the North Atlantic Alliance also deserve special attention. In December 2024, **NATO published a list of 12 critical raw materials for defense** (Fig.3) that are essential for the defense industry of allied countries[13]. The list includes aluminum, beryllium, cobalt, gallium, germanium, graphite, lithium, manganese, platinum, rare earth metals, titanium, and tungsten.

These raw materials play a key role in the production of advanced weapon systems such as combat aircraft, ships, missiles, and jet engines. For example, aluminum is used to make lightweight yet durable components in aircraft and rockets, improving their maneuverability and performance. Graphite, due to its high strength and thermal stability, is important in the production of tanks and ships, as well as in the construction of submarine hulls, where it contributes to reducing acoustic signatures and increasing stealth capabilities. Cobalt is essential in the manufacture of superalloys used in jet engines, missiles, and submarines, which must withstand extreme temperatures and stresses. **The security of supply of these raw materials is therefore essential for maintaining NATO's technological advantage and operational readiness.** Disruptions in their availability could adversely affect the production of critical equipment.

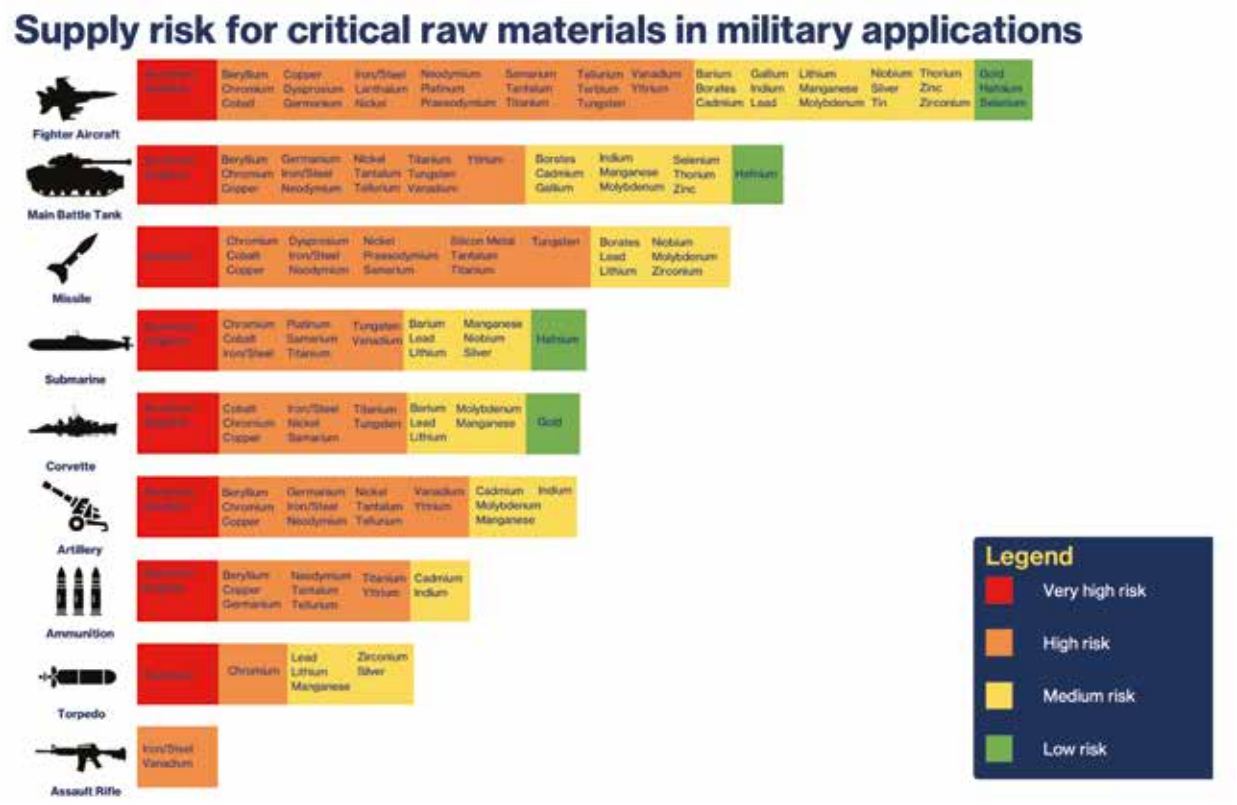


Fig. 3. Risk to the supply of critical raw materials according to NATO (Strategic raw materials for defense Mapping European industry needs)[13]

The identification of critical defense raw materials is NATO's first step towards building stronger and better protected supply chains, which is crucial for the Alliance's defense and security. The NATO initiative is part of an action plan approved by the Alliance's defense ministers in June 2024 to protect supply chains from disruptions that could affect NATO's deterrence and defense capabilities. The list was developed with the participation of *the* NATO *Industrial Advisory Group* (NIAG), using a defense-capability-focused methodology. The public release of the list underscores NATO's commitment to supporting member countries in securing the materials necessary for the development and delivery of the Alliance's defense capabilities.

2.3.3 European Union

The situation in the European Union is, of course, also a reflection of global trends, in which China continues to dominate as the largest supplier of a number of key raw materials. Other countries are also important, such as Russia and South Africa, which are joints of the largest global suppliers of platinum group metals, Australia, with over 50% of the lithium market, the US in the field of beryllium and helium, and Brazil in niobium (Fig. 4).

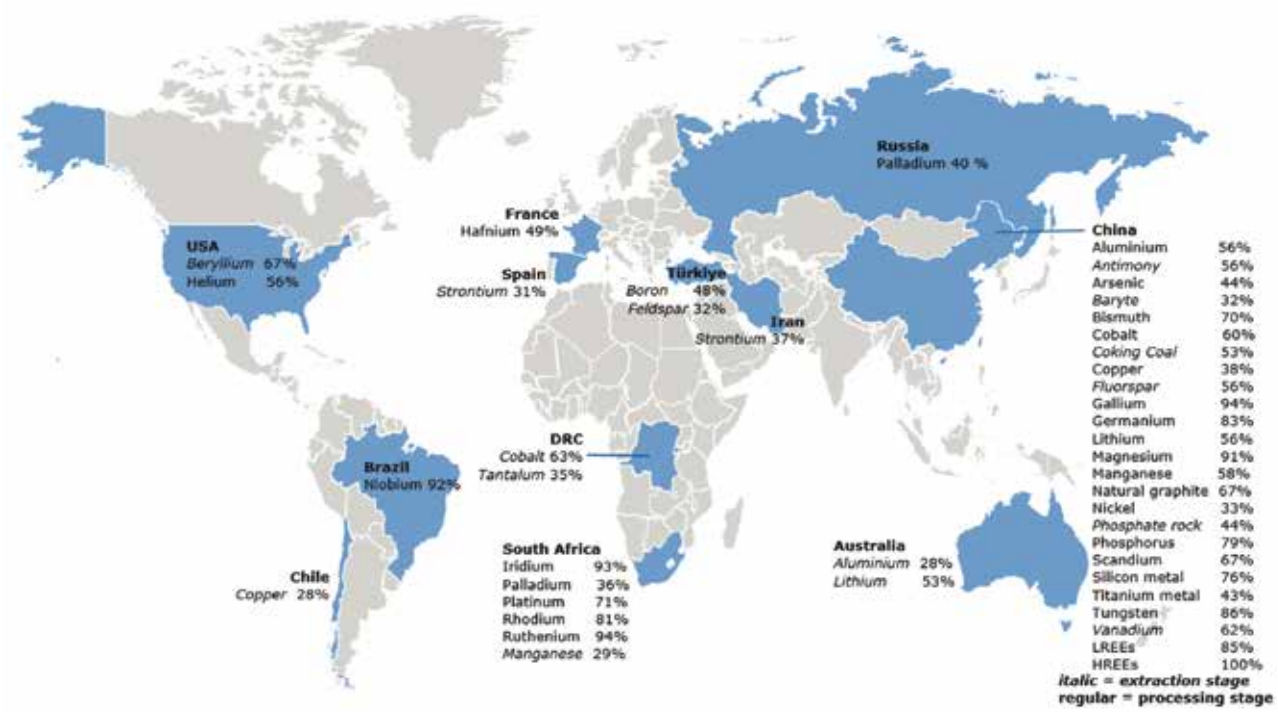


Fig. 4: Main global CRM providers according to the EU Study 2023[3]

When breaking down the set of critical raw materials, including rare earth elements and platinum group metals, into individual raw materials**,** it is clear that **China is the world's largest supplier of 34 out of 51 critical raw materials, while meeting 100% of global demand for 10 elements from the HREE group, i.e., heavy rare earth elements.** In the case of the European Union, it will be the largest supplier for 23 raw materials (Fig. 5).

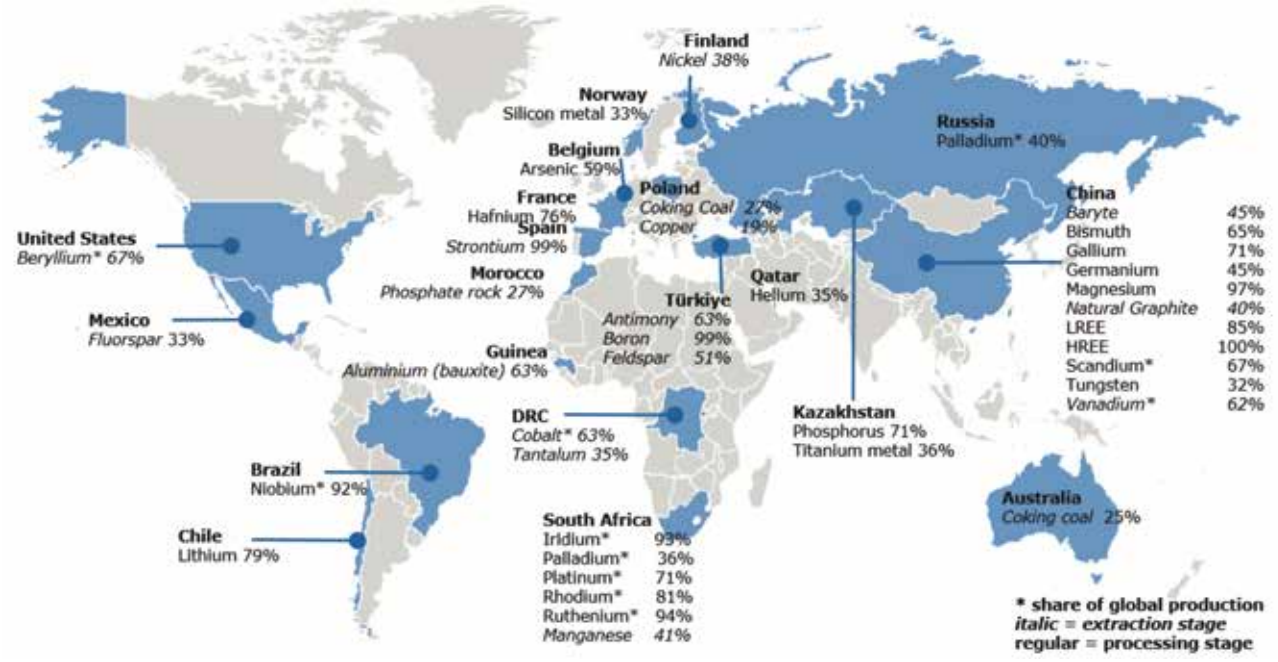


Fig. 5. Main suppliers of CRMs to the EU according to the 2023 study[3]

The importance of Poland, which accounts for 28% of the European Union's supply of coking coal and 19% of copper, is noteworthy. In the context of European policy objectives, the potential of several other European countries should also be recognized, such as Belgium with a 59% share in the area of arsenic, France, which meets 76% of hafnium demand, Spain, which provides 99% of strontium supplies, and Finland, where nickel production has increased and now meets 38% of EU consumption (Fig. 5).

As highlighted in the report "*Supply chain analysis and material demand forecast in strategic technologies and sectors in the EU – a foresight study*" published in 2023 by the Joint Research Centre[14] , **after more than a decade of implementing policies on the security of critical raw materials, the European Union is permanently and increasingly dependent on imports of many critical raw materials, especially from countries with increased geopolitical risk, such as China, Russia and the Democratic Republic of Congo.** The report also highlights the issue of ownership of mining facilities in third countries, as exemplified by the fact that **70% of cobalt mines in the Democratic Republic of Congo are owned by China and supply this raw material exclusively to Chinese refineries.** It is estimated that the concentration of supply in the hands of a limited number of countries, which often use export control instruments as a foreign policy tool, poses a fundamental threat to Europe's strategic autonomy. This situation is particularly important in light of the accelerating energy and digital transitions, which are radically increasing demand for selected groups of raw materials, such as lithium, cobalt, nickel, graphite, and rare earth metals. Achieving the EU's policy objectives will result in an unprecedented increase in demand for raw materials between now and 2030 and 2050 (see section 2.2.4). Bottlenecks have been identified in many areas in Europe, such as the lithium and graphite supply chains, for which there was no refining capacity in the EU for battery applications in 2021. The EU's position is stronger for refined cobalt (8% of global production capacity in 2020) and nickel for battery production (10% of global production capacity in 2021). In order to mitigate the associated risks, the supply chain analysis referred to above once again recommends that the EU take measures including:

1) diversifying raw material supplies and establishing long-term agreements and partnerships,
2) increasing EU production capacity,
3) increasing recycling and reuse to strengthen the circular economy, and
4) implementing substitutability, innovation, and alternative solutions.

3. The strategic importance of critical raw materials in the European Union

The dispute over Greenland, the conflict in Ukraine, the trade war, the currency war, and finally the loss of competitiveness of the European economy to China and the US. All these events are further stages in the ongoing global race for access to rare earth elements and metallic elements such as lithium, cobalt, nickel, copper, and others. There can be no digital or energy transformation without these raw materials. Without them, it would be impossible to produce solar panels, batteries, wind turbines, electric vehicles, and other key infrastructure components. Dependence on their supply is a feature of virtually every field of the innovative economy, from optical technologies and aviation to medicine and the arms industry. The scale of demand is easy to illustrate by pointing out that **it takes almost half a ton of strategic raw materials to produce a single F-35 fighter jet.** The most "raw material-intensive" industry is the production of electric cars, which accounts for 40-50% of total metal consumption. **The production of an average electric car requires over 200 kg of metals, more than six times more than a combustion engine car.** The most consumed metals are graphite (66 kg), copper (53 kg), nickel (40 kg), and magnesium (25 kg) (Fig. 6). The second area with a huge demand for metals is the production of power grids and photovoltaic panels (35-45%), while other technologies consume 5% of the total.[15]

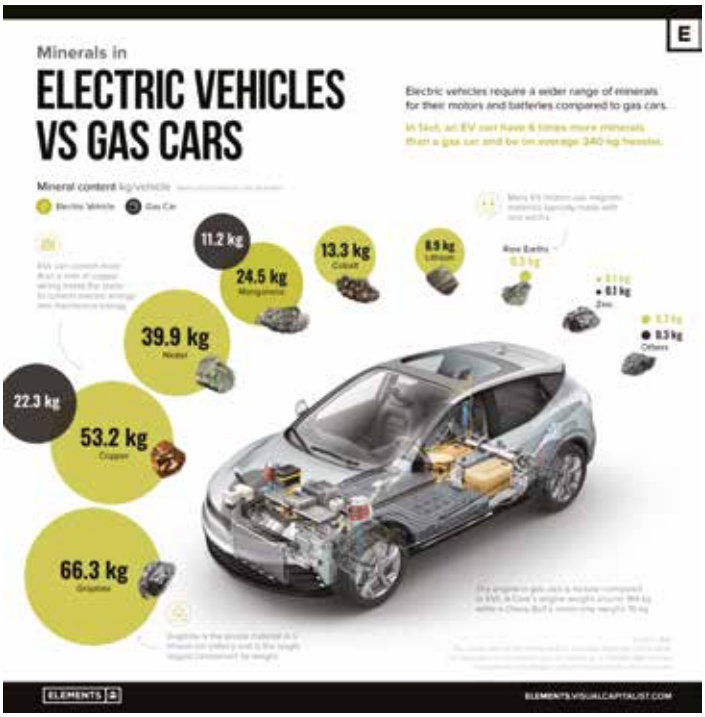


Fig. 6. The amount of critical raw materials needed to produce an electric car compared to a fuel-powered car [16]

To illustrate the seriousness of the situation and the need for access to critical raw materials and rare earth metals, a chart prepared by the International Energy Agency is appropriate. It shows how many kilograms of raw materials are needed to produce an electric car, a conventional car, and how much is needed to build an energy source for one megawatt of power—renewable, conventional, and nuclear (Fig. 7).

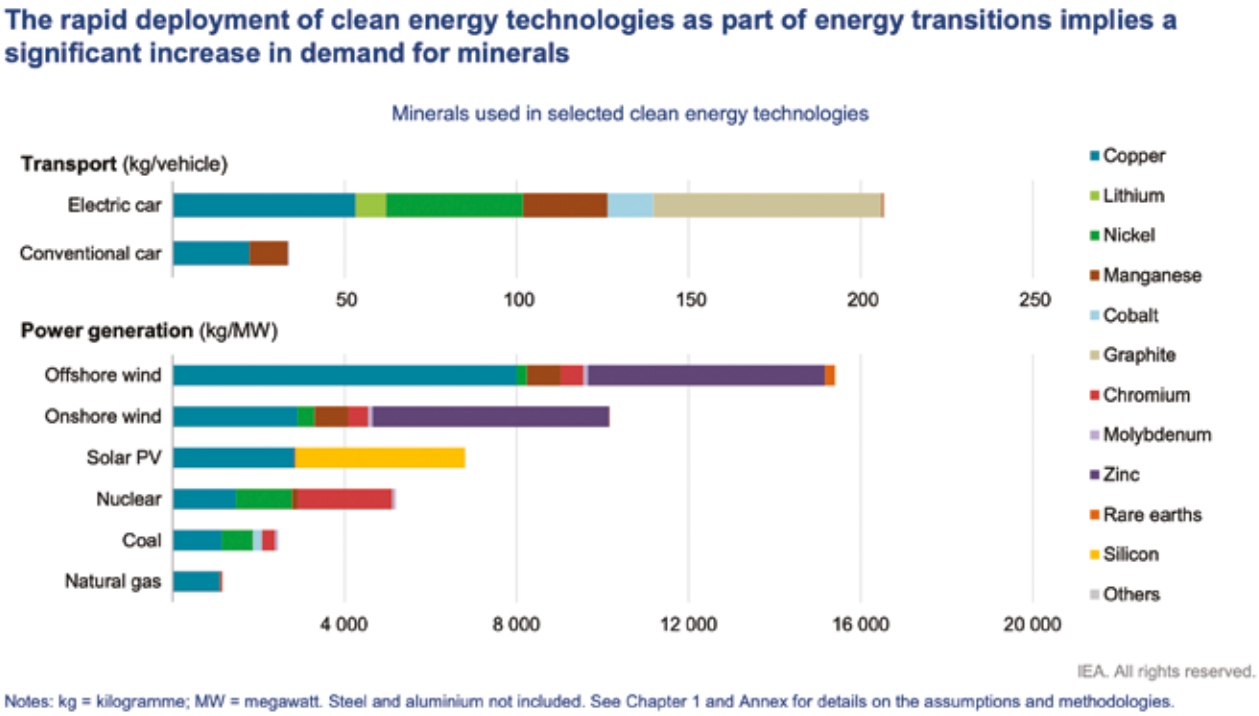


Fig. 7. Increase in demand for critical minerals with the rapid implementation of clean technologies[17]

3.1. Access to critical raw materials as a foundation for development and creating competitive advantage

In the case of critical raw materials necessary for the energy transition, the EU is almost entirely dependent on imports or sourcing outside its borders. Suppliers of these raw materials, both at the extraction and processing stages, are often highly concentrated in a small number of third countries. According to data from the International Energy Agency, for example, 97% of the EU's magnesium is sourced from China. Heavy rare earth elements (HREE), used in permanent magnets, are refined exclusively in China, 63% of the world's cobalt used in batteries is mined in the Democratic Republic of Congo, while 60% is also refined in China, and 74% of the graphite used as a material in battery anodes is also mined in China (Table 4). Chile is also an important country in the critical raw materials supply chain, supplying copper and lithium. Other important countries include Australia, Indonesia, and the DRC (see EU data in Chapter 2.3.3 and Chapter 4.3 of the Report).

Table 4. Global leaders in the extraction and processing of critical raw materials[18]

Extraction

	Cobalt	Copper	Graphite	Lithium	Nickel	REE
1	Congo 71%	Chile 23%	China 74%	Australia 43%	Indonesia 47%	China 68%
2	Russia 5%	Peru 12%	Mozambique 6%	Chile 29%	Philippines 12%	US 12%
3	Australia 2%	Congo 12%	Brazil 6%	China 17%	Russia 5%	Australia 5%

Processing

	Cobalt	Copper	Graphite	Lithium	Nickel	REE
1	China 75%	China 41%	China 100%	China 63%	Indonesia 47%	China 89%
2	Finland 10%	Chile 12%	-	Chile 33%	Philippines 12%	Malaysia 10%
3	Canada 3%	Japan 5%	-	Argentina 4%	Russia 5%	Estonia 1%

Overview of top extractors and producers of selected minerals by country
Source: Statista, EBN, IEA

This situation exposes the EU to significant supply risks. There are precedent cases of countries using their strong position as suppliers of critical raw materials against buyer countries, for example by imposing export restrictions. With the global transition to renewable energy and the digital transformation of our economies and societies in the coming decades, demand for some of these critical raw materials is expected to grow rapidly. **Despite significant differences in the levels of demand forecast by analysts from different companies, institutions, and teams, all sources predict multiple increases in demand for key raw materials.** For example, global demand for lithium used in the production of batteries for electromobility and energy storage could increase by 2034 compared to 2023 by as much as 6.5 times[19] and by 2050 by as much

as 89 times. According to analysts at the International Energy Agency, demand in the EU for rare earth metals used to make permanent magnets used in wind turbines and electric vehicles is also expected to increase six- or sevenfold by 2050. According to forecasts, EU demand for gallium, used in the production of semiconductors, will increase 17-fold by 2050. Other forecasts are discussed in sections 2.2.4 and 2.3.3 of the Report.

The projected increase in demand can be mitigated to some extent by substituting materials and increasing their efficiency and circularity, but these measures are not expected to reverse the trend quickly. There is a risk that current and planned capacities will not meet more than 50% of the projected demand for cobalt, and demand for rare earth metals is expected to grow faster than the increase in their extraction capacity in the future. Many countries have therefore adopted policies to actively secure their supplies of critical raw materials, which has led to increased competition for resources.

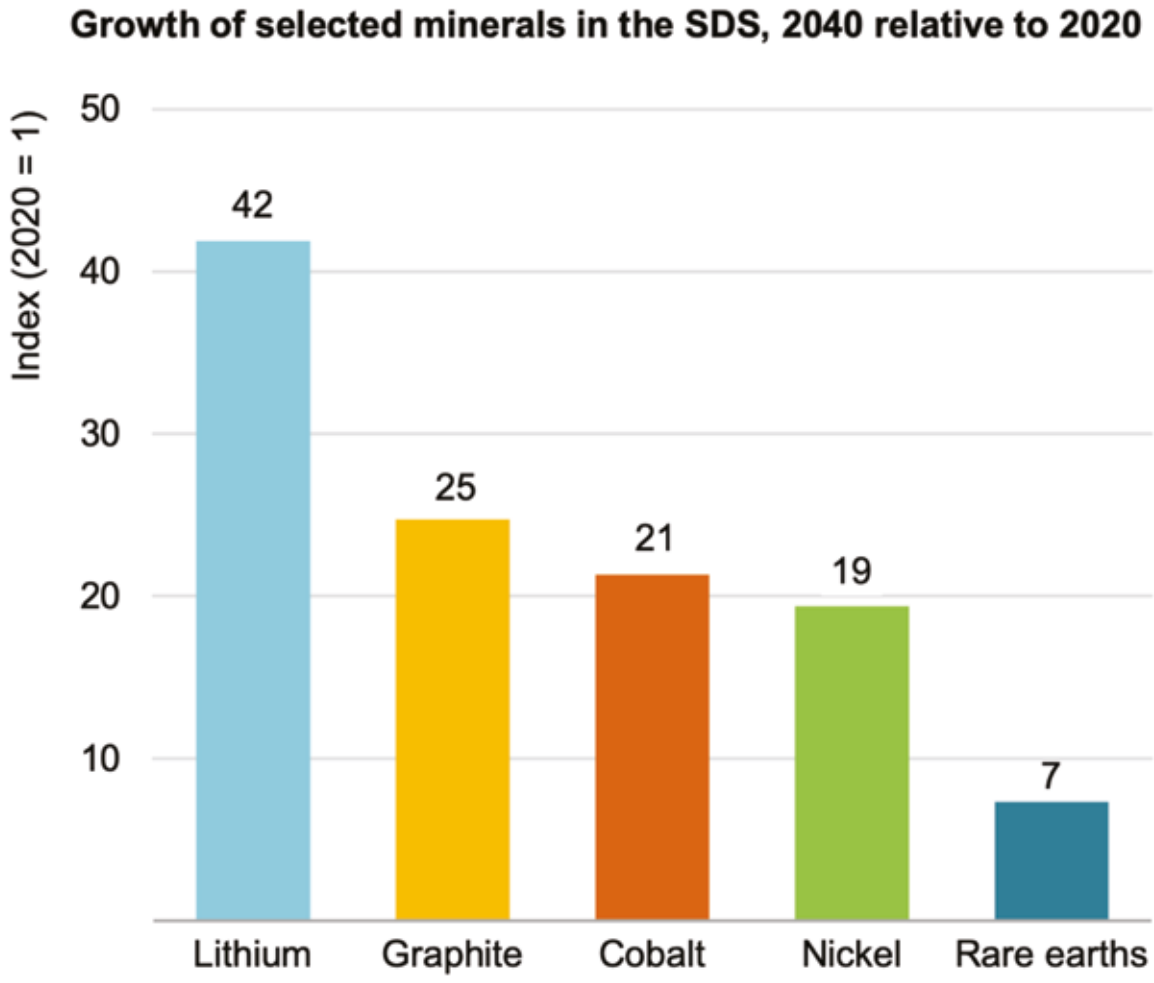


Fig. 8. Chart showing five critical raw materials and the multiple of their projected demand growth in EU industry in 2040 compared to 2020.[20]

Disruptions to the supply of essential goods during the COVID-19 crisis and the energy crisis triggered by Russia's war in Ukraine have highlighted the EU's structural dependencies on supplies and their potentially damaging effects in times of crisis.[21] The critical importance of raw materials for the energy and digital transitions and for defense and space applications means that disruptions in their supply would have significant negative effects on EU industry. This would jeopardize the functioning of the single market and further damage the EU's already low competitiveness, while also threatening existing

jobs, job creation, and working conditions and wages. Furthermore, without security of supply of critical raw materials, the EU will not be able to achieve its energy and digital transformation goals.

3.2. European Union measures to support industry access to critical raw materials and the situation in Poland

The 2008 Raw Materials Initiative and the 2020 Action Plan on Critical Raw Materials provided a framework for initiatives to analyze the criticality of raw materials, international diversification, research and innovation, and the development of production capacities for critical raw materials in the EU (an issue described in Chapter 2).

Currently, the most important document of the European Commission is *the* already described *Critical Raw Materials Act* (CRMA), which, as already mentioned, identifies 17 strategic raw materials and 34 critical raw materials, of which the consulting company Arup has identified six that are crucial for the energy transition. These are: cobalt, copper, graphite, lithium, nickel, and rare earth metals. They are essential for the creation of products enabling the functioning of wind and solar energy and zero-emission transport[22] . In this context, particularly from the Polish perspective, it is worth noting the role and importance of copper (Fig. 9).



Fig. 9. Use of copper in wind turbines[23]

Poland has deposits of key raw materials, but we are already facing a multifaceted crisis in terms of their availability. One of the fundamental problems in this area is the increasingly visible **shortage of personnel**. The unfair and consistently negative portrayal of mining and the raw materials sector in public debate has led to a clear downward trend in the number of specialists trained in mining and geology for many years. Despite attractive salaries, there is a growing shortage of highly qualified specialists in the industry. This trend can and must be reversed, especially considering that Poland not only needs professionals, but, unlike many countries,

can also boast excellent university departments and a rich scientific base . **KGHM Polska Miedź S.A and Jastrzębska Spółka Węglowa S.A.** KGHM is the market leader in the extraction of strategic raw materials, including copper, which is particularly important for the energy transition. It has access to deposits on three continents and operates copper smelters in Poland that meet the highest European standards. JSW S.A., on the other hand, is one of the world's leading producers of coking coal, which is essential in the steel production process.

In addition to deposits, increasing the volume of raw materials recovered through **recycling** is rightly considered an important element of raw materials policy. Here, too, Polish companies have and are expanding their expertise**.** When discussing important raw materials, steel scrap cannot be overlooked. It has a different nature and significance, including in terms of legal regulations, but is of fundamental importance for the entire steel industry, especially for the production of steel with different properties.

3.3. What measures should be taken in the European Union to improve the security of supply of critical raw materials in key areas of the economy

In the short term, the only solution is **to diversify supply sources**, which is obviously not an easy task. Countries with raw material deposits no longer want to be cheap suppliers to which rich countries outsource environmentally destructive extraction and processing. Chile, in the process of modernizing its FTA (*Free Trade Agreement)* with the EU, has raised the need to implement its own policies to support the development of a domestic battery production chain instead of merely acting as a lithium exporter. What is more, there are calls for the creation of a "lithium OPEC" to control the supply and prices of this raw material. In the face of the erosion of the global free trade system, commitments made in trade agreements, not to mention the WTO system, may also become less and less credible. It is also worth remembering that deposits and processing plants in third countries may also be (and often are) owned by strategic competitors of the EU. China owns 70% of the mining industry in the Democratic Republic of Congo, which is the main supplier of cobalt, and is aggressively investing in access to deposits in other countries.

It is clear that **the EU will not be able to meet its demand from its own natural resources** due to a lack of sufficient deposits. In addition to the lengthy administrative procedures involved in starting up mining, environmental issues are controversial in Europe.

Raw material recovery and innovations that reduce dependence in the long term are likely to increase the EU's raw material independence. However, these are not solutions that are available in the short term. Above all, **financial resources are needed** to implement all these measures. Investments in extraction, processing, recovery, or research into new technologies take many years and are capital-intensive. By introducing a legally binding commitment to achieve climate neutrality by 2050 and legislation under the "Fit for 55" package, the EU must encourage investors to invest in projects with attractive and secure returns. A combination of private and public funds in the form of subsidies, guarantees and cheap financing from, for example, the European Investment Bank will be necessary to finance the investments in question.

It is worth remembering that other players, primarily the US and China, but also Japan and South Korea, are developing their own support programs to secure raw material supplies for the climate transition. Combined with growing protectionism and geopolitical rivalry, this means that competition for critical raw materials may become one of the main areas of international rivalry in the coming years.

The United Nations has also addressed the challenges of critical raw materials in its report *"Resourcing the energy transition: principles to guide critical energy transition minerals towards equity and* justice"[24] , which is dedicated to the role of critical raw materials in the energy transition. The UN points to the challenges associated with the growing role of critical raw materials and ensuring good practices for sustainable development. Critical raw materials such as copper, lithium, nickel and cobalt are essential components of many rapidly developing clean energy technologies and, therefore, of the energy transition, and "a world powered by renewable energy sources is a world hungry for critical minerals." For developing countries, critical minerals represent a strategic opportunity to create jobs, diversify economies, and rapidly increase revenues. But only if they are properly managed. The race to zero emissions must not trample on the poor.

The renewable energy revolution is happening, but „we must steer it in the right direction" - comments UN Secretary-General António Guterres in the report[24].

The first course of action must be to **structurally reduce supply risks**, which must mean creating a common framework to ensure the resilience and preparedness of economic operators for emerging challenges and reducing the exposure of industry to supply disruptions. In addition, the EU's potential to increase its extraction, processing and recycling capacities remains untapped. **In all Member States, knowledge of deposits often dates back to a time when critical raw materials were not as sought-after resources as they are today.** This also needs to change.

4. The global battle for raw materials – Europe's position

As rightly assessed by the European Union and analysts from all institutions, the global economy and the technological progress that drives it, are increasingly dependent on specific raw materials, defined as strategic and critical. They are used to produce both socially desirable consumer goods and products of exceptional importance for military and energy security. They are essential for the development of modern technologies and are therefore crucial in economic, military, and geopolitical competition in the modern world.

With the growing demand for critical raw materials, competition between countries for access to them has intensified, while at the same time there is a growing awareness of the need to guarantee their supply—under stable conditions in terms of volume, continuity, and price predictability. Securing supplies has come to be understood as both internal (domestic, community) extraction and recycling, and as securing purchases from "friendly" or at least predictable countries. Guaranteeing the supply of critical raw materials is not only about securing their extraction, but also their processing (in terms of available infrastructure and technology) and the safety of their transport to production centers.

The European Union has entered the race for critical raw materials, starting with identifying the problem and proposing solutions at the legislative level (*Study on the Critical Raw Materials for the EU.* 2023, CRMA Regulation, Draghi report, assumptions: *The Clean Industrial Deal)*, followed by concrete actions (internal and external investment project lists, proposed tools for the actions being prepared).

Recognizing the problem and designing measures (often for over a decade) does not fundamentally change the situation. It is necessary to significantly accelerate and implement further tools supporting the achievement of the outlined objectives. As indicated in this Report**, not only China, but also countries with which the European Union maintains allied relations (such as the US, Japan, South Korea, Canada, and Australia) seem to be ahead of the European Union in implementing appropriate solutions.** They are not only seeking to secure supplies through standard contractual and trade relations, but are also focusing their efforts on building geopolitical agreements between countries and are increasingly using tools such as **foreign investments** carried out either by entities controlled by the investing state or by private corporations using financing provided by the investing state.

4.1. Draghi Report – the role of critical raw materials in the new model of European Union competitiveness

The Draghi report, published on September 9, 2024 [25], on European competitiveness and the future of the European Union, is also important from the perspective of assessing the situation of the EU and its member states in terms of raw material security and aspects of economic competitiveness related to the availability of raw materials.

According to the report, Europe is currently facing three major transformations, the first of which is **the need to accelerate innovation** and find new drivers of growth. Second, **Europe must reduce high energy prices** while continuing to decarbonize and transition to a circular economy. Third, Europe must **respond to a world of less stable geopolitics,** where dependencies are becoming vulnerable and it can no longer rely on others for its security. Meanwhile,

decades of globalization have led to a high level of interdependence between major economies, which has raised the costs of changing this situation quickly, with these interdependencies not being evenly beneficial to the interdependent countries. For example, while the EU is largely dependent on China for critical raw materials, China is dependent on the EU for absorbing its excess production capacity. At the same time, this situation gives the Chinese economy a growing advantage, which China is actively exploiting. Nevertheless, this global interdependence is changing: all major economies are actively seeking to reduce their dependence and increase their own potential. China is striving for technological autonomy and vertical integration of the supply chain, from raw material extraction to processing and from manufacturing to export.

To respond to these changes, Draghi's report proposes a new industrial strategy for Europe. Trade policy within the European industrial strategy should be based on a careful, case-by-case analysis of possible actions, rather than on a "one size fits all" approach to trade. In some cases, the EU should use its trade policy arsenal to keep barriers low, in others to level the playing field, and in others still to secure critical supply chains. When it comes to increasing security and reducing dependencies, **the EU must ensure access to critical resources and protect key value chains. This may require concluding preferential trade agreements with key partners and securing key supplies, including through take-or-pay agreements and direct investment in production facilities abroad.**

Access to critical raw materials is crucial for the clean technology and automotive industries, but the report notes that their supply to Europe is highly concentrated. The global market for critical raw materials for the energy transition has doubled in the last five years, reaching €300 billion in 2022. The acceleration in the deployment of clean energy technologies is causing unprecedented growth in demand (Fig. 10). Between 2017 and 2022, global demand for lithium tripled, while demand for cobalt increased by 70% and nickel by 40%. According to forecasts by the International Energy Agency, by 2040, demand for raw materials used in "clean" energy technologies will increase by 4 to 6 times.

According to the authors of the report, the concentration of critical raw material supplies among a few suppliers poses **two main threats to Europe**. The first is **price volatility**, which makes investment decisions difficult. For example, although this is an extreme case, the price of lithium rose twelvefold in two years, then fell again by more than 80%, making it difficult to open mines in the EU. While oil reserves and gas storage play an important role in mitigating energy market shocks, there are no requirements to maintain reserves of critical raw materials. A second risk is that **critical raw materials may be used as a geopolitical weapon,** as a large part of extraction and processing is concentrated in countries with which the EU has no strategic ties. For example, China is the largest single processor of nickel, copper, lithium, and cobalt, accounting for 35–70% of processing activities, and it exploits its dominant market position (Figs. 10, 11, 12). Between 2009 and 2020, export restrictions from this country increased ninefold. To date, little progress has been made in the EU in terms of diversification.

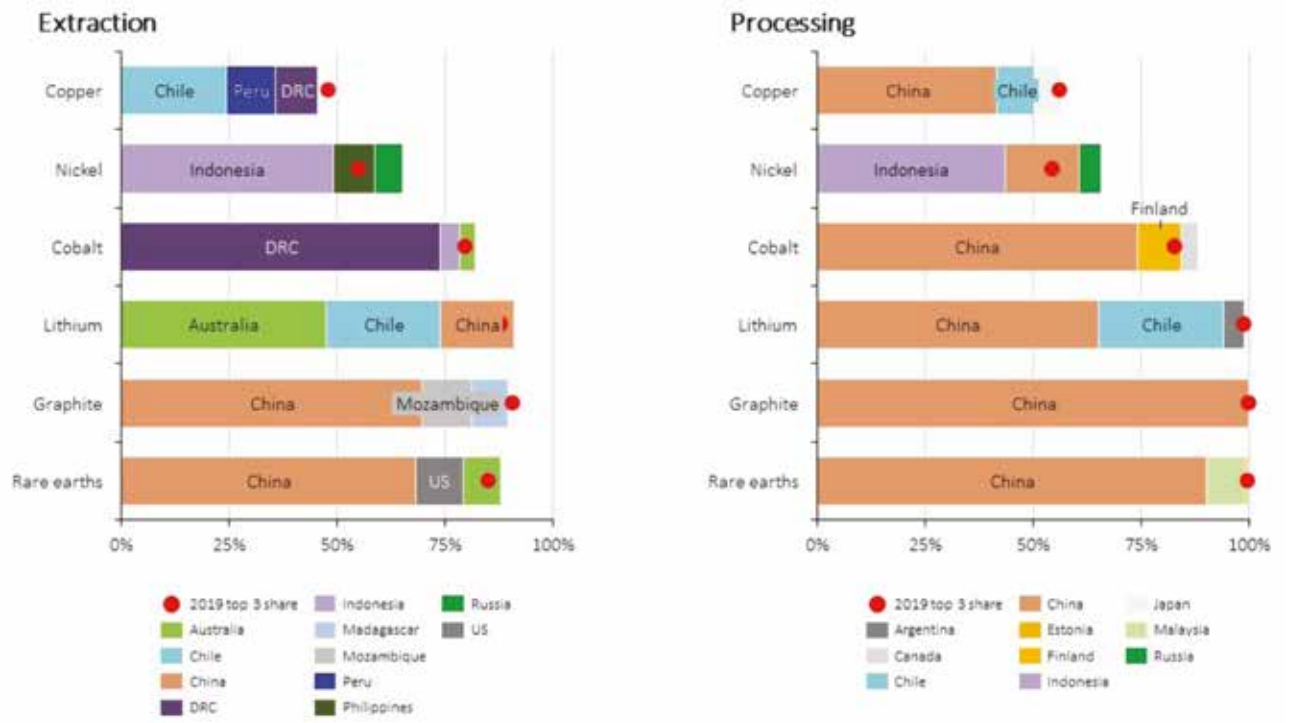


Fig. 10. Example of the increase in demand for selected critical raw materials presented in the Draghi report. (Based on: IEA, S&P Global, USGS, Mineral Commodity Summaries and Wood Mackenzie, 2024) [25]

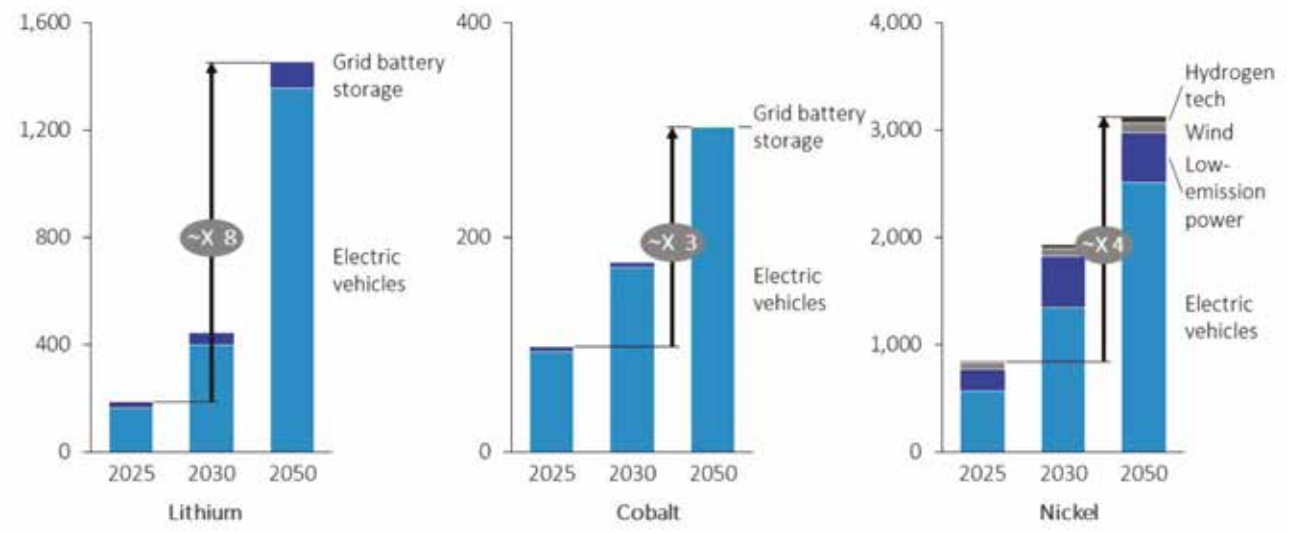


Fig. 11. Demand for selected critical and strategic minerals by use. (Based on: IEA, 2024)[25]

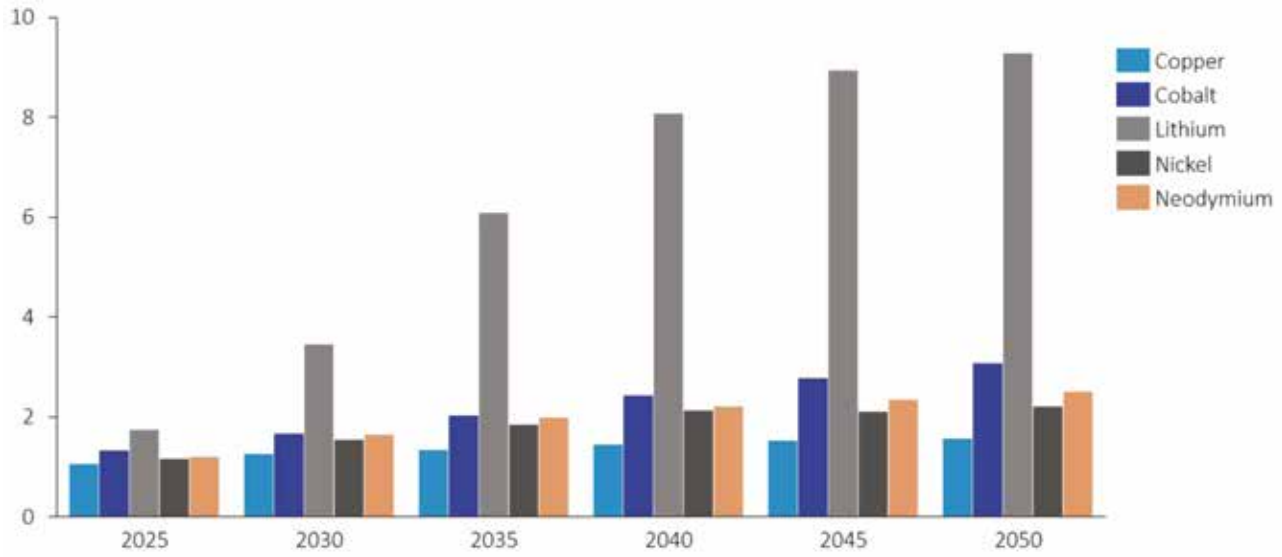


Fig. 12. Growth in relative demand for selected critical and strategic minerals. (European Commission, based on IEA, 2023)[25]

As a result, critical raw material prices are subject to significant risks of persistently high prices and above-average volatility. In addition, the price levels of these raw materials are crucial for the feasibility and scale of development of certain modern technologies.

Mining companies in the EU not only have to cope with high volatility in raw material prices on the market (Fig. 13), which hinders investment, but are also exposed to higher energy prices than in other global economies.

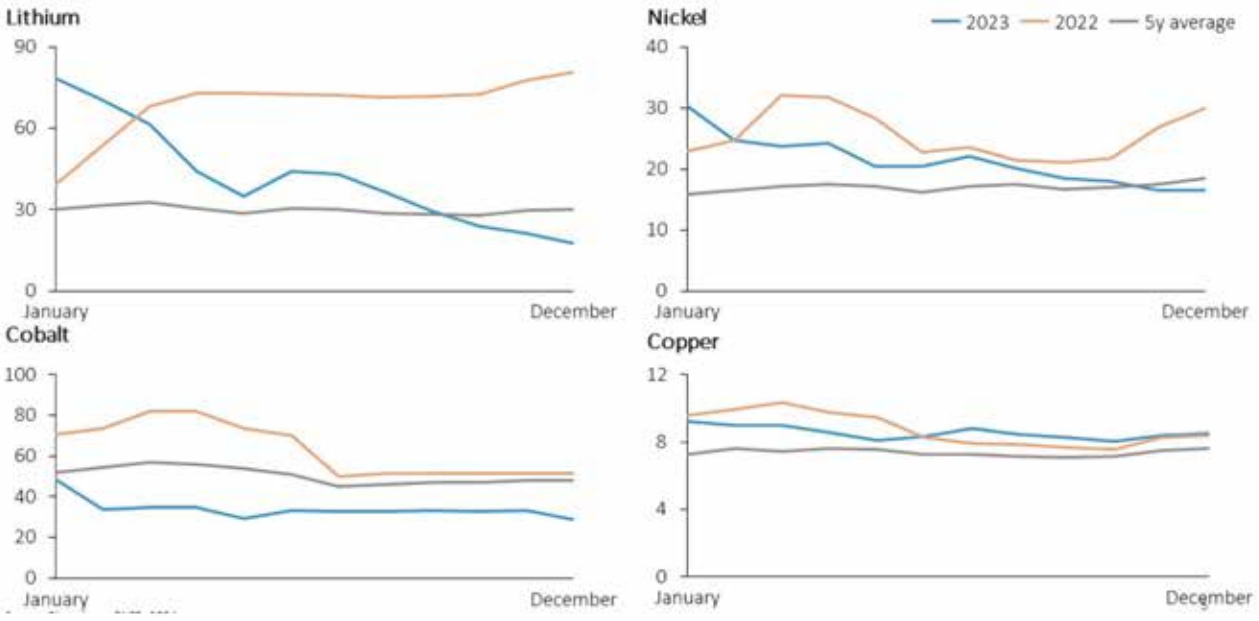


Fig. 13. Price changes of selected elements (metals), in thousands of USD/T. (Based on: Bloomberg, BNEF, 2024)[25]

According to Draghi's report, the EU is lagging behind its competitors. **There is no comprehensive strategy covering all stages of the supply chain (from exploration to recycling).** Furthermore, there is no EU-wide comprehensive approach to critical raw materials that would cover all internal and external instruments at EU level. The EU plans to increase its demand, e.g., for battery cells, without securing supplies that will come from outside, mainly from China.

Unlike other competitors such as China, the extraction and trade of raw materials in the EU is largely left to private actors and the market. While China promotes vertical integration for better control and management of the supply chain, and the US provides adequate financial, administrative, and diplomatic support, the EU does not provide this level of support to its companies, despite being aware of global geopolitical tensions.

Several sources of funding (both at European and national level) are available in the EU for the development of projects based on critical raw materials, from innovation (e.g., the Horizon Europe program) to production (e.g., through the European Investment Bank). Nevertheless, **according to the authors of the report, the EU is feeling the effects of a lack of dedicated financial support for mining investments.** Private companies preparing mining projects, even when accumulating equity capital for these investments, are unable to adequately mitigate the numerous risks associated with such projects and need public support.

The EU has untapped potential in terms of the use of domestic raw material resources (Fig. 14) and recycling. Accelerating the construction of mines could enable the EU to meet its entire demand for certain critical raw materials. This, in turn, should be complemented by increased recycling and the sourcing of raw materials from abroad from diversified sources.

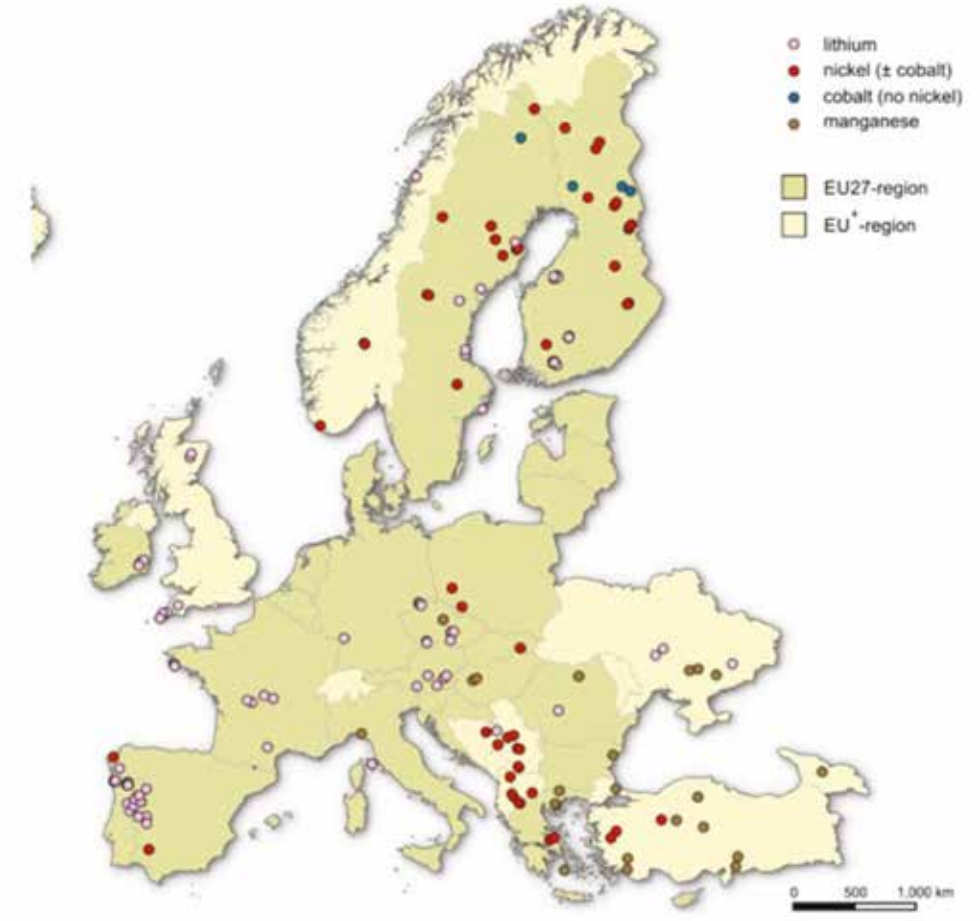


Fig. 14. Distribution of selected element deposits in the EU and neighbouring countries. (Based on: Tercienco Research Report, 2024)[25]

Undoubtedly, the CRMA is a first step in the right direction. However, whether it will prove to be a landmark document depends on its swift and effective implementation. **The Draghi report proposes priority actions that go beyond the CRMA**:

1) **Developing a comprehensive EU-level strategy based on the CRMA, from extraction to recycling.** While the CRMA identifies a number of individual national and international measures to ensure sustainable and secure supplies of critical raw materials, the EU should develop a more comprehensive and coordinated strategy covering the entire value chain.
2) **Establishment of a special EU platform for critical raw materials**. Building on the experience of AggregateEU and the Euratom Supply Agency, and taking into account the successful Japanese and Korean models, the EU could create a purchasing platform that would pool the scattered resources of Member States in order to leverage the EU's collective market power. The platform would support the implementation of the defined EU strategy through joint procurement of critical raw materials (similar to the model used in South Korea and Japan) and enable the management of future strategic stocks of critical raw materials at EU level.
3) **Developing financial solutions to support the creation of a critical raw materials value chain (extraction, processing, recycling).** Extraction activities are currently excluded from EU financial support, while production can only be supported under certain conditions (to a large extent if it concerns clean technologies such as solar or wind energy). While most investments should be made with private capital, the risks associated with investing in politically unstable third countries, for example, may be too high for individual investors without support from the EU and Member States.
   Furthermore, the capital requirements necessary to secure supplies are on such a scale that they could challenge the liquidity needs of every industry in the EU. Based on the EU platform, it would be possible to develop new financial solutions, and the platform could also act as an intermediary in aggregating available financial potential.
4) **Further development of diplomacy on critical raw materials to ensure supply and diversification.** According to the authors of the Draghi report, in order to reduce its vulnerability to risks, the EU must develop a genuine "foreign economic policy" based on securing critical raw materials.
   It is recommended that the EU further develop its "resource diplomacy" in the field of critical raw materials. Proposals include modernizing the Global Gateway portal — which promotes investment in third countries — to focus on the EU's strategic needs, and develop joint strategies with other buyers from strategically linked countries, for example through the G7+ Critical Raw Materials Club (including Japan, South Korea, and Australia).
5) **Further develop joint strategies with other global buyers in the G7/OECD** (e.g. with Japan).
6) **Further promote the untapped potential of domestic resources in the EU in conjunction with better regulation and integration with industry at different levels of the value chain**. Domestic supplies of critical raw materials could meet the EU's demand for certain materials by 2030, while significantly reducing dependence on others. Europe must have the workforce and know-how to extract and process critical raw materials available in Member States and to develop technologies for their extraction and processing.
   The EU must exploit the potential of domestic resources through extraction, recycling, and innovation in alternative solutions. Unlike fossil fuels, the EU has deposits of certain critical raw materials, such as lithium, in Portugal. Accelerating the opening of domestic mines could enable the EU to meet its entire demand for certain critical raw materials. The EU should also thoroughly explore the potential of environmentally sustainable deep-sea mining: it is estimated that the seabed contains many times the known land reserves of, for example, copper, titanium, manganese, cobalt, nickel, and rare earth elements.
   The CRMA Regulation already calls on Member States to implement shorter timeframes for issuing permits for "strategic projects" (see section 2.2.2), which currently take three to five times longer. The Draghi report recommends additional measures to speed up the pace of permit issuance, such as increasing administrative capacity by introducing a requirement to allocate pre-defined human resources to strategic projects.

7) Enhancing European excellence in **research and innovation in alternative materials or processes to replace critical raw materials in various applications**. This could significantly reduce dependencies by involving different components or metals that are more readily available or cheaper.
8) Closed loop: **creating a genuine single market for waste and recycling** in Europe. By 2050, the EU could potentially meet more than half of its demand for metals for clean technologies through local recycling.
9) **Accelerating the creation of a sustainable market for critical raw materials in the EU**, including simplifying and harmonizing sustainability legislation.
10) **Establish strategic stocks of selected critical raw materials in the EU**. Unlike other economies, the EU currently has no strategic stocks of critical raw materials. There is no mechanism to counteract both short- and long-term disruptions and price volatility in the supply of critical raw materials, for example due to geopolitical tensions or market shocks. To ensure security of supply, Japan and Korea operate stockpiles on a rotation basis, whereby raw materials are acquired, stored for a specified period, and then transferred to industry, thereby avoiding the technical challenges associated with long-term storage.
11) **Increasing market transparency with regard to wholesale contracts for critical raw materials in the EU**.

Unlike many other commodities, critical raw materials are not widely traded on exchanges. Raw materials such as cobalt, lithium, and rare earth elements are mainly sold on the basis of negotiated bilateral agreements between producers and consumers. As these transactions are usually not transparent, the prices of critical raw materials are set in an inefficient and highly volatile manner.

4.2. The Clean Industrial Deal – the role of critical raw materials in the new European Union competitiveness model

The Clean Industrial Deal (CID), announced by the European Union on February 26, 2025[26] , is a plan to strengthen European competitiveness and, at the same time, in the area of critical raw materials, the next stage in refining the measures outlined in the CRMA Regulation.

According to its authors**, European industry, which is struggling with high energy costs and fierce international competition, needs immediate support.**

The CID is intended to identify specific measures that will make decarbonization a driver for European industrial growth. These measures include reducing energy prices, creating good jobs, and establishing the right conditions for companies to grow.

The CID will also focus on **energy-intensive industries, including those related to metal ore extraction and production.** According to the authors of the CID, this industry **needs support** on its path to decarbonization and clean energy so that it can cope with high energy costs and unfair international competition.

An important element of the CID is to be **the circular economy**, which will reduce waste and extend the life cycle of products, among other things by promoting recycling.

The CID points out that **maximizing limited raw material resources and reducing dependence on raw material suppliers from third countries is crucial** for European competitiveness and market resilience.

As part of ***the Affordable Energy Action Plan***, implemented to reduce energy costs and aimed at the transition to a low-carbon economy, there will be, among other things, an acceleration of electrification and a reduction in dependence on imported fossil fuels. Another important element is **the promotion of "made in Europe" products/services** in public and private procurement.

The tools for raising over EUR 100 billion to finance the CID objectives are to be **the implementation by the European Commission of a new state aid framework, the strengthening of the innovation fund, the design of an industrial decarbonization bank, the stimulation of research and innovation under *Horizon Europe***, and **the strengthening of the *InvestEU* instrument** so as to increase the value of financial guarantees supporting investment in the EU. Rapid implementation of the CRMA measures will be crucial to securing access to critical raw materials. To this end, the European Commission will:

– establish a mechanism enabling European companies to take joint action to secure demand for critical raw materials,
– create an EU center for joint procurement of critical raw materials on behalf of interested companies in the fourth quarter of 2026 to obtain better prices and purchasing conditions for these raw materials (in line with the recommendations of the Draghi report),
– adopt, also in the fourth quarter of 2026, legislation on the circular economy.

The aim would be to achieve a 24% recovery rate by 2030. In addition, **starting in the first quarter of 2025, lists of Strategic Projects are to be created**, among other things, which should ensure diversification of supply throughout the value chain and facilitate access to public and private funding for these projects.

In line with the CID objectives, European industry is to benefit from decarbonization, and one of the key elements of decarbonization is electrification powered by green energy, the transition from fossil fuels to clean energy systems requiring more minerals. According to the CID, demand for rare earth metals, base metals, and battery components is expected to grow exponentially in the coming years. The EU's green transition will require the expansion of local production of batteries, solar panels, permanent magnets, and other clean technologies. To meet demand, broad access to a wide range of raw materials will be needed. Critical raw materials, on the other hand, are raw materials of high economic importance for all key global economies, whose supply is likely to be disrupted due to the concentration of sources and the lack of good, affordable substitutes. Critical raw materials are also important for the EU in areas such as:

– industrial value chains: non-energy raw materials are linked to all sectors at all stages of the supply chain,
– strategic technologies, e.g. in the space and defense industries: technological progress and improvements in quality of life depend on an increasing number of diverse raw materials,
– climate, energy and the environment: clean technology requires raw materials – they are indispensable in solar panels, wind turbines, electric cars and energy-efficient lighting.

The Draghi report, based on European Commission data from 2023, provides information on the European Union's dependence on imports of critical raw materials, which has already been presented in this report in section 2.3.3. Based on EC data, it highlights that China supplies the EU with:

– in terms of light rare earth elements: 85% of cerium, 85% of lanthanum, 85% of neodymium, 85% of praseodymium, and 85% of samarium,
– heavy rare earth elements: 100% of dysprosium, 100% of erbium, 100% of europium, 100% of gadolinium, 100% of holmium, 100% of lutetium, 100% of terbium, 100% of thulium and 100% of yttrium,
– in addition: 45% barium, 65% bismuth, 71% gallium, 45% germanium, 97% magnesium, 40% natural graphite, 67% scandium, 32% tungsten and 62% vanadium.

Kazakhstan supplies 65% of phosphorus, 36% of metallic titanium, Qatar 35% of helium and Turkey 63% of antimony, 99% of boron and 51% of feldspar. In Africa, Morocco accounts for 27% of phosphates, Guinea 63% of aluminum, the Democratic Republic of Congo 35% of tantalum, and South Africa 41% of manganese and 71% of platinum. Australia provides 25% of coking coal, and Russia 29% of nickel. In the Americas, Brazil accounts for 92% of niobium, Chile 79% of lithium, Mexico 33% of fluorite, and the US 60% of beryllium. A comprehensive discussion of the European Union's dependence on external suppliers of critical raw materials is presented in *the* "*Study on the Critical Raw Materials for the EU. 2023*."

In this context, it is also worth noting that **China is** simultaneously **restricting EU and US companies' access to critical raw materials**. According to a Reuters report dated June 4, 2025,[27] global car manufacturers are warning of the consequences of Chinese restrictions on rare earth exports. The restrictions on rare earth exports introduced at the beginning of April 2025 were China's response to the tariffs imposed by President Donald Trump, but they affected more than just the US. The suspension of supplies covered raw materials and their derivatives, such as permanent magnets, which are essential for the production of cars, weapons, semiconductors, electronics, and a range of consumer goods. However,

this is only the latest in a series of measures taken by China, which has previously used restrictions on rare earth exports as an integral part of its strategy to maintain its dominant position in the extraction and processing of critical raw materials and to use them as powerful bargaining tools. This is described, among others, *by the Center for Strategic & International Studies* in its article "*The Consequences of China's New Rare Earths Export Restrictions*" dated April 14, 2025.[28] – in **December 2023, China introduced a ban on rare earth mining and separation technologies.** This had a significant impact on the development of rare earth supply chain capabilities outside China due to two main factors. First, China has specialized technical expertise in this field that other countries do not have (see also section 4.4). For example, it has an absolute advantage in solvent extraction techniques for rare earth metals, an area where Western companies have faced challenges in both implementing advanced technological operations and addressing environmental concerns. Second, while many separation, processing, and production facilities are currently under construction, it will take several years to complete their construction and bring them fully online. As a result, China currently maintains a monopoly on refined heavy rare earth metals. Foreign companies wishing to import critical raw materials from China have to contend with an opaque and highly complex permit application process.

China is also highly active in the field of critical raw materials on other continents, particularly in Africa and South America. The Stimson Institute, in its article "*Competing for Africa's Resources: How the US and China Invest in Critical Miner*als" dated February 28, 2025,[29] , indicates that **as early as 2023, China's total economic involvement in Africa was estimated at $21.7 billion under the Belt and Road Initiative. Estimates suggest that China has allocated USD 8-10 billion of these funds to projects in Africa related to critical raw materials and has the largest portfolio of such projects on the African continent.** Examples of this expansion include the acquisition of the Lubambe copper mine in Zambia in 2024, the Bougouni lithium mine in Mali in 2023, the Goulamina lithium project in Mali in 2023, the Khoemacau copper mine in Botswana in 2023, the Tenke Fungurume cobalt mine in the Democratic Republic of Congo in 2023, the Goromonzi lithium processing plant in Zimbabwe in 2023, and the conclusion of a memorandum of understanding between China and Nigeria at the China International Mining Conference in 2023 on the extraction of lithium, niobium and tantalum.

In November 2020, China published the "New Energy Vehicle Industry Development Plan (2021-2035)," calling for the accelerated development of new electric vehicles and promoting the "development of the entire energy storage battery value chain," encouraging companies to improve their ability to secure key resources such as lithium, nickel, cobalt, and platinum. Three years later, China identified the "new three" as an important driver of economic growth, with a particular focus on the development of foreign trade. The "new three" technologies are electric vehicles, as well as lithium batteries and photovoltaic raw materials, all of which are dependent on critical raw materials.

These policy initiatives require Chinese companies to strengthen their supply chains for critical raw materials, and Africa plays a key role in meeting this demand. **In 2020, China imported almost 90% of its cobalt from the Democratic Republic of Congo, and in 2024, Côte d'Ivoire was the third largest supplier of nickel ore to China.**

The current situation threatens years of efforts to build secure global supply chains for critical raw materials and highlights the challenge for Western countries to reduce their dependence on China in this area. Building infrastructure to reduce dependence on China will obviously take years and involve extensive research, permits, and construction. Higher prices may encourage investment in new mines and facilities, but investors may hesitate due to China's ability to flood the market and lower prices. In this context, **the European Union has an important role to play in providing support to secure its own capacity for the extraction and processing of critical raw materials.**

It is worth noting that as part of the actions resulting from the CRMA, on March 25, 2025, the European Commission announced a list of 47 strategic projects to secure critical raw materials in the European Union[30] . On June 3, 2025, the European Commission announced 13 strategic projects for the extraction and processing of critical raw materials outside the European Union with a total value of approximately €5.5 billion. These new foreign projects (located in the United Kingdom, Canada, Greenland, Kazakhstan, Madagascar, Norway, Serbia, Ukraine, Zambia, Brazil, the French territory of New Caledonia, Malawi, and South Africa) will focus on raw

materials essential for the production of batteries for electric vehicles and energy storage, including lithium, cobalt, manganese, graphite, and rare earth metals.

The question arises, however, whether the measures envisaged in the Clean Industrial Deal are sufficient and how they compare with the measures and intentions of other countries, including the United States, described later in this study. The report also describes investment opportunities in critical raw materials in Ukraine and Greenland, which is particularly important in the context of the European Union's plans for investment outside the EU.

4.3. An overview of policies on critical raw materials in selected countries

The Draghi report emphasizes that large economies outside Europe are actively seeking to secure independent supply chains and reduce their vulnerability to threats. It can be said that there is currently a race to gain market share faster than the competition. Different approaches are being used, with national governments usually playing a dominant role in securing the raw material potential of their economies.

As mentioned, **China is actively investing in mining assets in Africa and Latin America and in overseas refining as part of its Belt and Road Initiative**. Its foreign investment in raw material extraction under the Belt and Road Initiative reached a record $10 billion in the first half of 2023 alone, and Chinese companies plan to double their assets in foreign mines containing critical raw materials.

The United States is using *the Inflation Reduction Act, the Bipartisan Infrastructure Act*, and defense funds to develop large-scale domestic processing, refining, and recycling capabilities, as well as its geopolitical power to secure the global supply chain. The US model for increasing critical raw material capacity allows for rapid and large-scale action. However, it is scattered across different government agencies (the Department of Defense, the Department of Energy, the Office of Education and Culture, and the Development Finance Corporation). The US federal strategy for securing safe and reliable supplies of critical raw materials provides a framework and enables action to address the challenges of the critical raw materials supply chain. These include strengthening domestic supply chains for critical minerals, strengthening international trade and cooperation, and improving access to domestic critical mineral resources. As part of the Mineral Security Partnership, the United States is also analyzing foreign projects involving mining, processing, and recycling that ensure access to critical raw materials.

As indicated in the aforementioned article by the Stimson Institute dated February 28, 2025.[29] based on data from the Bureau of Economic Analysis, the United States invested $7.4 billion in Africa in 2023, including just under $300 million in critical raw materials, which unfortunately represents only 4% of total US investment on the continent in 2023.

The United States is particularly vulnerable to disruptions in critical raw material supply chains. In 2024 The Special Commission on China reported that Beijing met more than 50% of US demand for 24 critical raw materials, including more than 90% of demand for rare earth elements from China. US officials emphasize that this dependence "poses a serious economic threat to US national security." Rare earth elements are particularly important for US national security because they are critical to a range of defense technologies. This includes F-35 fighter jets, Virginia and Columbia-class submarines, Tomahawk missiles, radar systems, Predator unmanned aerial vehicles, and the Joint Direct Attack Munition series of smart bombs. For example, the F-35 fighter jet contains over 900 pounds of rare earth metals. The Arleigh Burke-class DDG-51 destroyer needs about 5,200 pounds, while the Virginia-class submarine uses about 9,200 pounds. China's bans on critical raw material supplies enable China to strengthen its military capabilities faster than the United States. Gallium and germanium, two critical raw materials essential for the production of semiconductors in the US, were prime examples of retaliatory disruptions by China through export controls.

In its 2024 National Industrial Defense Strategy**,** the Department of Defense (DOD) set a goal **of developing a complete *mine-to-magnet* supply chain for rare earth metals that can meet all US defense needs by 2027**. According to an article by the Center for Strategic & International Studies article dated April 14, 2025, since 2020, the Department of Defense has allocated over $439 million to build domestic supply chains, but US capabilities are largely in the early stages and developing mining and processing capabilities will require long-term efforts.

In the aforementioned article, "*Competing for Africa's Resources: How the US and China Invest in Critical* Minerals," the United States, in an effort to diversify its supply chains for critical raw materials, turned to expanding cooperation with Africa. In August 2022, the White House published the US Strategy for Sub-Saharan Africa, committing to "help African countries use their natural resources more transparently," including critical minerals. **The US administration then took steps to engage African countries politically and economically to further deepen their partnerships on critical raw materials.** The United States operates in Africa through institutions such as **the U.S. International Development Finance Corporation (DFC) and the U.S. Export-Import Bank, lending funds for mining and energy projects.** U.S. government institutions and private U.S. investors are particularly active in projects in Angola (the Longonjo rare earth metals project), Rwanda (tin, tungsten, Trinity Metals projects), Tanzania (nickel, Kabanga project), Uganda (Orom-Cross graphite project), South Africa (neodymium, praseodymium, dysprosium and terbium, Phalaborwa project), and Mozambique (Balama Graphite project). Both the US and China are investing not only in the extraction of critical raw materials. Both countries are seeking to provide infrastructure that will increase the efficiency of trade in raw materials (in the case of the US, for example, the Lobito railway corridor project from Zambia to Angola). **The US approach to investment in Africa is significantly more focused on cooperation with private companies than the Chinese approach.** The DFC mainly supports private companies with grants and loans, while China lends to African governments or Chinese companies with Chinese State participation. The DFC competes with Chinese entities by emphasizing the environmental and social responsibility (ESG) of the investments it finances.

On April 5, 2025, President Trump issued an executive order directing the US Department of Commerce to investigate the threat to US national security posed by various critical imported minerals[31]. **Within 180 days, the Department of Commerce, in consultation with the Secretaries of the Treasury, Defense, and others, is required to submit a report to the president on whether the U.S. dependence on imports of critical raw materials and their products poses a threat to national security.** The report will also include recommendations for actions to mitigate such threats, including potential tariffs, export controls, or incentives to increase domestic production, and policy recommendations to strengthen the supply chain for critical raw materials in the United States through strategic investments, permit reforms, and enhanced recycling initiatives.

This regulation is consistent with other measures taken by the US executive and legislative authorities, including the *Congressional Research Service* report on critical raw materials prepared on February 21, 2025 commissioned by the US Congress[32], President Trump's Executive Order 14241 of March 5, 2025[33], and President Trump's Executive Order of January 20, 2025[34], which declares a national energy emergency and aims to address energy shortages and critical raw material production.

Executive Order 14241 of March 5, 2025 on immediate measures to increase US production of critical raw materials sets out immediate measures to facilitate and accelerate the production of minerals across the country, emphasizing the need for secure, predictable, and affordable supplies of raw materials essential to many industries, including defense, technology, transportation, and infrastructure. It requires the Department of Defense, in coordination with other relevant departments, such as the Departments of the Interior, Energy, and Agriculture, to identify critical raw material projects, establish priorities, and expedite the issuance of permits for relevant projects, and mobilize funds to revitalize the U.S. critical raw materials industry.

On July 9, 2025, President Donald Trump announced **the introduction of 50% tariffs on copper imports to the United States**, effective August 1, 2025.[35] In announcing the new tariffs, he said they were based on an assessment of threats to national security following an investigation into copper trade ("Section 232"). The president stated that the US would build a dominant copper industry. He blamed previous administrations for the decline of the US copper industry, saying that copper was and is needed for the production of semiconductors, aircraft, batteries for electric vehicles, and military equipment. When assessing the situation in connection with the decision to impose 50% US tariffs on copper, it should be borne in mind that US smelters have limited copper production capacity. The United States consumes about 2 million tons of this metal annually, while production is about 1 million tons. Local smelters have a production capacity of less than 400,000 tons, which means that they meet about 20% of local demand[36] . In

view of the above, it seems that President Donald Trump's decision should be interpreted in the context of the measures taken in connection with the above-mentioned Executive Order 14241 of March 20, 2025, on immediate measures to increase US production of raw materials. The Regulation sets out, in a highly prescriptive manner, measures to increase US production of critical raw materials, including copper. Furthermore, the Regulation specifies very precise responsible administrative units and sets short deadlines for the implementation of solutions initiating processes aimed at restoring the extraction and processing of critical raw materials in the United States[37].

Of course, questions arise as to what further legislative, financial, and executive measures the United States will take to increase the scale and accelerate mining and smelting projects at the investment stage. Short-term customs protection, combined with domestic demand far exceeding domestic production capacity, will not offset the US copper deficit. In the medium and longer term, however, customs protection will be one of the key tools to encourage investors to implement long-term projects in the territory protected from foreign competition, but it must be accompanied by further instruments supporting the investment phase.

The tariffs on copper imposed by the United States on August 1, 2025, ultimately covered copper semi-finished products (pipes, wires, rods, sheets) and products with a high copper content. These tariffs did not cover refined copper (cathodes, concentrates, scrap). As a result, there will be growth in the American copper smelting and processing industry and in the production of semi-finished and finished copper products, i.e., investment projects with a shorter implementation period than copper ore mining. Supporting the development of mining requires the implementation of a wide range of measures aimed at increasing the number of new projects and shortening the overly long investment processes associated with planned and emerging copper ore mines.

Japan, which is heavily dependent on other regions of the world for critical raw materials, has been developing a strategic approach to increasing access to foreign mining projects since 2000. The Japan Organization for Metals and Energy Security (**JOGMEC**) invests in mining and refining assets around the world, manages strategic stockpiling, and, since the introduction of the recent Economic Security Act, has the authority to expand processing and refining facilities in Japan.

In terms of innovation, **Japan has focused on developing more efficient production processes, reducing the use of critical raw materials, and developing substitute products.** Finally, Japan has begun exercises to explore the potential of domestic offshore deposits (e.g., cobalt and nickel). This strategy has proven effective, resulting in a reduction in Japan's dependence on Chinese supplies of rare earth metals from 85% in 2009 to 58% in 2018. Japan has set itself the goal of reducing its dependence on rare earth metal imports to below 50% by 2025.

According to information from the Draghi Report, JOGMEC identifies the needs of Japanese industry and supports the security of supply. **JOGMEC has extensive intelligence capabilities and is able to assess potential resource projects around the world**. The agency provides financial support to Japanese companies in developing mining, smelting, refining, and recycling projects, conducts targeted exploration, purchases, and stores critical minerals. JOGMEC provides the funds necessary for mineral resource exploration projects in the form of capital support or loans to assist Japanese companies, leading to a faster transition to mine development. JOGMEC also provides debt guarantees for development funds lent by private financial institutions. In addition, from 2022, capital investments and debt guarantees will cover domestic ore processing and smelting companies. In June 2020, the Japanese national parliament passed legislation to **expand the scope of JOGMEC's financial functions.** This was intended to better support the involvement of Japanese companies in mining projects outside Japan. The scope was expanded to **allow financing of projects beyond the exploration phase to the development and production phases.** JOGMEC also provides grants to the public sector for research and supply chain resilience (under the Economic Security Promotion Act, particularly for battery metals and rare earth magnets) and the creation of critical raw material stocks (the Japanese government subsidizes stocks by paying interest on loans taken out by JOGMEC for the purchase of raw materials, as well as the costs of maintaining and managing warehouses).

South Korea's strategy to "ensure a reliable supply of critical raw materials" is based on previous government measures to reduce its dependence on supplies from specific countries. The strategy **identifies 33 critical raw materials to ensure**

economic security and ten additional critical raw materials of strategic importance to ensure stable supply chains for South Korea's high-tech industry.

In addition, South Korea's strategy supports the development of global supply and warning systems to notify of threats in the supply chain. **Stocks of critical raw materials are to be sufficient for 100 days.** Key measures in the strategy also include strengthening international cooperation and reducing risks related to foreign supplies, as well as promoting public financial guarantees to support mining companies' investments in the extraction and processing of critical raw materials. In 2021, South Korea also established ***the Korea Mine Rehabilitation & Mineral Resources Corp.*** **(KOMIR).** This government agency is tasked with **supporting stable supplies of essential raw materials, managing risks and dependencies in the supply chain, and developing overseas mining and processing capabilities**.

Both **Canada** and **Australia** have recently introduced national strategies on critical raw materials to position themselves as global suppliers of sustainable raw materials. **Compared to the EU, both Canada and Australia have more efficient and faster processes to accelerate the production, processing, and, and supply chains of critical minerals.** In addition, they are working to create resilient and sustainable supply chains through international partnerships.

The article cited, "*The Consequences of China's New Rare Earths Export* Restrictions" [28], clearly states that while some countries are working to develop their deposits of light and heavy rare earth metals, China continues to maintain a monopoly on their refining. Australia, Brazil, South Africa, Saudi Arabia, Japan, and Vietnam are pursuing initiatives and investments to strengthen key rare earth mining, processing, and research and development, as well as magnet production. In order for the United States to build alternative supply partners to ensure long-term supply chain security, it is important that it continues to provide financial and diplomatic support for the success of these production initiatives. In addition, according to the above-mentioned analysis, Australia is working to develop its Browns project to become the first significant producer of dysprosium outside China. However, much remains to be done in terms of building processing and refining capacity outside China. Australian company Lynas Rare Earths is the largest producer of separated rare earth elements outside China, but it still sends oxides to China for refining. **It is assumed that Australia will be dependent on China for rare earth element refining until at least 2026.**

Cooperation with international partners can also help overcome gaps in technological know-how when it comes to the separation and processing of rare earth elements. Several countries are leading the way in the development of critical raw materials and rare earth-specific research and development initiatives to support the development of this strategic sector. The Australian Critical Raw Materials Research and Development Centre is working to strengthen international research and development cooperation on critical raw materials. The center includes initiatives in rare earth metal processing and downstream processing led by government agencies in collaboration with industry and universities to enhance technical capabilities. Japan has a Rare Earth Metals Research Center at the Muroran Institute of Technology, as well as a joint initiative with Vietnam to improve rare earth metal mining and processing at the Rare Earth Metals Research and Technology Transfer Center in Hanoi. The initiative was launched in 2012 when Japan sought to strengthen and diversify its rare earth supply chains in response to China's 2010 ban on rare earth exports.

Given that **China has overtaken the rest of the world in its efforts to secure both the supply of critical raw materials and the use of processing technologies, including for military purposes**, this clearly raises risks that this advantage could be used for Chinese economic and geopolitical domination. Western countries have lagged behind, although they have recently accelerated their efforts to secure critical raw material supplies and develop technology in this area. The European Union therefore has a lot of work to do to protect itself from Chinese dominance in the raw materials and technology sectors and to keep pace with other developed economies.

4.4. New raw material areas and their importance. The Arctic, Greenland, and Ukraine on the world's raw material map

New raw material areas are not really new, but they have been overlooked due to a series of events and have been partially **"rediscovered**." To understand the whole

situation in the field of raw materials and, in a way, the start of a raw material war and Ukraine's involvement in it, this situation must be viewed in the context of the global geopolitical situation, taking China into account.

Currently, Ukraine's economy is being systematically destroyed as a result of the war that has been going on since February 2014. However, it was not until the fall of 2021 that this conflict began to escalate and turned into a full-scale war that has been ongoing since February 24, 2022, initiated by Russia's armed invasion of Ukraine. Placing its hopes in the inaction of the democratic world and Ukraine's weakness, Russia has decided to fully and directly exploit its military potential to achieve its now undisguised imperial ambitions. It is worth asking whether, in addition to rebuilding Russia's sphere of influence across Eastern Europe, Putin's goal is not also to gain access to resources, including mineral resources present in Ukraine.

For decades, China has based its policy and strategic directions on the belief that politics and domination will depend on raw materials and advanced technologies – **"The Middle East has oil, we have rare metals," said Deng Xiaoping in 1992.** However, these words were only heard a few years after the announcement in 1986 by China of *the National* Plan *on Key Basic Research and Development* and the implementation of the "National Program on Key Basic Research Projects (Program 973)" to achieve technological and strategic superiority in various fields of science, in particular in the development of the rare earth minerals industry[38], [39] . This was also made possible by Prof. Xu Guangxian's development of innovative methods for separating rare earth elements (REE) and a clear declaration to build modern technologies based on REE, which China has abundant reserves of. As a result, China has gradually gained dominance in the rare earth metal supply chain (today it accounts for 90% of global REE ore processing). However**, the most important link in this process is the technology used to extract these metals, which is strictly protected**.

However, REEs are not the only factor behind China's dominance and the parallel transformation of its economy, which has been actively pursuing a wide-ranging national development plan for several decades. The changes that can be observed today in China, mainly in the areas of modern technologies, transport infrastructure, and urban agglomeration development, prove the success of the implementation of long-term strategic plans based on raw materials, modern technologies, low costs (throughout the entire chain of activities), and a less rigorous approach to environmental issues.



Fig. 15. REE resources in China. Based on USGS data for Newsweek[40]

Data from the US Geological Survey (USGS) show that **China is the world leader in rare earth elements, but not only that. In 2024, they were estimated at 44 million tons (Fig. 15), which means that almost half of the world's total known reserves are located there (over 90 million tons).** By comparison, **the United States has only 1.9 million tons of REEs** (Fig. 16) and is heavily dependent on imports from China. Dominance in the chain, from discovery through production to export, gives China enormous control over global REE prices. The export restrictions imposed by China in 2016 led to an increase in global prices for these elements, which was also evident in China's earlier actions, e.g., the 2007 export limit to retain REEs in order to develop its own market; an increase in export duties to 25% in 2011 and further current export restrictions[41], including to the US as a result of the escalating trade war. The Middle Kingdom is showing the world that it has gained dominance in a key technological area and will use this advantage.

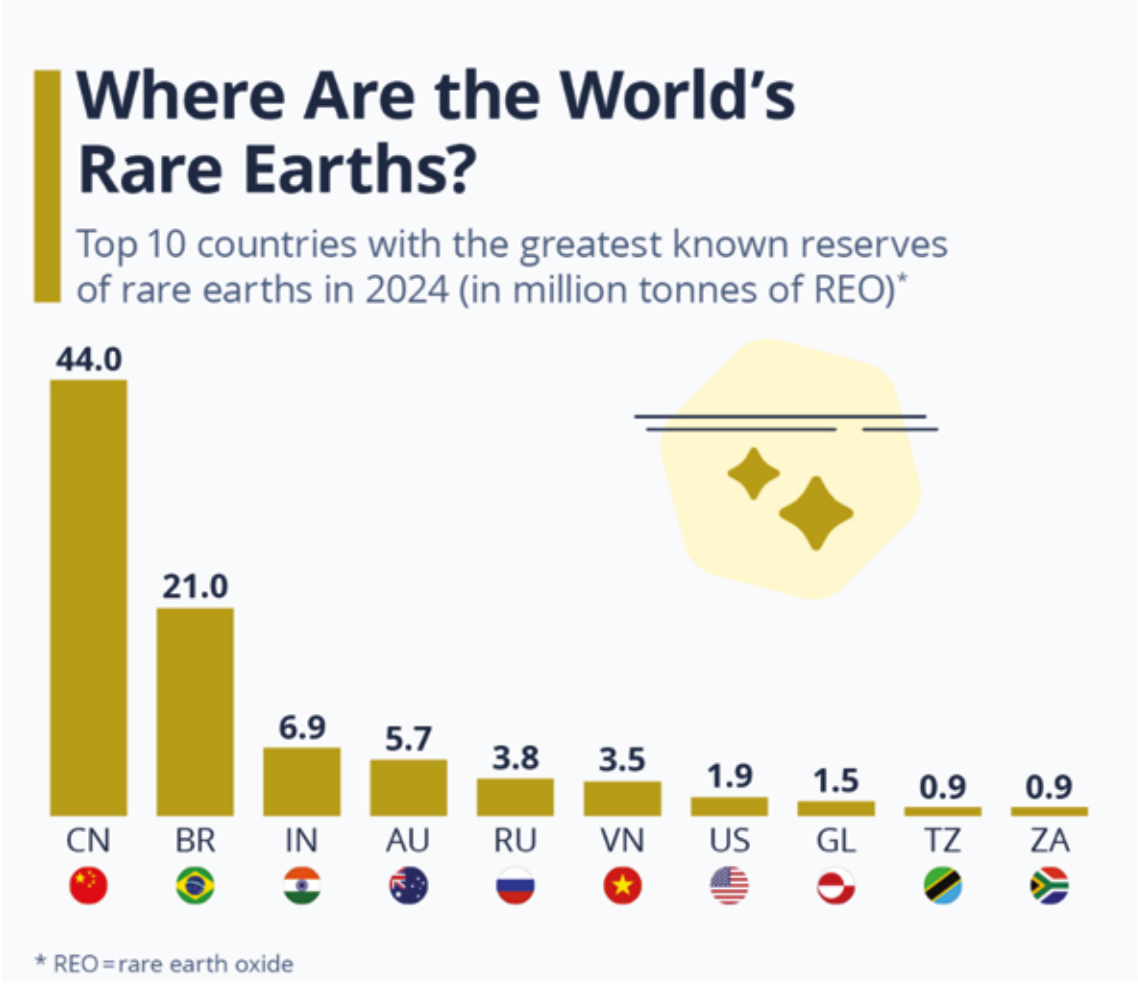


Fig. 16. Ranking of the world's most resource-rich countries in REE. (Statista via USGS) [42]

4.4.1. Ukraine

Returning, however, to the question posed earlier, "Could Putin's goal also be raw materials?", it should be noted that prior to Russia's armed invasion of Ukraine, Ukraine was not associated with large investments in mineral extraction. The war, social changes in Ukraine related to increasingly strong aspirations for freedom and democracy, combined with the growing economic influence of the European Green Deal, have changed the image of Ukraine, which from a post-Soviet country corrupt and opaque country to one increasingly perceived as rich in various raw materials necessary for the energy transition. These raw materials were recognized and documented to varying degrees, but it was quickly revealed, and became a topic of widespread

discussion, that **Ukraine has approximately 20,000 deposits containing 117 minerals and elements, including 22 of the 34 minerals recognized by the European Union as critical (CRM).** According to the Geological Institute of Ukraine, Ukraine has, among others, rare earth elements such as lanthanum and cerium, neodymium, erbium, and yttrium and scandium. However, detailed data are not available. Ukraine is also rich in lithium, beryllium, manganese, gallium, zirconium, graphite, apatite, fluorite, and nickel[43]. Ukrainian mineral deposits are fairly well known, but the maps of these resources are based on outdated Soviet-era studies. These studies did not take into account the costs or technical feasibility of extracting minerals from these deposits, and many locations, e.g. REE, are considered unprofitable for mining. Another significant drawback is the administrative barriers to investment (inefficient and complex regulatory processes), as well as difficulties in accessing geological data and obtaining land rights. Another important area is the need to align Ukrainian standards with EU regulations, particularly following the introduction of the CRMA Regulation. Overcoming these constraints may take many years before investment can begin, and significant initial expenditure will also be necessary. Another important element is the implementation of and consistent compliance with transparency standards, anti-corruption policies, and competition rules, which significantly affect the ability to do business. On the positive side, however, there is access to highly skilled and relatively inexpensive human resources and a well-developed infrastructure. It should be noted that the Ukrainian government has prepared and is currently preparing approximately 100 concession areas for announcement, as reported by the State Geological Service of Ukraine (UGS). Information on investment opportunities in the exploration and extraction of strategic and critical raw materials is easy to find on the UGS website: https:/www.geo.gov.ua/en/critical-raw-materials/, but are they attractive enough to pursue?

Currently**, many of Ukraine's resources are located in the east and south of the country, including in regions occupied by Russia**. Most of the rare earth metal reserves are also located in these regions, including Donetsk and Luhansk (part of Donbas), as well as in Zaporizhia, Kherson, and Crimea, a peninsula in the Black Sea[44].

A very good diagnosis of the raw material situation in Ukraine was presented by Mykhailov et al. (2020)[45], (Fig. 17, 18). They **analyzed Ukraine's raw material base in terms of elements that are essential for the development of "green energy" in Europe. They distinguished four groups,** which differ in terms of geological certainty, available resources, and stages of potential and/or commercial development. These are:

(1) **Iron, manganese, and graphite** – large deposits that **have been exploited** for a long time in Ukraine and have almost unlimited resources/prospects for further production.
(2) **Lithium and rare earth elements (REE)** – deposits that have been mostly explored and have **significant resources, but are not being exploited**. They may be included in development after appropriate geological and economic assessment.
(3) **Cobalt and nickel** – deposits that have been discovered, but **their resources are rather small** and there are some technological problems with ore enrichment; these deposits can only be exploited if their economic viability is further confirmed by an objective economic and geological assessment.
(4) **Aluminum and lead** – small deposits and mineralizations are known, but their reserves and ore grades are rather low, so **their exploitation is doubtful** and the prospects for commercial extraction cannot be determined.

It is worth looking at all of Ukraine's mineral resources in this way, which also gives a certain view presented by professionals.



Fig. 17. Sketch of the main mining regions and deposits of critical elements for green technologies in Ukraine. Mining regions: I, Kryvyi Rih (Fe); II, Kremenchuk (Fe); III, Bilozerska (Fe); IV, Nikopol (Mn); V, Tokmak (Mn). Ore deposits: 1, Zavallivske (Gr); 2, Petrivske (Gr); 3, Balakivske (Gr); 4, Burtynske (Gr); 5, Troicke (Gr); 6, Mariupolske (Gr); 7, Yastrubeske (Zr, REEs); 8, Polokhivske (Li); 9, Dobra (Li); 10, Novopoltavske (Ta, Nb, REE); 11, Shevchenkivske (Li); 12, Azovske (Zr, REE); 13, Mazurovske (Ta, Nb, Zr, REEs); 14, Kapitanivske (Cr, Ni, Co); 15, Ternuvatske (Ni, Co); 16, Devladivske (Ni, Co); 17, Prutivske (Ni, Co, Cu); 18, Vysokopolskie (Al); 19, Yuzhnokopolskie (Al); 20, Beregiwsk, Bigansk, and Muzuwisk (Pb, Zn, Au); 21, Bilawsk (Pb, Zn). According to Mykhailov et al. 2020. The occurrence of deposits is also classified by so-called metallogenic areas (Mykhailov 2023[46]), as shown in Fig. 18.

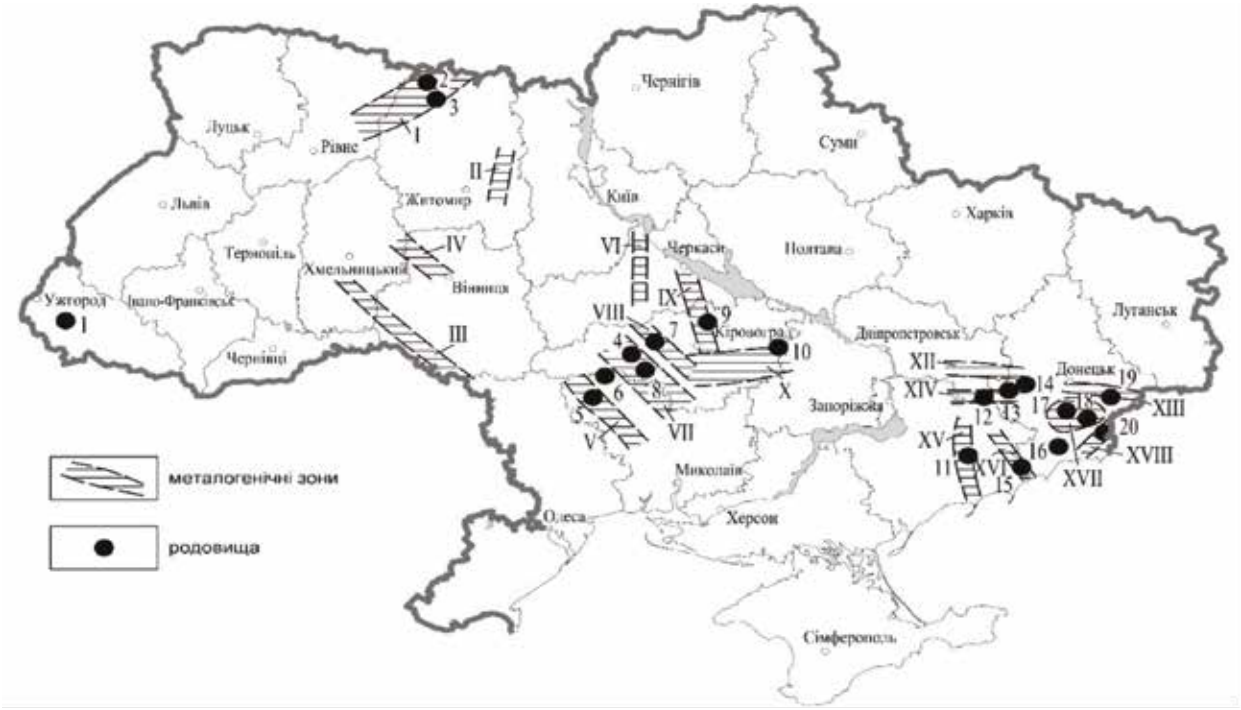


Fig. 18. Metallogenic zones and deposits within them: i – Sushchano-Perzhanska; II – Koczerivska; III – Podilska; IV – Khmielnytska; V – Golovanivska; VI – Zvenigorodska; VII – Yuliivska; VIII – Khmielivska; IX – Kirovogradska; X – Novoukrainska; XI – Tersianska; XII – Fedorowska; XIII – Donbaska; XIV – Gaichurska; XV – Tchernigivska; XVI – Sorokynska; XVII – Oktyabrska; XVIII – Kalmiuska. Deposits: 1 – Malobiganske (Ge); 2 – Jastrubecke (REE, Zr); 3 – Perzanske (Be); 4 – Stankuvatske (Li, Ta, Nb); 5 – Lozovatske (REE, U, Th); 6 – Kalynivske (REE, U, Th); 7 – Polokhivske (Li, Ta, Nb); 8 – Pivdne (REE, U); 9 – Tarasivske (REE); 10 – Zhovtorichenske (Sc, U, Th, Fe, V); 11 – Novopoltavske (Nb, REE); 12 – Uspienivske (REE); 13 – Shevchenkivske (Li); 14 – Voskresenivske (Li); 15 – Kruta Balka (Ta, Nb, Li); 16 – Azov (Zn, Zr, Nb); 17 – Mazury (Nb, Zr); 18 – Anadolskie (REE); 19 – Pokrovo-Kiriyivske (Be, REE); 20 – Petrowo-Hnutivske (REE). According to Mykhailov 2023.[46]

However, the available data on Ukraine's raw materials, which are more journalistic in nature, indicate only some of the raw materials and elements. These are:

- **Graphite** – **Ukraine's reserves are among the largest (in the top five) in the world**. Six deposits are of key importance: Zavallivske, Petrivske, Balakivske, Burtynske, Troicke, Mariupolske (Fig. 17, 19). Annual production is 5,500 tons. Reserves are estimated at around 13.7 (or 18.6) million tons, and even up to 500 million tons. Some information on graphite also indicates that there are 300 graphite deposits in Ukraine, containing over 1 billion tons, which accounts for 20% of the world's graphite reserves.[47]
- **Beryllium** – according to the USG, Ukraine has 13.9 (or 15.3) thousand tons of beryllium oxide, which, regardless of the actual amount, **could meet global demand for its production for up to 40 years**. The resources of this raw material are concentrated in one deposit: Perzhanske (Fig. 18, 19), which also contains tantalum, niobium, zirconium, molybdenum, lithium, zinc, and others.
- **Titanium** – Ukraine has **the largest titanium deposits in Europe**, accounting for 7% of global production of this metal, and has 28 deposits containing minerals of this element (Fig. 18, 19).
- With **the largest uranium deposits in Europe**, Ukraine has been among the world's top ten producers of this ore for many years (it produces 2% of the world's uranium concentrate and meets about 30% of the demand of its nuclear power plants), mining it in three mines in the Kirovohrad region (central Ukraine). The recoverable reserves are estimated at 45,600 tons of uranium (Fig. 18, 19).
- **Gallium** – Ukraine ranks **fifth among the world's gallium producers**, extracting it from other ores it mines.

– **Lithium** – Ukraine **does not** currently **mine** lithium, but only has potential. According to the Ukrainian Geological Service, **Ukraine's reserves account for almost 3% of global reserves**. Four locations are indicated (Polokhivske, Dobra, Shevchenkivske, and Kruta Balka) (Fig. 18, 19). It is estimated that Ukraine has about 500,000 tons of lithium, one of the largest confirmed reserves in Europe, worth up to $11.5 trillion.

– **REE** – these deposits have not yet been developed, and experts believe that **the country has the largest recoverable REE resources in Europe**. The USG reports that they occur in six deposits, including the most famous Novopoltawskoye apatite ore deposit (Fig. 18, 19). The total REE ore reserves in Ukraine are estimated at 2.6 billion tons. Lithium and REE belong to the second group according to the classification of Mykhailova et al. (2020)[45].

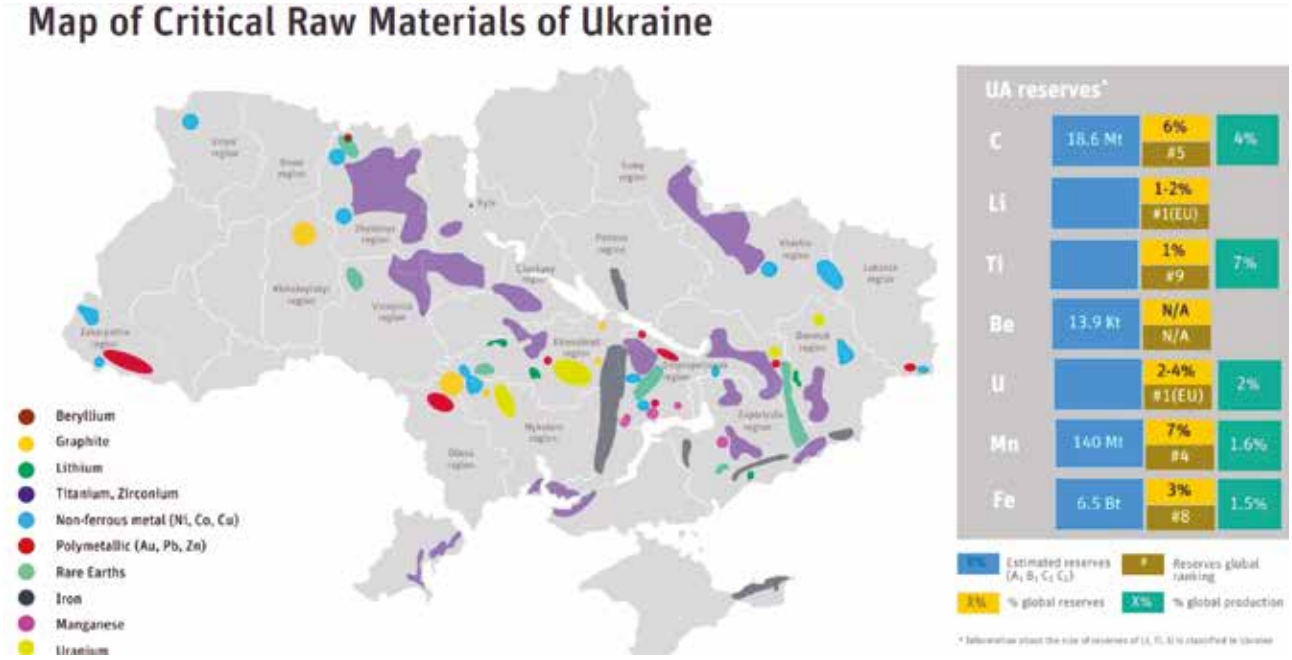


Fig. 19. Regional distribution of various elements and minerals in Ukraine according to UGS. The table shows approximate resources (deposit documentation categories: A_1, B_1, C_1, C_2), % of global resources found in Ukraine, global ranking by resources, and production in Ukraine in relation to global production. Based on: UGS.

In addition to those listed above, there are other equally important resources in Ukraine that should be mentioned. These are iron ores and co-occurring titanium and iron ores, as without iron, the economic development, reconstruction of Ukraine, and energy transition of Ukraine, Europe, and the US will not take place. The mined resources are estimated at **27 billion tons of iron ore, which puts Ukraine in 6th place in terms of global iron ore production.** There are about 88 deposits throughout the country. These rich iron ore deposits are mainly located in Kremenchuk, Kerch, Mariupol, Bilozersky, and Kryvyi Rih (Fig. 17). Of the 88 deposits, 60 are located in the Kryvyi Rih basin, which has minable reserves of about 19 billion tons. The Kremenchuk basin has about 4 billion tons, and the Belozersk basin has 2.5 billion tons. **A large part of the iron ore deposits is mined by open-pit mining.** It is important to note that Ukraine exports iron ore mainly to China.

Another important ore is **manganese ore**. Ukraine is **among the top ten** manganese ore **producers** in the world and has the largest reserves of this raw material in Europe. The main deposits are located in the southern part of Ukraine (Nikopol Tokmak, Fig. 17).

Coal cannot be overlooked, as it is the main fossil fuel, whose **reserves can meet the energy and industrial needs of Ukraine for the next 500 years.** It is the largest source of fossil fuels in Ukraine, accounting for 95% of reserves. Ukraine has the 7th largest coal reserves in the world and the 2nd largest in Europe, with approximately 34 billion tons of recoverable reserves and approximately 90-115 billion

tons of geological reserves. The main coal deposits are located in the Donbas and Lviv-Volyn basins. These two deposit areas account for 95% of Ukraine's coal reserves, with Donbas accounting for 92.4% and the Lviv-Volyn basin for 2.5%. Over 30% of the resources in both basins are energy coal. Most of the coal mined in Ukraine is intended for domestic use, especially for electricity generation.

In addition**,** Ukraine has **significant reserves of non-ferrous metals such as copper (4th place), lead (5th place), zinc (6th place) and silver (9th place) in Europe**, in terms of deposit size. There are also nickel and cobalt deposits in the relatively safe regions of Kirovohrad and Dnipropetrovsk.

Crude oil and natural gas are also important raw materials, of which Ukraine has considerable reserves, and even during the war, intensive exploitation and exploration work is being carried out (e.g., in the Poltava region), but also in the Lviv, Volyn, Dnieper and Donetsk regions. It is estimated that **Ukraine has over 1.1 trillion cubic meters of recoverable natural gas reserves (approx. 5.4 billion m³of geological reserves), over 135 million tons of crude oil, and approximately 80,000 tons of gas condensate (400 million tons in geological reserves).** Three regions of Ukraine have hydrocarbon reserves: the Dnieper-Donets Basin, the Carpathians, and the Black Sea and Crimea region. The Dnieper-Donets Basin is the main oil and gas production region, accounting for 90% of Ukraine's total production[48].

According to various data (e.g., from the Ukrainian government), **approximately 20% of Ukraine's mineral deposits and half of its rare earth elements remain under Russian occupation; and according to Ukrainian analytical centers (e.g., *We Build Ukraine)* and the National Institute for Strategic Studies, approximately 40% of Ukraine's metal resources are currently under Russian occupation, while according to Forbes estimates, as much as 70% of them are currently under Russian control or near the front line (**Fig. 20)[49], which indicates a significant area of uncertainty, overestimation, or underestimation. Maps published and authorized by the geological service also contain different and inconsistent information. In this context, looking from the perspective of the currently discussed end of the war in Ukraine and Russia's demands regarding the occupied areas (Luhansk, Donetsk, Zaporizhzhia, Kherson, Crimea, Fig. 20), Ukraine's starting position is very difficult.

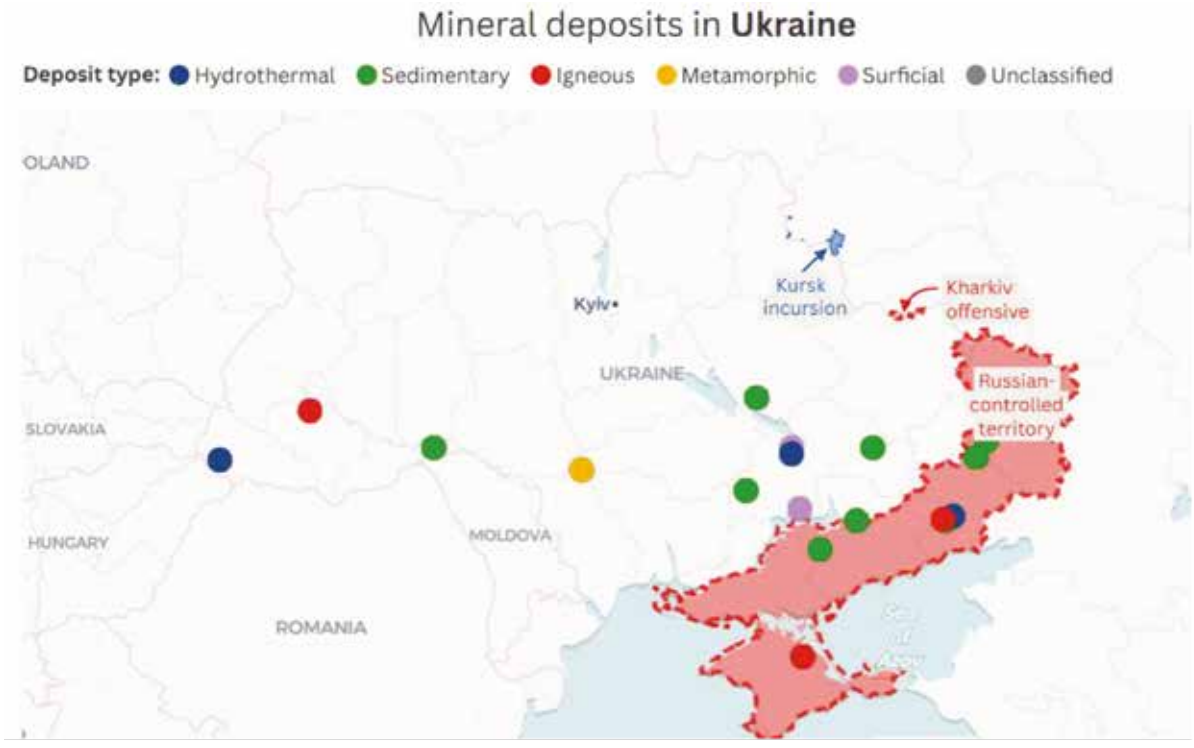


Fig. 20. Area occupied by Russia and distribution of selected raw material deposits, classified according to their origin. (Based on: Newsweek – via USGS, Institute for the Study of War, February 24, 2025)[50]

Russia has seized at least two Ukrainian lithium deposits during the war – one in Donetsk and the other in the Zaporizhzhia region in the south-east. Not to mention the coal deposits in the Luhansk and Donetsk regions. So it is not only lithium and REEs that may tempt Russia, but also other raw materials. The seizure of each successive "piece" of Ukraine is beneficial to Russia. Both in terms of territory – strengthening its great power status – and in terms of natural resources. These deposits are located in a more urbanized area than Russia, which would certainly facilitate their exploitation.

Therefore, **the agreement between Ukraine and the United States**, which is to provide the United States with preferential access to new concessions for Ukrainian raw materials, mainly critical minerals, is important. This is to finance investments in the reconstruction of Ukraine and to compensate the US for its financial and military assistance[51] . The motto of this cooperation is "Not Russia as a plunderer, but the US as a partner." From the beginning of the war, the EU has also clearly stated that natural resources are essential for both Ukraine and Europe in the energy transition process. For the US, access to strategic and critical mineral resources has become a key factor in the context of rivalry and trade war with China, which is why it was so keen to sign the agreement. Clearly aware of the political circumstances and the position of the US economy, restrictions on supplies from China could significantly affect the development of modern technologies. However, the difficult US-Ukrainian negotiations, which took place largely in full view of the global public, were conditioned by the need to find a solution that was beneficial to both sides. From the US perspective, securing access to new resources such as lithium, titanium, manganese and REEs, which Ukraine possesses and which play a key role in the energy transition, the defense industry and digital technologies, seems to be a good move. The negotiated agreement, which was ratified by the Ukrainian Verkhovna Rada on May 9, covers both technological and financial aspects of exploration, documentation, and development of deposits on terms favorable to US companies. For Ukraine, this means funds for reconstruction and know-how in the field of extraction and processing technologies. For the United States, the agreement means diversification of sources of strategic raw materials, increased economic pressure on Russia and China, and a stronger alliance with Ukraine as a strategic partner in Eastern Europe. By adapting its legislation to the standards required by its partners and maintaining its Western course, Ukraine has a chance not only to rebuild its economy, but also to become one of the leaders in the global market for strategic raw materials. For the United States, this is a way to secure its own economic and technological interests in the face of increasingly complex global competition. However, the implementation of the agreement will require determination, coordinated action, and the overcoming of a number of political and technical challenges[52].

4.4.2. Greenland

The mineral resources of Greenland, which belongs to the Arctic circle, must be considered in a slightly different context, taking into account, of course, the geopolitical context.

In the geological past, from about 280 million years ago to about 200 million years ago, there was a single supercontinent called Pangea. Its breakup began about 200 million years ago, forming the present-day image of our globe. The northern hemisphere and the continents on it, are called Laurasia. Greenland was separated from North America about 35 million years ago as a result of the formation of the Atlantic Ocean, which lasted over 150 million years (from about 180 million years ago). Laurasia is today's North America, Europe, and Asia, which share a common history, and Ukraine, which is located in the southwestern part of this plate. The result of this shared history of the continents is their similarity in geological structure. However, geological structure is not only about rocks and their characteristics, but also about the deposits found within them. **Historically, before it was separated (by the Baffin Sea), Greenland shared a common history with the Canadian part of the American continent**, which is equally rich in mineral resources. It is precisely in the raw material wealth of Canada and Greenland that the main reason for the US administration's strong interest in these countries should be sought today. Greenland has become a clear and high-profile media target for the Trump administration. The US president believes that Greenland is of strategic importance to US national security due to its location near potential trade routes and its known and undiscovered mineral resources needed for technological transformation. President Donald Trump stated bluntly: "We need Greenland for

economic security." This is why Greenland has become a target for the new US administration, but it has also been a target for China for many years. It is worth noting that expanding its territory is nothing new for the United States; after all, in 1803, the US acquired Louisiana from France, and in 1867, Alaska from Russia.

The Center for Minerals and Materials (MiMa) within the Geological Survey of Denmark and Greenland (GEUS) has reviewed the potential of CRM resources in Greenland (Rosa et al. 2023)[53] . The results show that **25 of the 34 minerals recognized by the European Commission as "critical raw materials" can be found in Greenland**. Greenland is also rich in REE deposits. **Greenland's rare earth element resources are almost equivalent to those of the entire United States** (Fig. 21), and much more is likely to be found under the ice cap. The Greenland ice sheet covers almost 79% of the island (Pachytel 2025[54] , based on MacGregor et al. 2024), with the remaining 21% being exposed bedrock, which has facilitated exploration, but as can be easily seen, this is only 21%. The remaining area of the island is unexplored, so it is not possible to make a complete assessment of Greenland's resources, but much more can be expected.



Fig. 21. REE resources in Greenland (based on USGS for Newsweek)[40]

Three of Greenland's largest REE deposits are located in the southern province of Gardar (Figs. 22 and 23). **There is a large deposit rich in rare earth elements such as neodymium, cerium, lanthanum, and yttrium, as well as gallium, a critical mineral that has recently been placed under export control by China due to its military applications.** REEs are also found in other deposits, such as Kvanefjeld/Kuannersuit (where the total REE oxide content exceeds 11 million tons). **The Kvanefjeld rare earth deposit is** believed **to be one of the largest in the world.** However, mining has been suspended due to the presence of uranium, the production of which is prohibited in Greenland (the project is currently under arbitration).

The Kringlerne/Killavaat Alannguat deposit currently under exploitation contains Zr-REE-Nb-Ta with reserves of at least 4.7 billion tons (Pachytel 2025, according to Tanbreez, 2025). This mine could also meet **86% of global demand for dysprosium.** It also has gallium, on which China has also imposed export restrictions. Other known deposits in southern Greenland include the Appat deposit (3.2 million tons of Zr-Y-REE ore), Motzfeldt (340 million tons of Zr-Nb-Ta-REE-U-Th ore), in southwestern Greenland there is the Sarfartoq deposit (5.9 million

tons of P-Nb-REE ore), and in the central-eastern part there is the Milne Land deposit (4 million tons of Zr-U-Th-REE-Ti ore). REE deposits have also been found in other parts of Greenland. Greenland does not have significant potential for lithium (not included in REE).

An important raw material on the list of minerals found in Greenland is **graphite**, which must be imported almost entirely by the European Union. Geological analyses have identified at least **nine significant** graphite **deposits and occurrences** (Figs. 22 and 23). The best-characterized deposit is the Amitsoq deposit, located in southern Greenland. With estimated resources of 8.28 million tons, this deposit could make it one of the most productive and profitable mines in the world. The project is planned as an underground mine, with construction scheduled to begin in 2026 and graphite production in 2028. In another deposit, Eqalussiut/Akuliaruseq (western Greenland), graphite resources have been estimated at 12.6 million tons, so this potential is growing. **Molybdenum** has also been found in Greenland**,** with reserves currently estimated at 245 million tons of ore. It occurs in the Malmbjerg deposit in central-eastern Greenland, where mining is planned for 2029. There are other molybdenum deposits, e.g., Kap Simpson and Flammefjeld (southeastern Greenland), and research indicates greater potential. Three deposits and two significant occurrences of niobium and tantalum have been described in Greenland to date **(**Figs. 22 and 23). For example, the Motzfeldt deposit (southern Greenland) contains 340 Mt of Nb-Ta resources, as well as significant amounts of U and Th (Pachutel 2025, based on RAM Resources, 2012). Given the growing demand for **niobium and tantalum,** Greenland could become a source of these raw materials for the EU.

Titanium and vanadium occur **in five important deposits** Moriusaq and Thule Black Sands (northwestern Greenland) are also rich in ilmenite deposits in the Thule Black Sand province (Pachytel 2025, based on Dawes, 1989), with reserves of 117.3 million tons in the Moriusaq deposit and 19 million tons in the Thule Black Sands deposit (Pachytel 2025, based on Rosa et al. 2023). The Isortoq deposit is located in the southern part of the island, where Ti-V-Fe mineralization occurs and resources of 70.3 million tons (with Fe, $TiO_{(2)}$ and V_2O_5 (Pachytel 2025 after Turner, Nicholls, 2013). In eastern Greenland, the (Skaergaard intrusion) may contain resources of 104 million tons with Ti and V admixtures (Pachytel 2025 after Sorensen et al. 2016). Other occurrences of titanium and vanadium enrichment have been reported in Sinarsuk (southwestern Greenland) and Stendalen (southern Greenland). The **beryllium** deposit in Greenland, Taseq, is located in southwestern Greenland. Copper occurs in Greenland, but its occurrence is poorly explored. It most often occurs together with **nickel, platinum, and cobalt. Zinc and lead** also occur (in northern Greenland) and **gold** in the south around the Sermiligaarsuk fjord. **Iron ore** is found in Isua in southwestern Greenland, Itilliarsuk in central western Greenland, and northwestern Greenland along Lauge Koch Kyst. There are also deposits of titanium and vanadium (in southwestern, eastern, and southern Greenland). Similarly, **platinum group metals** (Pt, Pd, Rh, Ru, Ir, Os) occur in eastern Greenland (Figs. 22 and 23) (Pachytel 2025 after Nielsen et al., 2015). The coast of Greenland near the Danish Strait is rich in **precious metals** (Pt-Pd-Au, Cu-Ni-Pd-Au, Ni-Cu-PGM). Pt-Pd-Rh, Ni-Co-Cu-PGMCr-Ni-Cu-PGM mineralizations are also found in southwestern Greenland, and Pt-Pd-Au-Cu in the south. Greenland also has **strontium, hafnium, zirconium, antimony, and phosphorus (**11.5 million tons, Pachytel 2025, based on Rosa et al., 2023). Uranium is also found in Greenland, but its mining has been banned since 2021. However, it often coexists with REEs, which may hinder their exploitation (e.g., the Kuannersuit deposit)[55].

Most of these, mostly preliminary documented resources, require specific business plans and all permits, including environmental permits, to build a mine, which under today's conditions can take several to more than a dozen years.

There is currently no active CRM production in Greenland, and REEs are the only ones with significant resources identified (approximately 1.4% of global resources). The combination of growing demand for key elements and the reduction of ice cover has led to a surge in exploration in Greenland. The government's raw materials strategy identifies five priorities. These are: better sharing of geological knowledge; effective, predictable and transparent management; simplified procedures for moving from exploration to exploitation; sustainable development of the mineral resources industry; and a competitive model of taxes and royalties. In 2024, there were 147 active mineral extraction concessions, of which only three were for oil. Most of the mineral extraction concessions

are located in the west, southwest, and far south of the island. Twenty of these are related to rare earths. Thirty-four concessions are for copper and other minerals such as platinum, cobalt, nickel, as well as titanium, vanadium, and silver. One of these (Tanbreez) is an exploitation concession. Despite the government's enthusiasm for the development of mineral extraction and the potential for large-scale production of rare earth metals, the issue is highly controversial, as many Greenlanders fear environmental damage and changes to their traditional way of life. Even if these concerns are interrelated, **the cost of extraction will be significantly higher than in many other parts of the Arctic due to geographical remoteness, poor infrastructure, and a shortage of available labor**[56] .

To sum up Greenland's raw material resources, several facts should be noted.

Firstly, **Chinese companies are already present in Greenland**. China already has shares in some companies and deposits and is trying to acquire more in order to gain access to REEs.

Secondly, **the United States has joined the competition with China in this area** and has expressed interest in acquiring all of Greenland's resources.

Thirdly, **the extraction of certain raw materials is currently restricted or prohibited** due to environmental protection policies, e.g., the extraction of oil, natural gas and uranium. There are a number of processes involved in obtaining permits and opposition from the indigenous population to the development of mining, which is blocking its development.

Fourthly, **Greenland lacks the necessary** infrastructure—there are no roads or railways outside the cities. Travel is by boat or plane, which is crucial for mining operations and will significantly increase the time from exploration to production.

Fifth, **Greenland is a poorly explored but mineral-rich area with a competitive licensing system, a stable political environment, low investment risk, and a mining-friendly government**.

Sixth, **the Greenlandic government has been cooperating with the EU** on sustainable resource extraction and environmental protection since 2012, so the EU has a different starting point than the US, but a worse one than China.

Seventh, **Greenland's mineral resources have been fairly well explored by a research institute under the Danish Ministry of Climate and Energy**, the Geological Survey of Denmark and Greenland (GEUS). Unlike those in Ukraine, the latest equipment and research techniques were used, which significantly increases the reliability of the results regarding the potential of the ice-free part of the island (Figs. 22 and 23). **The resources that have already been documented could meet at least 25% of global demand, but this is more likely to happen in the distant future.**

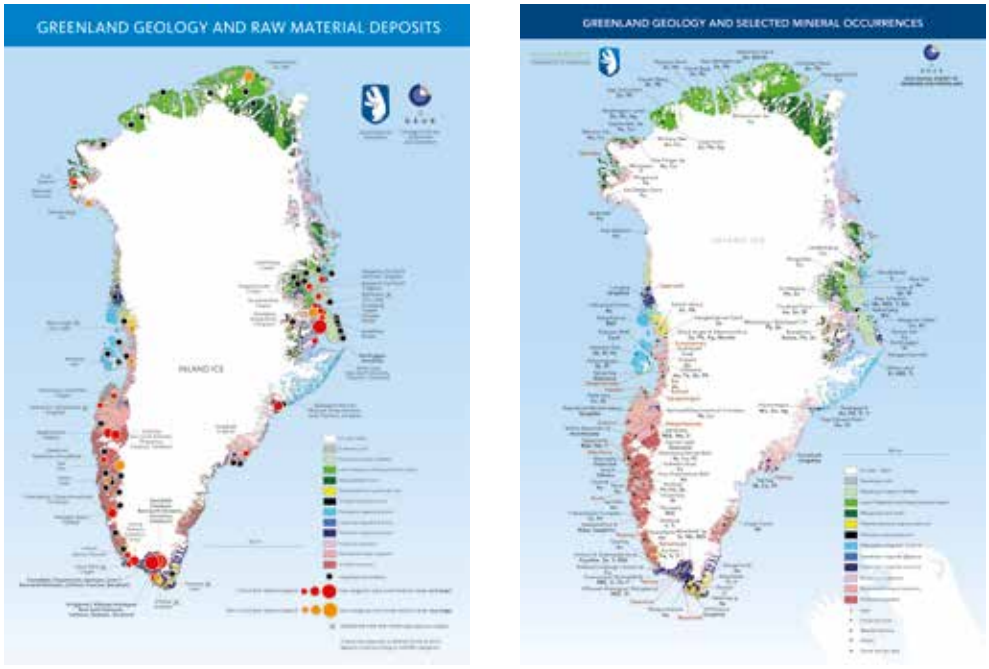


Fig. 22 and Fig. 23. Resource maps of Greenland[57]

4.4.3. Arctic (excluding Greenland)

The Arctic is the area of the Earth surrounding the North Pole. The Arctic includes parts of Russia, Canada, Norway, Sweden, Finland, Alaska (United States), Greenland (Danish territory), Iceland, and the Arctic Ocean. **The legal status of the Arctic has not yet been regulated by any international agreement.** The dispute over the division of the Arctic has been going on for years. So far, each of the countries bordering it has made claims. Since 1925, Canada has been applying **the so-called sector theory,** according to which a country whose territory is adjacent to the Arctic can claim all land areas in its sector, both discovered and undiscovered, but the boundaries of these areas are not mutually agreed upon (Fig. 24). The Arctic region is also of interest to the EU. On November 20, 2008**,** the European Commission adopted a communication **entitled "The European Union and the Arctic Region,"** which outlines the basic areas of action planned by the European Union, mainly in the field of protecting the natural environment and the people living in the Arctic region, researching and monitoring natural and anthropogenic processes, and promoting the sustainable use of the region's natural resources. The EU's policy towards the Arctic has been regularly updated since then. For example, the 2016 communication "An Integrated European Union Policy for the Arctic," adopted on April 27, 2016, or "A stronger EU engagement for a greener, peaceful and prosperous Arctic" of October 13, 2021[58] . These documents are perceived as the European Union joining the competition for the Arctic and its resources, which should not raise any objections in light of the current geopolitical and raw material situation in the world.

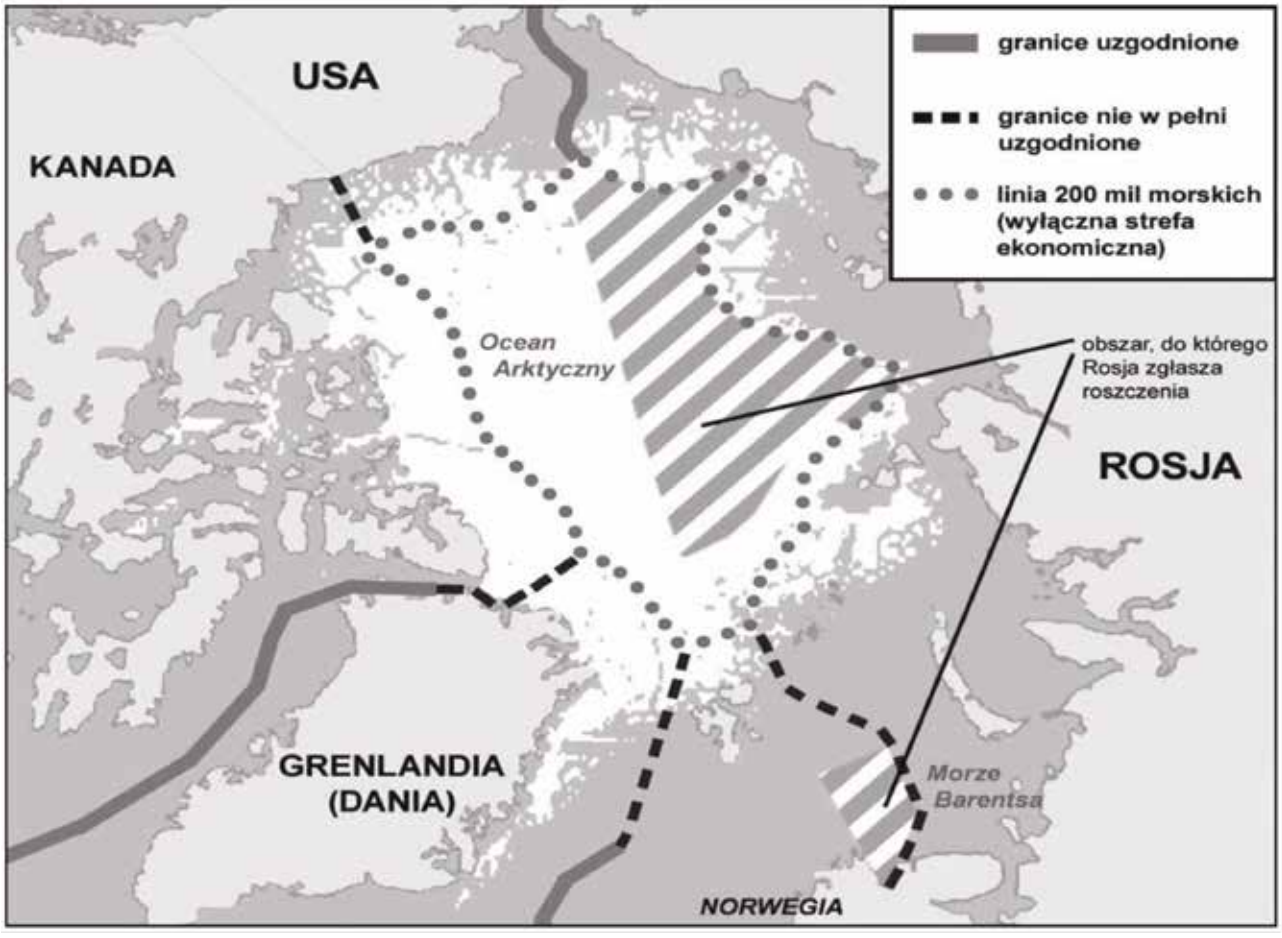


Fig. 24. The disputed area around the North Pole. According to Kijewski (2009)[59]

According to estimates by the United States Geological Survey (USGS), the Arctic (Fig. 25) contains **approximately 13% of the world's undiscovered oil reserves**, or approximately 90,000 billion barrels (12 billion barrels of recoverable oil), 5.9% of the world's oil reserves, as **well as approximately 30% of the world's currently known natural gas reserves** (50 trillion m^3)and **significant CRM deposits.** Most of these hydrocarbon resources, **approximately 84%, are located offshore.** According to a 2008 USGS estimate, more than one-fifth of the world's undiscovered oil and natural gas resources are located beyond the Arctic Circle. However, despite these huge reserves, all those interested in these areas continue to ask themselves whether the extraction of these resources in the Arctic is and will be profitable given the costs and extreme conditions. At the same time, the issue of climate change is also being discussed. Regardless of these conditions, a race for dominance in the Arctic is underway between the US, Norway, Russia, Denmark, and Canada.

Hydrocarbon exploitation in the Arctic may reach its peak within a few decades. However, this period may turn out to be longer, regardless of demand and prices for these raw materials, due to environmental and technical reasons (even with modern extraction technologies). The current political and economic situation in the world, the areas of influence of individual countries, and the melting of the ice cap around the North Pole may, in the long term, facilitate shipping in the region. This would be beneficial for Russia in terms of new opportunities for maritime exports of oil and natural gas from Siberia, but also for China, which is promoting cooperation between Arctic countries to build a "Polar Silk Road" for trade and research[59] .

Despite its extreme environment, the Arctic is an important historical resource region with great potential for new discoveries. Its geological structure is complex and has been shaped by virtually the entire history of the Earth, from the Archean era to the formation of the Arctic Ocean. Therefore, both the geological structure and the deposit conditions are complex, but there are no spectacular resources. The physical, human, and geographical conditions are also complex, which means that the costs of extracting minerals from the Arctic are significantly higher and the timelines longer than in many other parts of the world. The Arctic is also influenced by various countries with different policies, environmental sensitivities and ambitions. From the perspective of today's knowledge and political conditions, it is likely that the share of raw materials from the Arctic will not increase significantly in the near future, both in Western Europe and North America. However, everything depends on the speed and growth of demand for CRMs and REEs, the economic competitiveness of mineral supplies from the Arctic regions compared to supplies from the rest of the world, and the scale of government and public support in the Arctic countries.



Fig. 25. Map of the Arctic and adjacent areas from Andrews-Speed (2025)[60]

The Arctic accounts for more than 10% of global production of only three minerals: palladium (<44%), platinum (<13%) and nickel (<11%). In all three cases, **Russia is the main supplier of these raw materials**, with a large part of these supplies coming from the Russian company Nornickel's mines in the Arctic. Canada is the second largest supplier **of nickel** in the Arctic region. The Arctic supplies less than 5% of global demand for other key minerals: **cobalt** (<3.8%), copper (<4.1%), **graphite** (<1.5%) and REEs (0.7%). In each case, Russia is the dominant producer. It is also the leading producer **of gallium** (<0.8%), **germanium** (<3.6%) and **tellurium** (12%), which is also mined by Sweden (4%) in the Arctic. The data also show that the Arctic contains a relatively small proportion of the world's mineral reserves – less than 10% in all cases. Russia has the largest reserves there, especially REE (<9%), copper (<8%), platinum group metals (<7.8%) and nickel (<6%), and smaller shares of other minerals.

Table 5. The most important minerals and metals in the Arctic[60]

	Ore production		Ore reserves		Metal production	
Metal	**Arctic share of global**	**Key Arctic countries**	**Arctic share of global**	**Key Arctic countries**	**Arctic share of global**	**Key Arctic countries**
MOST CRITICAL						
Cobalt	<4.7% (<3.8%)	Russia <3.8%[14] Canada 0.9% (0%)[15]	<4.4% (<2.3%)	Russia 2.3% Canada 2.1% (?0%)		
Copper	<6.3% (<4.1%)	Russia <4.1%[16] Canada 2.2% (0%)[17]	<9% (<8%)	Russia <8% Canada 1% (?0%)	<4.8% (<3.7%)	Russia 3.7% Canada 1.1% (?0%)
Gallium					<0.8%	Russia <0.8%[18]
Germanium (2021 data)					<3.6%	Russia <3.6%[19] Canada (?0%)[20]
Graphite (natural)	<1.7% (<1.5%)	Russia 1%[21] Norway 0.5% Canada 0.2% (0%)[22]	<7.3% (<5.0%)	Russia 5.0% Norway (0.2%) Canada 2.0% (?0)		
Indium					4.2%	Canada 3.7% (?0%)[23] Russia 0.5% (?0%)[24]
Lithium	1.9% (0%)	Canada 1.9% (0%)[25]	<3%	Canada 3% (?0%)		
Manganese	0%		0%			
Nickel	<11%	Russia <6%[26] Canada <5%[27]	<8.1%	Russia <6.4% Canada <1.7%		
Palladium	<51% (<44%)	Russia <44%[28] Canada <8% (0%)[29]				
Platinum	<16% (<13%)	Russia <13%[30] Canada 3% (0%)[31]				
Platinum Group Metals			<8.2%	Russia <7.8% Canada 0.4% (?0%)		
Rare earth metals	0.7%	Russia 0.7%[32]	<11%	Russia <9% Greenland 1.4% Canada 0.8%[33]		
Tellurium					20% (<16%)[34]	Russia <12%[35] Canada 4% (0%)[36] Sweden 4%[37]

The Arctic, however, makes a small contribution to global supplies of raw materials of lesser economic importance. The exception is **vanadium** (<20%), which comes entirely from Russia. **Silver** is supplied by Arctic Russia and Alaska (<8.4%). Arctic Russia also accounts for 6.4% **of the world's phosphate**, with Finland accounting for a further 1.4%. Finland also supplies 5% of the world's **chromium ore** production**. Selenium,** which is a by-product of copper or zinc refining, comes from Russia and Sweden (together they supply up to 10.2%). The Arctic has fairly high global reserves of vanadium (<26%) and silver (<19%). In the case of other metals, most of the reserves are located in Arctic Russia. The exception is **chromium,** of which Finland has the largest reserves.

Regionally (Fig. 25), the situation is roughly as follows: The United States – **Alaska** – has been mined and still has deposits of copper, silver, gold (e.g., Kennecott); lead, zinc, and silver (e.g., Red Dog); chromium. However, with a few exceptions, these mines have long been closed or blocked for environmental reasons (**e.g., the Pebble deposit is the world's largest undeveloped deposit of copper and gold, as well as molybdenum, silver, and palladium).**

In **Canada,** the most important regions are: Raglan and Nunavik, Quebec: nickel, copper, platinum group metals; Keno Hill, Yukon: silver with lead and zinc. In **Norway,** where mining has a minimal share of Norway's GDP, some CRMs are mined in the Arctic. In Kvannevann – manganese with iron ore, in Skaland: graphite (approx. 0.5% of world production). There are plans to start mining deposits such as copper, cobalt, nickel, vanadium, platinum group metals and REEs, and even to reopen long-closed mines, e.g. in Svalbard. Central and southern Norway have potential for copper, cobalt, and nickel mining, and there is additional potential for REEs in the south.

In **Sweden,** mining traditions date back to the Viking era (e.g., the Falun copper mine over a thousand years ago). Iron ore has been mined since the 17th century. The production of other elements, such as copper, gold, silver, lead, and zinc, began in the second half of the 20th century. Many of these mines have already been closed, but several are to be reopened. Mining contributes less than 1% of Sweden's GDP. A large part of Sweden lies north of 60° N and almost all of it is used for mining and mineral extraction. In the Arctic regions, exploration is carried out in: Garpenberg (copper and silver with lead and zinc); Lovisa Gruven (silver with lead and zinc); Renstrom, Kristineberg, and Kankberg (copper, tellurium, and silver with lead and zinc), Björkdal (copper with lead and zinc); Kiirunavaara and Leveäniemi (phosphate with iron ore); Aitik (copper and silver). With the exception of the large Aitik mine , production from these mines is small. Arctic Sweden does not contribute significantly to global production and does not have reserves of any critical mineral ores. **The most important discovery announced in 2023 was a potentially large deposit of rare earth metals** (Per Geijer with reserves of approx. 1 million tons) near the Kiruna iron ore mine in the far north of Sweden. However, it is argued that the exploitation of this deposit will exacerbate the damage already caused to the way of life of the indigenous Sami people by the iron mine in Kiruna.

Almost all **of Finland** lies in the Arctic. Active mines in Arctic Finland extracting key minerals include: Talvivaara: copper, cobalt, and nickel with zinc; Sotkamo: silver with lead and zinc; Chemia: chromium; Kevitsa: copper, nickel, cobalt, and platinum group metals; Siilinjärvi: phosphate. Finland is currently a significant producer of chromium ore, accounting for 5% of global production and holding 1.5% of global reserves. The country also mines 0.4% of global phosphate resources and holds 1.4% of reserves. Finland also has reserves of cobalt, platinum group metals, REE, manganese, chromium, nickel, tellurium, and vanadium. Several mines in Finland are being reopened, particularly for the extraction of copper, vanadium, and titanium. Several exploration projects are focused on copper, nickel, and platinum group metals. A large mine is being developed in Sakatti, Lapland, where copper, nickel, and platinum group metals are mined. Other exploration projects focus on REEs, vanadium, manganese, and phosphates. However, there is a view that, as in the Arctic region of Norway and Finland, the expansion of mining in Finnish Lapland threatens the environment and the way of life of the Sami people, which may limit the development of mining.

Russia has the largest area of the Arctic and the largest territorial claims (Figs. 24 and 25). It is also currently one of the world's largest producers of many products. **Mining accounts for about 12% of Russia's GDP.** Active mines in Arctic Russia extract key raw materials and minerals in Dukat, Magadan region (silver), Kupol, Chukotka region (silver with gold); Pavlov, Novaya Zemlya (silver with lead and zinc); Talnach, Taymyr Peninsula (nickel, copper, cobalt, platinum

group metals, silver, selenium, tellurium), Zhadanov, Kola Peninsula (copper, nickel, phosphate), Northern Urals region (rare earth metals, aluminum (bauxite), Central Timan region (rare earth elements, gallium, vanadium, aluminum (bauxite), Kovdor (phosphate). Russia accounts for a significant share of global production and reserves of key elements. According to , the most important elements mined in the Arctic include palladium (<44%), platinum (<13%), nickel (<6%), copper (<4.1%) and cobalt (<3.8%). It also produces small amounts of graphite (<1.0%) and REEs (0.7%). Russia has significant resources in the Arctic, especially rare earth elements (<7.8%). The Tomtor deposit in Yakutia has great potential for increasing REE production, but the development of the mine faces technological challenges. Among by-products, Russia produces gallium, germanium, indium, and tellurium. Only in the case of tellurium does Arctic mining appear to be significant. Russia is also a significant producer of aluminum (bauxite, <1.5%), phosphates (<6.4%) and silver (<4.6%).

Russia's vast mineral resources give it the opportunity to play a dominant role in the supply of key minerals. Western sanctions have caused Russian companies to increase exports of metals such as copper, aluminum, and nickel to China. A key priority for the Russian government is to strengthen the domestic mining industry in order to develop the economy and supply raw materials for the arms industry, but also for export. The Arctic appears to be a key region for the implementation of this strategy, but challenges such as the lack of modern technology and transport infrastructure pose serious obstacles to the rapid development of new deposits and, in many cases, the expansion of existing mines[56].

Today, Russia has a dominant position in the Arctic in many respects. It has the world's largest fleet capable of sailing year-round in the extreme conditions of northern waters and maintains dozens of military bases beyond the Arctic Circle. The US has one base in the Arctic: an airport on leased land in northern Greenland. Russia has deployed new troops in the north, increased submarine activity, and begun patrolling the Arctic skies with its aircraft, which routinely violate NATO airspace. These actions, along with those taking place in Ukraine, appear to reflect global ambitions. It is important to note that the northern territories are home to over 2 million Russians, including large cities such as Murmansk and Norilsk, which account for about a quarter of the population of the Canadian and American parts of the Arctic. In the United States, the largest Arctic city is Utqiaġvik, formerly Barrow (4,000 inhabitants). Russia sees the Arctic as a strategic resource and territorial base, but the lack of infrastructure, harsh climatic conditions and the aforementioned changes, which may transform the Arctic, are major obstacles to its development. In terms of raw materials, all these factors make access to resources present in the Ukrainian, much easier, which, as already mentioned, should be considered in the context of Russian aggression against this country.

China, whose expansion there is also visible, has a slightly different view of the Arctic. It sees this area solely in terms of resources, not territory, and wants to be present there to "keep its finger on the pulse." In addition to investing in Russian oil and gas, China is particularly interested in gaining access to new waterways that could shorten transport times between Asian and European ports by as much as two weeks. It is interested in and promotes cooperation between Arctic countries to build **a "Polar Silk Road**."

The areas discussed have been known for years as raw material areas with varying degrees of exploration, mainly due to geographical conditions. All of them, except for raw materials, have a complex cultural and geopolitical situation to varying degrees. Greenland, despite its unequivocal declaration of geopolitical neutrality, has become an important element of global rivalry. The discovery of raw materials does not necessarily determine whether their extraction will begin. This depends on local conditions and actual possibilities and needs.

Ukraine has a more complex situation, which may be partially resolved by the raw materials agreement signed with the US, but its implementation may pose a number of problems for the Americans.

The most realistic option is the continuation of raw material exploitation in the Arctic, where it is already underway. However, announcements regarding the reactivation of mines in Alaska or Norway may end in failure due to technical, environmental, and cultural reasons. The actions of the US, which is intensively seeking access to raw materials and safe investment havens, are obvious, especially since raw material projects are encountering problems within the US itself, such as the Resolution Copper project in Arizona,

with reserves of around 18 million tons of copper and molybdenum, which has been blocked by the indigenous inhabitants of the land Apache San Carlos, pointing out that the project area is sacred land of the tribe[60].

Russia's goal is to expand the spectrum of available raw materials, but it is limited by technology and the ability to quickly access deposits. Therefore, it is looking for areas where it is easier to develop activities than, for example, in the Arctic.

China is in a fairly good position, benefiting from long-term activities in, for example, the Arctic, Africa, and within China itself. These have brought the planned results, but intensive exploitation and processing of raw materials on its territory is becoming problematic due to the by-product of environmental degradation.

All areas are important in terms of raw materials, but differ in terms of access and development opportunities. A good example of this is the natural resources of Norway, Sweden, Finland, and Greenland (Denmark), whose development often conflicts with Scandinavian environmental sensitivities. It is difficult today to clearly assess which of these values will prove more important in this context and whether the plans for the exploitation of raw materials in these countries will be able to be implemented, even in a situation of raw material shortages.

5. Critical raw material mining projects – conditions, opportunities, and barriers

5.1. Technological, regulatory and environmental barriers – a European perspective

The development of critical raw material mining projects in Europe plays a key role in the context of raw material security, energy transition, and the growth of modern industrial sectors. However, the infrastructure and regulatory environment in Europe are not keeping pace with the growth forecasts for key raw materials, which have already been mentioned several times, resulting in serious delays and barriers to investment[61].

One of the main problems is technological barriers. Europe lags behind countries such as Australia, Canada and the United States in terms of technical infrastructure, access to equipment and engineering skills. According to data from the EIT RawMaterials report (2023), **there are only about 20 active *junior mining* companies** in **Europe, compared to over 200 in the US, Canada, and Australia.** Only 5% of global rare earth metal projects are currently being developed in Europe, which indicates low exploration potential compared to the global average. The development of critical raw materials mining in Europe faces a number of significant technological barriers that effectively limit the European Union's ability to build raw material sovereignty and become independent from imports from third countries. Despite clear political ambitions, as expressed, among others, in the European Raw Materials Strategy and the CRMA Regulation, **the actual implementation possibilities are limited by complex technological, infrastructural, and educational conditions**[62].

The most serious challenge therefore remains **the limited availability of effective technologies for the exploitation of poor and geologically difficult deposits**. Unlike the rich deposits in South America and Africa, many European resources of lithium, cobalt, rare earth metals and antimony are found in hard rock or in the form of minerals that are difficult to process (e.g., spodumene, bastnasite, monazite). For example, most European lithium deposits, occur as *hard rock*, which requires energy-intensive and costly pyrometallurgical or hydrothermal processes, unlike the much cheaper exploitation of brines in Chile or Argentina. Such barriers effectively reduce the profitability of European projects – according to Eurogeosurveys, **the average cost of lithium production in Europe is 35–50% higher than in non-EU countries**[63].

The second major obstacle is **the poorly developed infrastructure for the processing and refining of strategic raw materials**. Even if lithium, graphite or nickel were mined locally, their further processing into secondary raw materials – essential for battery production – often has to take place outside the EU, mainly in China or South Korea. For example, according to a report by the European Raw Materials Alliance, **as much as 97% of rare earth metal refining currently takes place in China,** even though Europe has its own deposits (e.g., the Norra Kärr project in Sweden and Kvanefjeld in Greenland, which is a dependent territory of the EU). Technological limitations also apply to graphite processing – only 1% of global battery anode production from natural graphite comes from Europe[64].

An additional problem is **the technological gap in deep-sea mining and seabed exploitation** (see section

6.1). Although the European Commission has declared its support for the sustainable use of raw materials from the oceans (*Deep-Sea Mining*), Europe has virtually no technological infrastructure or commercial facilities to carry out such operations. Areas potentially rich in manganese, cobalt, and nickel in the waters around the Azores and in the Mediterranean remain unexploited, mainly due to the lack of suitable vessels, deep-sea robotics, and marine environment monitoring systems. Countries such as Japan and China are much more advanced in this field, with a fleet of research and mining vessels and developing technologies for the automation of underwater work.

Technological limitations also have a human dimension. **Europe suffers from a chronic shortage of skills in mining engineering, process metallurgy and strategic geology**. Eurostat data shows that **the number of graduates in mining and raw materials has fallen by more than 60% since 2000, and the average age of a mining engineer in the EU is over 50.** By comparison, in **Canada and Australia, the technical education system has been integrated with raw materials policy, enabling these countries not only to develop their own deposits, but also to export know-how and technologies.** The EU also lacks specialized support programs for young scientists in the field of modern mining, which translates into a generation gap and difficulties in implementing innovations[65].

Low levels of digitization and automation are another technological limitation. In many EU countries, mining processes are still based on 20th-century technologies—mainly mechanical, without integration with monitoring systems, real-time geological modeling, or energy consumption management. Although Nordic countries such as Sweden (e.g., the Boliden mine) and Finland (e.g., Terrafame) are testing Mining 4.0—based on automation, robotics, and SCADA systems—in Central and Southern Europe, such solutions are only being implemented on a pilot basis, and cost barriers and lack of access to specialized solutions are effectively slowing down the process.

Limitations in the transfer of technology from laboratories to industry should also be pointed out. Europe lacks so-called intermediate infrastructure, i.e., pilot and demonstration facilities where new methods of metal extraction, purification, and recovery can be tested on a semi-industrial scale. As a result, many innovative solutions developed, for example, under *Horizon Europe* programs, do not find practical application in industry. By comparison, the **US and Canada have** *raw materials hubs* where research institutes and companies jointly test and implement new technologies with active state support.

Finally, **low efficiency in recovering metals from waste, known as *urban mining***, remains a serious technological barrier. Europe has declared that by 2030, 15% of lithium and 25% of cobalt used in battery production should come from recycling, but current technical capabilities are far from achieving these goals. The main problems are: material heterogeneity of used products (e.g., batteries, magnets, electronics), lack of component standardization, and the complexity of separation processes. In practice, this means that even if raw materials are found in used devices and vehicles, their recovery is economically unviable or technologically impossible without quality losses.

Technological barriers to the development of mining in Europe do not stem from a lack of raw materials, but from a lack of a systematic approach to technology, skills, and infrastructure. **Coordinated action is needed at EU and member state level: greater investment in R&D, the development of test centers, training programs, and active support for knowledge transfer between science and industry.** Without this, Europe will not be able to compete effectively with countries outside the EU or secure its own strategic needs in the era of energy transition.

The development of critical raw materials mining in Europe is not only hampered by technological issues, but equally, if not more, by **complex and often inconsistent regulatory frameworks at national and EU level**. Regulatory barriers are one of the main reasons why many mining projects in Europe never make it past the conceptual stage, even though they formally fit into the EU's strategic objectives, such as the Green Deal, the energy transition, and the development of raw material independence. In the absence of appropriate reforms, it is legal regulations – rather than a lack of resources – that may prove to be the key constraint on European mining in the 21st century. An analysis of the average time taken to obtain environmental decisions and mining permits in selected countries shows drastic differences.

The most significant regulatory barrier is **the length and unpredictability of the permit granting process**. According to European Commission data, **the average time for obtaining all necessary environmental and**

mining permits in the EU exceeds 10 years. In Poland, the entire process can take as long as 7 to 14 years, **while in Canada it takes only 2–3.5 years, and in Australia 1.5–2.5 years.** These delays are mainly due to conflicts over local spatial development plans (MPZP), protests by non-governmental organizations, multiple court appeals, and water and environmental regulations that are not in line with the realities of mining. What is more, the process is scattered across many institutions: from the municipal and regional levels, through national ministries, to EU environmental supervisory bodies. As a result, investors are forced to repeatedly submit documentation, adapt to changing interpretations of regulations, and conduct lengthy consultations, which often end in the refusal or withdrawal of permits after they have been issued.

Another obstacle is **the lack of harmonization of regulations between Member States**. Despite the functioning of the single market, procedures for granting mining concessions, environmental impact assessments (EIA), agreeing on reclamation plans, and obtaining water law permits vary significantly from country to country. For example, while EIA procedures are relatively transparent and predictable in Finland, there is considerable decision-making opacity and a high risk of political intervention in Portugal and Romania. These differences not only hinder the planning of cross-border investments, but also create a phenomenon known as "forum shopping",i.e., the preference for jurisdictions with less stringent requirements, which may undermine the coherence of the EU's raw materials policy.

Another significant problem is **the discrepancy between raw materials policy and environmental and biodiversity policy**. Regulations such as Natura 2000, the Habitats Directive and the Birds Directive, although fundamental from a nature conservation point of view, often conflict with the location of strategic raw material deposits. Examples include blocked projects where deposits overlap with areas under strict habitat protection. In **Central and Southern Europe, over 30% of potential lithium and REE deposits are located in areas subject to some form of nature protection, which significantly complicates the investment process.** In practice, this means that the EU's climate goals (decarbonization, electromobility) may be difficult to achieve with the current level of environmental regulations.

Added to this is **the lack of uniform and binding standards for investors' environmental and social responsibility**. Although ESG guidelines exist, national requirements for investors vary significantly, from very strict (e.g., Germany, Austria) to relatively lenient (e.g., Bulgaria, Greece). **The lack of common criteria for assessing social impacts** (e.g., loss of land value, impact on public health) means that administrative decisions are often opaque and local communities have limited trust in the procedures. In the absence of transparency, even projects with high potential, such as Jadar in Serbia and Barroso in Portugal, are halted as a result of public protests, which often stem from unclear regulations and a lack of real dialogue.

Regulations on land use and regional planning also constitute a serious constraint. In many EU countries, there is **limited scope for changing local land use plans for mining investments**, especially if the deposit is located in agricultural, environmentally valuable or tourist areas. Outdated or insufficiently flexible spatial plans block access to resources that are crucial for the EU's security of raw materials.

Finally, **the lack of a single, comprehensive supervisory authority for CRM projects** should be mentioned. The current decision-making model, based on scattered competences between the ministries of energy, climate, environment, investment, and economy, not only causes delays but also leads to conflicting objectives. It happens that one ministry supports a project as part of an industrial strategy, while another blocks it on environmental grounds. In practice, investors get lost in administrative structures, and citizens are unclear about who is responsible for the final decision.

In summary, regulatory barriers to the development of European mining stem not so much from an excess of legislation as from its inconsistency, fragmentation, and failure to keep pace with the realities of the raw materials transition. **It is necessary to establish uniform, transparent procedures at the EU level that will, on the one hand, ensure the protection of the environment and social interests and, on the other, allow for the efficient and predictable launch of strategic projects.** Only then will Europe be able to achieve the ambitious goals of the Green Deal without becoming dependent on third countries for key resources. In the context of the development of European mining of critical raw materials,

environmental barriers play a particularly complex and multidimensional role. They are not solely the result of existing nature conservation legislation, as might appear from a regulatory perspective, but are largely linked to deeply rooted social attitudes, geographical conditions, conflicting policy objectives, and the complexity of Europe's natural landscape. As a result, environmental factors often act as a "soft veto" against projects which, although formally feasible, encounter a permanent decision-making impasse and implementation blockages.

Firstly, **Europe is a highly urbanized and spatially developed continent**. Even in areas potentially considered „peripheral" agricultural and recreational functions dominate or are subject to various forms of nature conservation. In such conditions, any new mining project, regardless of its scale, means a collision of spatial interests. An example is **Barroso in Portugal,** where a planned lithium mine is adjacent to areas of traditional agriculture and rural tourism, and is also located within the Natura 2000 network. The situation is similar in **Cínovec in the Czech Republic** and Zinnwald in Germany, where lithium mining takes place on the border of nature reserves and areas of high natural value. This means that even if formal approvals are obtained, the project faces real environmental barriers resulting from spatial, landscape, and ecological constraints.

Another barrier is **high public expectations regarding environmental protection and Europe's "green identity**." Over the past two decades, European societies have developed a strong environmental awareness, which manifests itself not only in climate demands but also in opposition to any form of interference with local ecosystems. In this context, the mining project becomes a symbolic threat—not only to nature, but also to social values such as lifestyle, landscape aesthetics, and natural and cultural heritage. The case of the **Jadar** project **in Serbia,** where the local community, despite assurances that environmental standards would be met, feared the degradation of the Jadar River and the loss of biodiversity in the valley, is an example of a situation in which environmental factors become emotionally "non-negotiable."

Another significant obstacle is **the lack of standards and tools for reliable, transparent, and comparable assessment of the environmental impact of investments**. In many EU countries, EIA (Environmental Impact Assessment) procedures are based on inconsistent criteria, and their results are difficult to communicate in a socially understandable way. What is more, even a positive environmental assessment does not guarantee acceptance, as it is often viewed by the public as subservient to the interests of the investor or the state. As a result, due to a lack of trust, environmental barriers are not so much formal and legal in nature as they are perceptual and socio-communicational.

Another important aspect is that **many mining projects are located in hydrologically sensitive areas**. The threat to surface and groundwater is one of the main arguments against investment, especially in the case of projects requiring significant amounts of water (e.g., lithium leaching, rare earth separation). In regions affected by climate change and drought, such as southern Portugal and southern Spain, competition for water resources is becoming a serious flashpoint. In Serbia and Romania, protests against the Jadar and Roșia Montană projects were largely motivated by the risk of drinking water contamination and destruction of river habitats.

Barriers related to reclamation and long-term environmental responsibility cannot be overlooked either. In Europe, unlike in many developing countries, local communities expect not only minimal damage during exploitation, but also comprehensive landscape restoration and site protection after the end of operations. The lack of clear reclamation plans, *reclamation bonds*, and reliable financial guarantees often leads to concerns that investors will abandon the site after the deposit has been exhausted. Examples of abandoned post-mining areas in eastern Germany and Romania remain in the public memory as a warning.

Finally, growing tensions between environmental protection goals and climate priorities create a conceptual barrier. **In theory, mining for critical raw materials is supposed to support the green transition by providing materials for batteries, wind turbines, and renewable energy infrastructure. In practice, however, local projects are often perceived as "dirty" and contrary to the idea of sustainable development.** This perceived contradiction – between short-term environmental costs and long-term climate goals – remains unresolved in public and administrative debate, hindering decision-making.

Environmental barriers to mining development in Europe are not limited to formal regulations. They are systemic in nature and result from a complex interplay

of natural, social, and cultural factors. Overcoming them requires not only technologies that minimize environmental impact, but above all **a new approach to spatial planning, social dialogue, and institutional trust**. Without this, even the most "green" mining projects may remain only on paper. Between 2015 and 2023, many European projects were blocked due to NGO campaigns and local community protests. However, there are also positive examples. In Finland, the Keliber Oy lithium mine project was implemented in full cooperation with the local government and the community. The investment resulted in the creation of 600 jobs, a drop in unemployment from 12.5% to 4.8%, and the development of mining-related services. A key factor in the success of the project was the early stage of public consultation and the involvement of local companies and institutions in the project. This model could serve as a reference point for other EU countries[66].

In the context of the challenges facing the European critical raw materials sector, the implementation of the **CRMA** is an important step towards improving the situation. It provides for a number of measures to speed up and simplify administrative procedures for investments in mining projects of strategic importance. One of the key objectives is **to reduce the duration of** permit granting **procedures** to a maximum of 27 months, which in the current reality is a significant reduction compared to the average time exceeding a decade. At the same time**,** the regulation provides for **support for exploration geology,** including the creation of geological databases and the stimulation of exploration projects, as well as the launch of dedicated financial instruments to support investments throughout the supply chain, from extraction to processing and recycling.

Another positive sign is **the growing interest of foreign investors, especially from the US and Canada, who are increasingly looking to Europe as a potential location for raw material projects**. Despite existing regulatory and social difficulties, the region is perceived as politically stable, technologically advanced and with significant geological potential. However, the effective implementation of these investments requires the removal of fundamental institutional barriers, such as opaque procedures, fragmented administrative competences, and the lack of clear and binding standards for mining projects.

In summary, **Europe has real potential – in terms of geology, technology and industry – to become an important link in the global supply chain for critical raw materials**. However, without far-reaching administrative and legal reforms, strengthening the education and science sector's expertise in geology and mining engineering, and effectively countering disinformation and campaigns that destabilize investment projects under the pretext of environmental protection, these opportunities may remain untapped. The experiences of countries such as Finland and Sweden, which are successfully implementing sustainable models for the development of the mining sector , show that change is possible – provided that decisive, coordinated and long-term action is taken at both EU and national level.

5.2. "Social License to Operate" – social legitimacy of raw material investments

In the 21st century, the functioning of the extractive industry – especially that related to critical raw materials – does not depend solely on regulatory permits or the availability of technology. *The so*-called *social license to operate (*SLO), i.e.**, the informal consent of the local community to conduct mining or processing activities,** is becoming increasingly important**.** This **concept goes beyond the letter of the law – it encompasses trust, acceptance, and a sense of social justice in the relationship between the investor and the community.**

The concept gained popularity in the second half of the 1990s, initially in Canada and Australia, where conflicts over gold and nickel mines led to projects being shut down despite meeting environmental requirements. Since then, the concept of SLO has evolved and today is one of the basic criteria for assessing social risk in large industrial investments, especially in mining and energy.

In Europe**, the case of the lithium mine in Barroso, Portugal, is a textbook example of a lack of social acceptance despite meeting formal investment criteria**. The project, although strategic from the point of view of the EU's energy transition, met with enormous resistance from the region's inhabitants. The main concerns were landscape degradation, impact on water resources, and threats to local agricultural traditions. Although the investor, Savannah Resources, obtained environmental approval in 2023, ongoing protests and social conflicts led to its effective suspension[67].

An even more dramatic example is the **Jadar** project **in Serbia**, developed by Rio Tinto. This project was to be one of the largest lithium investments in Europe, with an estimated production potential of 58,000 tons of lithium carbonate per year. **Despite its enormous economic scale and declared support for the development of the region, the public reaction was vehemently negative**. Local protests, demonstrations in Belgrade, road and bridge blockades, and a wave of distrust towards the government and corporations led to the Serbian authorities canceling the investment plans in 2022. In response to Rio Tinto's actions, a documentary film *entitled "Not in My* Country" was also made, in which the authors showed how the local community effectively organized itself to repel a project that was perceived as imposed from outside, opaque, and devoid of real benefits for the residents[68] .

Both the Portuguese and Serbian cases fit perfectly into the broader phenomenon known as ***"Not In My* Backyard" (NIMBY)** – a situation in which the public generally supports energy transition but opposes specific investments in their immediate environment. This attitude has evolved into "*Not In My* Country," which is a refusal to accept any raw material extraction within a country's borders, despite its dependence on raw materials from countries with lower environmental and human rights standards. These attitudes, although socially understandable, lead to the so-called export of environmental damage and expose the hypocrisy of some countries' raw material policies.

However, this problem is not limited to Europe. In the United States, investments in the extraction of lithium and other raw materials are also facing strong public opposition, despite the federal government's strong support for the so-called "green transition." One example is **the Thacker Pass project in Nevada, developed by Lithium Americas. Although this project is considered the largest lithium deposit in the US, its implementation has been hampered for years by protests from indigenous peoples, farmers, and environmental organizations.** The investor has been accused of failing to consult properly, insufficiently assessing the impact on cultural heritage, and posing a risk to groundwater. Although most of the allegations have been dismissed by federal courts, the project remains politically and socially controversial[69] .

A similar situation occurred with **the Rhyolite Ridge project, also in Nevada,** led by Ioneer. Here, protests focused on the protection of an endangered endemic plant species, *Tiehm's buckwheat*. Environmental organizations demanded that the entire area be placed under federal protection, which significantly delayed the project. Protracted court and administrative proceedings exposed the investor to millions of dollars in losses.

The situation is no different in the case of the aforementioned joint **Resolution Copper project**, developed by Rio Tinto and BHP in Arizona. Despite advanced planning and support from state authorities, the project has been temporarily suspended due to opposition from the Apache tribe, which considers the investment site a sacred place. The dispute escalated to the federal level, involving the US Department of the Interior, which clearly shows that social and cultural issues are becoming as important as geological and business analyses.

The social legitimacy of mining projects, regardless of the region of the world, is now becoming a prerequisite for their feasibility.

Companies that ignore local sentiments, cultural values, and community needs are increasingly encountering resistance that can completely paralyze an investment. **Another example of such a failure is the Ajax project in Canada, developed by KGHM and Abacus Mining.** Although the project received a positive environmental assessment at the federal level, it was blocked by the British Columbia government after a local referendum in which 62% of Kamloops residents voted against the project. The community pointed to threats to the quality of life, health, and the local economy based on tourism. The investment was abandoned, and the Polish investor, despite complying with all formal procedures, suffered serious financial and reputational losses.

All these cases show that a social license to operate is not an addition to the formal licensing system, but one of the most important elements of investment risk assessment. Companies that focus on transparency, honest dialogue, stakeholder engagement, and real benefits for the local community—such as employment, revenue sharing, and social investment—are much more likely to succeed in the long term.

From a European perspective, the role of social acceptance will grow as the European Union's raw materials policy intensifies. The implementation of the Critical Raw Materials Act points to the need not

only to shorten formal procedures but also to deepen social dialogue. There is a need for consultation at the investment concept stage and for the creation of participatory mechanisms to strengthen trust between investors and the community. Only then will it be possible to reconcile the economic, environmental, and social objectives that are the foundation of Europe's energy transition and strategic autonomy.

5.3. Examples of European mining projects – successes and failures

The development of mining projects in Europe over the past two decades has been an arena of dynamic tensions between the ambitions of the energy transition, the need for raw material sovereignty, and socio-political realities. Below, we analyze several representative projects, both successful and unsuccessful, that shed light on the complex nature of European raw materials policy.

Success – Terrafame (Finland)

The Terrafame project in Sotkamo, Finland, is now recognized as one of the most successful examples of the transformation and modernization of the mining sector in Europe. It is a model combination of critical raw material extraction, climate goals, the battery industry, and environmental responsibility. Its history began with the problematic legacy of the Talvivaara mine, which, although innovative in concept, ran into serious financial and environmental problems, mainly due to poorly developed bioleaching technology and sulfate leaks into nearby waterways.

After the Finnish state took control through Suomen Malmijalostus Oy (Finnish Minerals Group), Terrafame Oy was established in 2015 with the task of not only continuing nickel, zinc, and cobalt mining, but also completely restructuring the management and environmental control model. State intervention made it possible to finance the necessary modernization of the plant, implement modern water treatment technologies, fully digitize operational processes and, crucially, rebuild social trust.

Terrafame now produces around 40,000 tons of nickel per year, making it one of the largest suppliers of this metal in the EU. At the same time, the company produces cobalt sulfate (around 5,000 tons per year) and zinc sulfate, which is mainly processed on site. In 2021, a *battery-grade* nickel sulfate production facility was launched, enabling the company to enter directly into the supply chain for European traction cell manufacturers. Terrafame's customers include companies from Germany and Sweden, including suppliers to Tesla and Volkswagen.

Terrafame's success is not only the result of technological modernization and state support. From the very beginning, the company has focused on transparency – regular environmental reports, open consultations with local residents, a real-time emissions reporting system, and online access to environmental data. In addition, it cooperates with the University of Oulu and Finnish polytechnics in the field of training personnel for the metallurgical sector and environmental analytics. A comprehensive system of compensation for damage to the local community and social investment mechanisms (CSR) have also been introduced.

In 2023, Terrafame received certification from the International Responsible Nickel and Cobalt Initiative (IRMA), confirming that its production processes comply with global ESG standards. This achievement not only increased the company's credibility among institutional investors, but also set a precedent for other European raw material projects.

Terrafame has become a symbol of how a project with a problematic start – with high social and environmental risk potential – can be transformed into a model for European mining in the 21st century. Key factors for success included strong public support, advanced environmental technologies, integration with the battery industry, transparency, and consistent building of public trust. Terrafame not only supplies strategic raw materials, but also demonstrates that European environmental standards can be compatible with profitability and market resilience.

Success – Cínovec Project (Czech Republic)

The Cínovec lithium project, located in northwestern Czech Republic, right on the border with Germany, is one of the most promising and advanced critical raw material mining projects in the European Union. The project is being carried out by Geomet s.r.o., a company owned by the Australian company European Metals Holdings (49%) and the Czech energy giant ČEZ Group (51%).

From the outset, the project has enjoyed strong support from both state institutions and local authorities, and its strategic importance was formally confirmed when it was included in the list of key CRMA projects by the European Commission in March 2024.

The Cínovec deposit is the largest known hard rock lithium resource in Europe. Total mineral resources are estimated at over 7.3 million tonnes of lithium carbonate equivalent (LCE), of which approximately 53 million tonnes are proven resources and over 360 million tonnes are indicated and estimated resources. From a technical point of view, the project is characterized by a high degree of geological exploration and very favorable mining conditions, including relatively shallow deposits and easy access to infrastructure. The planned annual production is 29,386 tons of battery-grade lithium hydroxide, which is expected to meet approximately 8% of the EU's total lithium demand by 2030. In addition, the deposit contains tin and tungsten deposits, which increase the economic value of the operation.

Several key factors have contributed to the success of the project. First, **a well-chosen public-private partnership.** The involvement of the ČEZ Group, a state-controlled company, has ensured not only financial stability (more than €29 million was invested at an early stage), but also political support and influence on decision-making institutions. From the outset, the project has been integrated into the Czech Republic's strategy for energy transition and raw material independence. Secondly, **the excellent location:** Cínovec is located in a region with a centuries-old mining tradition, which promotes public acceptance. In addition, its location close to the German border facilitates integration with the battery industry and electromobility in Central Europe. The project has direct access to rail, energy and industrial networks, which significantly reduces investment costs.

Another important aspect is **the sustainable approach to operational planning**. From the outset, Cínovec has been developed in accordance with high environmental standards. It is expected that the processing facilities will be partially powered by renewable energy sources, including photovoltaics, and in the longer term, integration with small modular reactors (SMRs) is being considered, which will enable a low carbon footprint to be achieved. In addition, the technological process has been optimized to reduce waste and enable its partial reuse in other industries. The investor is also conducting extensive information and consultation activities at, which translates into a high level of local acceptance.

It is also worth noting that the Cínovec project has attracted the interest of EU institutions and has been identified as a priority for funding under instruments such as *the Just Transition Fund* and *InvestEU*. This translates into the possibility of obtaining financing not only for the exploitation phase, but also for the development of the local industrial ecosystem, including processing, lithium research and development centers, and vocational training. The Czech Republic sees Cínovec as an opportunity not only to supply a strategic raw material, but also to build a complete value chain within the energy transition – from mining and processing to the production of battery components[70].

The success of the Cínovec project is not only due to the availability of a rich lithium deposit, but also to a comprehensive approach to investment: strong public-private partnership, effective project management, high environmental standards, and consistent public communication. Cínovec shows that even in the demanding regulatory environment of the EU, it is possible to develop a large mining investment in line with the principles of sustainable development and social acceptance. This project represents a real opportunity to strengthen European raw material security and reduce dependence on lithium imports from third countries, in particular from China and South America.

Failure – Barroso Lithium Project (Portugal)

The Barroso Lithium project, developed by the British company Savannah Resources in northern Portugal, aimed to create the largest lithium mine in Europe. The spodumene reserves in the Barroso region are estimated at around 28 million tons, which could meet a significant part of the European Union's demand for lithium needed to produce batteries for electric vehicles. Despite a positive environmental decision issued by the Portuguese environmental agency APA in May 2023, the project faced strong public and legal opposition, which effectively blocked its implementation.

The main controversies surrounding the project concerned its **location in the Barroso region, recognized by the FAO as a Global Important Agricultural Heritage System** (GIAHS). Residents of

the village of Covas do Barroso and the surrounding villages feared the negative impact of the mine on the environment, including water resources, the landscape, and traditional agriculture and livestock farming. Protests by local communities, supported by environmental organizations, gained momentum, leading to blockades, demonstrations, and legal action to stop the project.

In addition, the project became embroiled in **a corruption scandal** that led to the resignation of Portuguese Prime Minister António Costa in November 2023. The investigation, known as "Operation Influencer" concerned irregularities in the granting of concessions for the extraction of lithium and hydrogen, including the Barroso project.

Despite attempts to improve relations with the local community, including changes in company management and the opening of local offices, Savannah Resources failed to win over residents to the project. In February 2024, the Portuguese public prosecutor's office filed a request to annul the environmental decision for the project, citing legal violations and insufficient environmental risk assessment.

The failure of the Barroso Lithium project was due to a lack of public acceptance, insufficient communication with local communities, and legal and political controversies. Despite the potential economic and strategic benefits for the European Union, the project failed to gain the trust of the region's residents, which ultimately led to its suspension.

Failure – Jadar Project (Serbia)

The Jadar project, developed by Rio Tinto in western Serbia, aimed to create one of the largest lithium mines in the world. A deposit of jadarite, a unique mineral containing lithium and boron, was discovered in 2004 in the Jadar River valley near the town of Loznica. It was estimated that **the project could supply up to 90% of Europe's lithium demand, making Serbia a key player in the supply chain for the battery and electromobility industries.** However, despite the potential economic benefits, the project faced strong **social and environmental opposition,** which ultimately led to its suspension.

In 2021–2022, Serbia experienced **mass protests against the Jadar project**. Thousands of citizens, supported by environmental organizations and the political opposition, expressed concerns about potential groundwater pollution, environmental degradation, and threats to agriculture in the region. The protests included road and bridge blockades, as well as demonstrations in Belgrade and other cities. In response to public pressure, the Serbian government withdrew all permits for Rio Tinto in January 2022, announcing the end of the project.

However, in July 2024, the Serbian Constitutional Court ruled that the government's decision to revoke the permits was unconstitutional, paving the way for the project to potentially resume. This decision was met with an immediate public reaction, with mass protests erupting again and demonstrators accusing the government of ignoring the will of the people and threatening the environment.

Faced with growing public opposition, the Serbian government announced in August 2024 a plan to hold **a referendum** on the Jadar project, scheduled for the end of 2025. Until then, all work on the project has been suspended. Despite Rio Tinto's attempts to convince the public of the benefits of the project, including organizing information sessions and publishing environmental impact assessments, public confidence in the project remains low.

The Jadar project has become a symbol of the conflict between economic interests and environmental protection and the rights of local communities. A lack of effective communication, insufficient consideration of public concerns, and legal controversies have led to the suspension of the project. This case highlights the importance of transparency, public engagement, and respect for the environment in the implementation of large industrial projects.

Failure – Roșia Montană Project (Romania)

The Roșia Montană project, planned by the Canadian company Gabriel Resources, aimed to **create the largest open-pit gold mine in Europe**, located in the historic region of Transylvania in western Romania. The deposits in this area were estimated at approximately 314 tons of gold and 1,500 tons of silver. The project involved the use of cyanide technology for the extraction of precious metals, which raised serious environmental concerns. Despite the potential economic benefits , the project faced strong public and legal opposition, which ultimately led to its cancellation.

The main controversies concerned the planned use of cyanide in the mining process and the need to destroy four mountains and resettle the inhabitants of three villages. In addition, the Roșia Montană area is known for its unique Roman mining galleries, which would have been destroyed as a result of the project. In 2013, **mass protests** against the project took place in Romania and abroad, involving around 200,000 people. These protests led to the rejection of the project by the Romanian parliament in 2014.

In 2021, the Roșia Montană area was inscribed on the UNESCO World Heritage List, effectively preventing any mining projects in the area. In response to the cancellation of the project, Gabriel Resources filed a lawsuit against the Romanian government, seeking $4.4 billion in damages. In 2024, the International Centre for Settlement of Investment Disputes (ICSID) dismissed the company's claims, ruling in favor of the Romanian government[71] .

The Roșia Montană project collapsed due to a lack of public acceptance, environmental concerns, and legal controversies. This case highlights the importance of transparency, social engagement, and respect for cultural heritage in the implementation of large industrial projects.

An analysis of selected mining projects in Europe, both successful and unsuccessful, reveals clear patterns contributing to their final outcomes. Although each project has its own geological, social, and economic characteristics, there are certain universal determinants that systematically influence the chances of success of raw material investments.

On the success side, such as Terrafame in Finland and Cínovec in the Czech Republic, **the synergy of three key pillars** comes to the fore**: institutional support, high environmental standards, and social acceptance**. In both cases, the involvement of the state, both financial and political, played a decisive role. In Finland, a state-owned shareholder took responsibility for the takeover and modernization of the problematic plant, restoring public confidence. In the Czech Republic, the state-owned energy company ČEZ not only invested in the development of the Cínovec project, but also enabled it to be included in the national and EU energy transition strategy. **The approach to public communication and transparency** was also important**.** Both Terrafame and Geomet (the operator of Cínovec) conduct extensive information campaigns, offering local communities not only knowledge about their plans, but also participation in the decision-making process. Transparency and environmental responsibility translate into social and political stability in the investment environment. It should also be emphasized that investment successes were associated with a high level of operational professionalism—modern technologies, energy optimization, ESG management, and integration with local research centers increase public and investor confidence.

On the other hand, **the failure** of projects such as Barroso in Portugal, Jadar in Serbia and Roșia Montană in Romania was largely **the result of a lack of social legitimacy, conflicts of interest and an incorrect assessment of the cultural and political environment**. In each of these cases, local communities were not only inadequately informed, but felt ignored and threatened. The projects were seen as imposed from outside – by large corporations or with political support from the government – without genuine dialogue or attempts to reach a compromise. In the case of Barroso, the project clashed with the local cultural identity and the region's status as an agricultural heritage area. In Serbia, investors underestimated the potential for social mobilization and distrust of foreign corporations, especially in the context of a lack of transparency in government actions. The Jadar project became not only an environmental conflict, but also a political and constitutional one. Roșia Montană, on the other hand, shows that ignoring aspects of historical heritage and attempts to use aggressive technologies (such as cyanide) in areas of high cultural sensitivity end not only in investment failure, but also in costly arbitration proceedings. Another common factor in these failures was **a lack of trust, both in investors and in state regulatory structures.** When the public does not believe in the intentions of investors and is unsure whether the state will stand by them in case of danger, immediate and difficult-to-reverse social resistance arises. What is more, most of the projects that ended in failure were characterized by a lack of flexibility and in responding to crises—no real changes in response to protests, too late information campaigns, or insufficient compensation for losses to local communities.

In light of the above, several fundamental conclusions can be drawn. **The success of a raw materials project in Europe does not depend solely on the wealth of the deposit or the level of strategic demand – it**

depends above all on how the project is embedded in the local social, cultural, and institutional context. Investors must consider social factors as equally important as technical and economic factors from the outset. Without social legitimacy (*Social License to Operate)*, even the best-designed mining project can be permanently blocked.

Faced with the energy transition and the need to diversify its supply of critical raw materials, Europe needs not only modern technologies and financial instruments, but also a new culture of investment based on trust, openness, and respect for the values of local communities. Otherwise, every subsequent project will repeat the mistakes of Roșia Montană, Barroso, or Jadaru.

6. Poland in European raw materials policy – potential and challenges

Although we know the global distribution of natural resources, which is the result of intensive geological research conducted since the 18th century, new deposits are still being discovered and documented on various continents. This is very clearly visible in the case of hydrocarbons, especially in Poland. **Almost every quarter is full of media reports on new discoveries of oil or natural gas deposits – raw materials which, despite the war and the cut-off of supplies from Russia, are not included in the EU list of critical and strategic raw materials.** Of course, the size of these deposits described in the media is small in relation to global reserves and discoveries, but it is worth emphasizing that these are the only raw materials that are being explored on such a large scale in Poland. The pursuit of a zero-emission economy seems to be overshadowing the importance of these raw materials in Europe, especially during a transition that is simply impossible without their use. It is worth emphasizing that **a just transition** must take into account the different conditions of individual EU member states, including the main raw materials on which electricity production is based in these countries. For example**, hard coal**, which is the main raw material used for electricity generation in Poland and is also used on a large scale in district and individual heating, is of strategic importance to the Polish economy.

At this point, it is worth noting the potential of Lubelski Węgiel Bogdanka, the most efficient hard coal mine in Europe.

In May 2023, LW Bogdanka announced a new strategy which, in addition to continuing energy coal mining until 2049, envisaged a wide-ranging diversification of its activities, one of the two pillars of which was to be the transformation of the company into a multi-raw material concern. This strategy was directly in line with global and European trends in securing access to critical raw materials and developing an industry based on sustainable mining. **Bogdanka planned exploration activities in over 20 locations, including the aforementioned potassium salts, non-ferrous metals, phosphorites, and even uranium, which was to enable the transition from a coal mine to a modern raw materials concern capable of serving the low-carbon energy sector, mineral fertilizers, and high-tech industries.**

This decision was consistent with the country's raw materials policy and EU initiatives such as *the Critical Raw Materials Act* and the industrial sovereignty strategy. Internationally, similar steps were taken by mining companies in Germany, Canada, and Sweden, which are transforming their operations from traditional mining to strategic raw material portfolio management. Bogdanka's 2023 strategy was therefore fully in line with the direction taken by the global mining sector today – moving away from coal monoculture towards the sustainable exploitation of non-energy raw materials.

However, in April 2025, the company published a strategy update that brought a significant change of direction. Plans to transform into a multi-resource company were abandoned, with a focus solely on optimizing coal mining and developing ancillary services. Although investments in sustainable industry and energy transition are still planned, plans to explore new resources have been withdrawn. As a result,

despite the fact that the country's geological potential remains unchanged, Bogdanka will not exploit it, at least at this stage.

However, it is worth noting that the earlier assumptions of the Bogdanka 2030 strategy were accurate and rational in light of the geopolitical and industrial challenges of the 21st century. The departure from these assumptions does not change the fact that Poland has significant reserves of strategic raw materials, the development of which – by other entities or, in the future, by Bogdanka – could strengthen the country's raw material sovereignty and support its industrial competitiveness in the era of energy transition.

In the case of crude oil and natural gas, these raw materials are both critical and strategic (see PSP 2050[74]), unlike the EU list of critical or strategic raw materials, where they are not included. It should be noted that the EU list of critical raw materials, in addition to 34 other raw materials, minerals and elements, **the EU list of critical** raw materials **also includes coking coal**, a raw material that is the basis for the production of coke, which is essential for activities in the iron and non-ferrous metal smelting, foundry, soda, graphite, lime, insulation materials and even agricultural industries, without which the energy transition would not be possible.

It is worth mentioning that Poland is home to the largest producer of coking coal in the European Union – Jastrzębska Spółka Węglowa, which plays a strategic role in ensuring the supply of this key raw material for the steel industry. **Unlike energy coal, coking coal is mainly used in the production of metallurgical coke and steel – a pillar of construction, automotive, critical infrastructure, and defense industries.** In the context of the changing geopolitical situation and EU industrial policy, JSW is currently in a unique position: it not only has operational resources and experience in mining, but also enormous potential for further development.

One of the key directions JSW should pursue is to increase its coking coal resource base through active exploration and investment in new deposits, both in the Silesia region and beyond. In view of growing tensions on global markets and the EU's dependence on coke imports from Asia, stable and secure sources of domestic raw materials are becoming not only an economic issue, but also a strategic one. JSW has both the infrastructure and organizational capital to become a mainstay of Poland's and Europe's raw material sovereignty in the field of coking coal.

The second, equally important direction for JSW's development should be the diversification of its revenue sources – not by abandoning its core business, but by intelligently expanding it. Here, strategic partnerships with other state-owned raw material giants, such as KGHM (non-ferrous metals) or Bogdanka, are a natural solution. This type of cooperation could allow JSW not only to enter new business segments (e.g., critical raw materials, metallurgical recycling), but also to jointly utilize know-how, infrastructure, and expertise in the management of large industrial projects. This would make it possible to build a complementary, stable industrial ecosystem based on domestic capital and resources.

The third and long-term direction of JSW's development should be to extend the value chain by moving from the position of a raw material supplier to a partner in the production of final steel products, especially those of strategic importance. JSW already has controlled companies producing coke and access to processing infrastructure, which creates the basis for the development of integrated chains for the production of high value-added steel components. Cooperation with the defense industry, both domestic (PGZ) and foreign, could enable the creation of a "steel corridor" for the production of weapons, armor, combat platforms, and strategic infrastructure components. **Given the scale of investment in the modernization of the Polish armed forces and the growing importance of the defense industry, this is a direction that could not only increase JSW's profitability but also strengthen national security.**

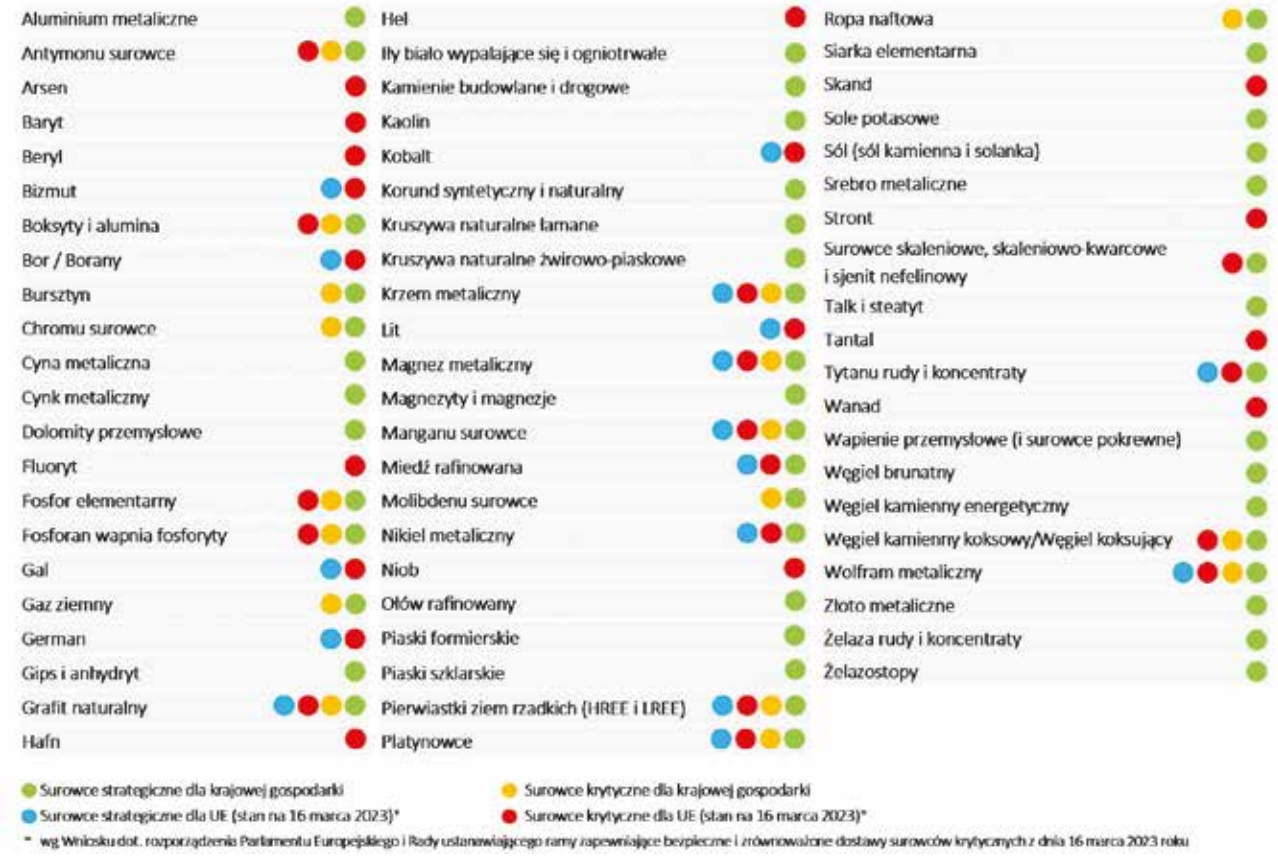
In summary, as Europe's largest producer of coking coal, JSW has a real opportunity to transform itself from a traditional mining company into a modern industrial entity with a broad portfolio of competencies and capital links. Increasing raw material resources, cooperating with other industry leaders, and entering new links in the production chain are actions fully in line with current global trends and EU industrial policy. In an increasingly uncertain world based on technological competition, the control over raw materials, JSW's transformation towards raw material and industrial integration may prove not only a necessity but also a strategic advantage for Poland.

6.1. Overview of the Polish raw materials sector

All documented resources can be found in the "Balance of mineral resources in Poland" published annually by the State Geological Service. It is available online at PIG-PIB[72] . The 2024 balance sheet contains information on **approximately 15,000 documented deposits.** Information on documented resources is grouped according to the type and intended use of the mineral. In the case of mineral deposits covered by mining rights, information on resources is presented broken down into individual resource exploration categories (A+B, $C_{(1)}$, $C_{(2)}$, D), together with information on off-balance sheet resources. These data are based on geological documentation of mineral deposits, approved and then sent by geological administration authorities (the minister responsible for the environment, provincial governors and county administrators) to the National Geological Archive. Similarly, information on changes in resources caused by mineral extraction is provided by deposit users in accordance with the provisions of the law[73] .

From Poland's point of view, **the Raw Materials Policy (PSP2050) adopted by the Council of Ministers on March 1, 2022**, is important. PSP2050 introduces a division into critical raw materials and strategic raw materials important from the perspective of the national economy and its proper functioning[74] . It is important to note that these raw materials have different references to the CRM (EU) list and different meanings for both the EU and Poland. A comparison of critical and strategic raw materials in the EU and Poland is presented in Table 6. The table shows that not all raw materials that are critical or strategic for the EU have the same significance for the Polish economy, and vice versa. Raw materials that are critical and strategic for the Polish economy are not of such importance on the CRM list. This is due to the different definitions adopted in PEP 2050 and CRMA.

Table 6. List of critical and strategic raw materials from CRMA and critical and strategic raw materials for the Polish economy [75]



These include graphite, metallic silicon, metallic magnesium, REE (HREE and LREE), platinum group metals, and metallic tungsten. Poland has significant resource potential, making it one of the most promising countries in Central and Eastern Europe in terms of opportunities for diversifying raw material extraction. In addition to hard coal, whose deposits are still of strategic importance, the country has proven and potential deposits of a number of raw materials, such as potassium-magnesium salts, phosphorites, rare earth metals, zinc, lead, uranium, gypsum, amber, as well as molybdenum and tungsten ores. These raw materials are particularly important in the context of the energy transition, the development of electromobility, renewable energy sources, and advanced technologies, i.e., areas considered key by the European Union and the OECD. Of course, many of these deposits are insufficiently documented, and therefore an ecosystem of support mechanisms for private companies from the *junior mining* sector needs to be built in order to exploit Poland's geological potential. Geological information obtained by private investors will be transferred to the Central Geological Archive, which will strengthen knowledge about Poland's resources and attract strategic investors.

As of today, **there are no documented REE deposits in Poland**, but elevated concentrations have been found in the Sudetes, near Szklarska Poręba, and in the Bogatynia area. In north-eastern Poland, on the Precambrian platform, there are two potential deposits, Tajno and Ełk, containing REEs, but the deposits are located at depths of around 1,000 m. Some small accumulations may occur in Baltic sands and in the Częstochowa and Świętokrzyskie regions, but they are also found in currently explored mine tailings.

Coking coal, which occurs alongside hard coal deposits, mainly in the Upper Silesian Coal Basin (Fig. 26, 80.06% of proven coal reserves are located within this basin). Currently, hard coal is mined in Poland in the Lublin Coal Basin and was mined until 2000 in the Lower Silesian Coal Basin (Wałbrzych region). It is impossible to consider coking coal resources separately from energy coal (these coals coexist). Therefore, in the "Balance Sheet," the balance sheet coal resources are jointly estimated at 64,596.29 million tons. Energy coal accounts for 70.97% (45,845.87 million tons), coking coal for 27.83% (17,974.29 million tons) and other coal for 1.2% (776.12 million tons). The resources currently being exploited amount to 43.93% of the total resources (28,376.22 million tons). Coking coal is mined by Jastrzębska Spółka Węglowa (JSW).

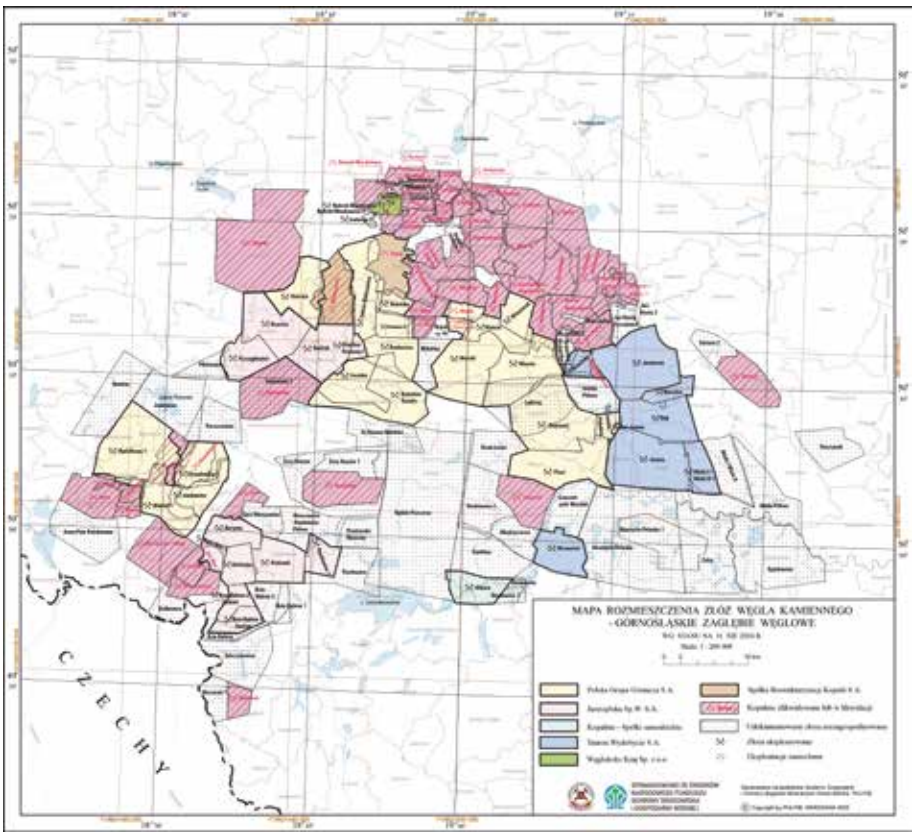


Fig. 26. Distribution of coking coal deposits mined by JSW and hard coal deposits mined by PGG and other mining companies. [76]

Copper and silver – in Poland, these metals are found in the world-famous Lubin-Głogów Copper Belt, Fig. 27 (Pre-Sudeten Monocline and North Sudeten Basin). Proven reserves in 17 deposits total 3,542.39 million tons of ore containing 56.92 million tons of copper and 164,730 tons of silver. The geological balance of Cu-Ag ore resources in deposits already exploited in the Pre-Sudeten Monocline amount to 1,487.46 million tonnes of ore with a content of 27.05 million tonnes of copper and 78.06 thousand tonnes of silver (a strategic raw material for the Polish economy).

In the recently published "*World Silver Survey* 2025" report prepared by The Silver Institute, **KGHM Polska Miedź S.A. ranked first in the category of "largest silver mines in the world" and second in the ranking of the largest producers of this metal, just behind Fresnillo in Mexico**. Silver production in the KGHM Group in 2024 reached 1,341 tons, of which 1,316 tons came from deposits located in Poland[77].

Copper deposits in Poland are the richest in the entire EU, with well-recognized and documented resources. These are polymetallic deposits—in addition to copper, silver is an equivalent component. They are accompanied by significant amounts of lead, zinc, cobalt, molybdenum, nickel, selenium, rhenium, gold, and platinum. Developed deposits currently under exploitation include Rudna, Sieroszowice, Polkowice, Lubin-Małomice, Głogów Głęboki-Przemysłowy, and Radwanice-Gaworzyce in the Radwanice Wschodnie area. All of the above-mentioned deposits are located in the Pre-Sudeten Monocline. The undeveloped deposits in the Pre-Sudeten Monocline and the North Sudeten Basin include: part of Radwanice-Gaworzyce, Bytom Odrzański, Retków, Wartowice[78].

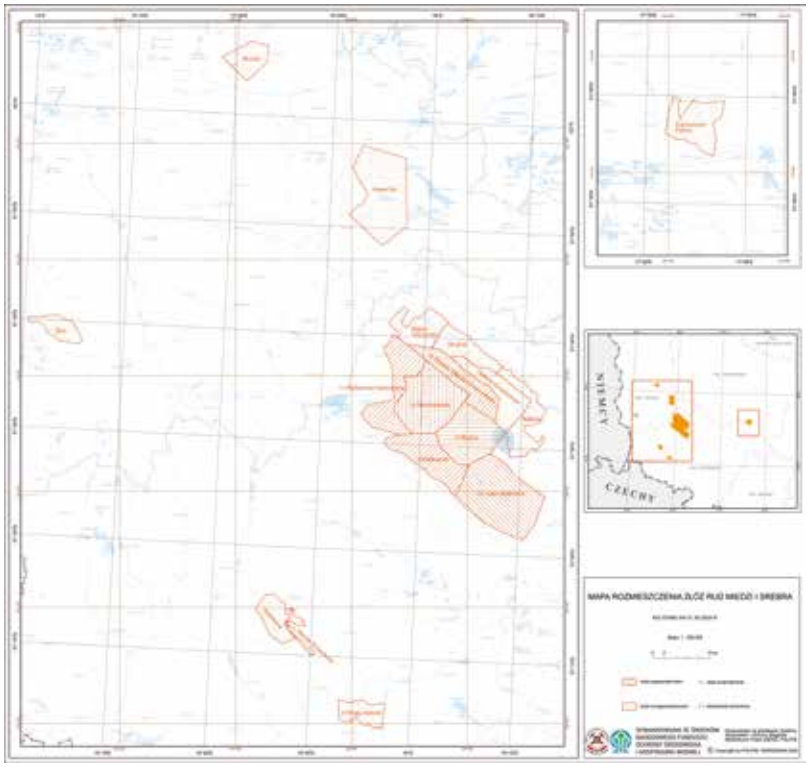


Fig. 27. Developed and undeveloped copper deposits in Poland[76]

Other raw materials included in the CRM list and found in Poland have low reserves and their exploitation potential is negligible.

Baryte found in deposits in Lower Silesia and the Świętokrzyskie Mountains, with proven reserves of 5.67 million tons, is not currently being exploited. Known barite and fluorite deposits are located in Boguszów near Wałbrzych (exploitation abandoned in 1997) and Stanisławów, where barite was mined until 1998.

The documented proven reserves **of phosphorites** are 8,000 tons (Lublin region). Other occurrences of this raw material are also known in Poland, but mining is uneconomical and has been abandoned (e.g., in Chałupki in 1961 and in Annopol in 1971). These reserves have also been removed from the balance sheet.

Gallium, germanium, vanadium, tungsten, cobalt–in small quantities, as elements accompanying polymetallic copper, zinc, and lead ores (gallium – Zn-Pb

ores; germanium – Zn-Pb ores; vanadium – Cu-Ag ores; tungsten – Mo-Cu-Wo ores, (0.18 million tons in the Myszków deposit); cobalt – Cu-Ag ores, e.g., the Pre-Sudeten monocline). Titanium, which is on the EU's CRM list, is critical and strategic, and is strategic for the Polish economy. It occurs in magnetite-ilmenite-vanadium deposits (Krzemianka and Udryń deposits in the Suwałki region), whose total reserves, although off-balance sheet, are at the level of 10 million tons-ilmenite-vanadium deposits (Krzemianka and Udryń deposits in the Suwałki region), whose total reserves, although off-balance sheet, amount to 1.3 million tons lying in an environmentally and touristically attractive area at a depth of approx. 850-2300 m.

When analyzing the Polish raw materials sector, **lignite** cannot be overlooked. Its geological reserves amount to 936.47 million tons and are still used for electricity production, but the future of its further exploitation is significantly threatened, and this raw material is being and will continue to be systematically replaced by other raw materials and renewable energy sources. Lignite is mined in four mines: Bełchatów, Turów, Konin, and Sieniawa.

Hydrocarbon resources have a significant economic impact on Poland. **Natural gas** deposits are mainly concentrated in the Carpathian Mountains and the Carpathian Foredeep, the Polish Lowlands and the Baltic Basin. In total, there are 324 deposits with total recoverable reserves of at 151,263.93 million m^3 and industrial reserves of 79.89 billion m^3. Poland also has small **oil** reserves accumulated in deposits in the same areas as natural gas. According to the "Balance Sheet," 88 deposits contain over 20,238,000 tons of crude oil, Fig. 28. Industrial reserves amount to over 9,740,000 tons. Exploration and appraisal of deposits is a rather complex process that can take up to several years before a deposit, once discovered, is developed, so this work is ongoing, with new discoveries being made every year and the prospects remaining quite good. This is true for the Carpathians and the Polish Lowlands, but also for the Baltic shelf, e.g.:

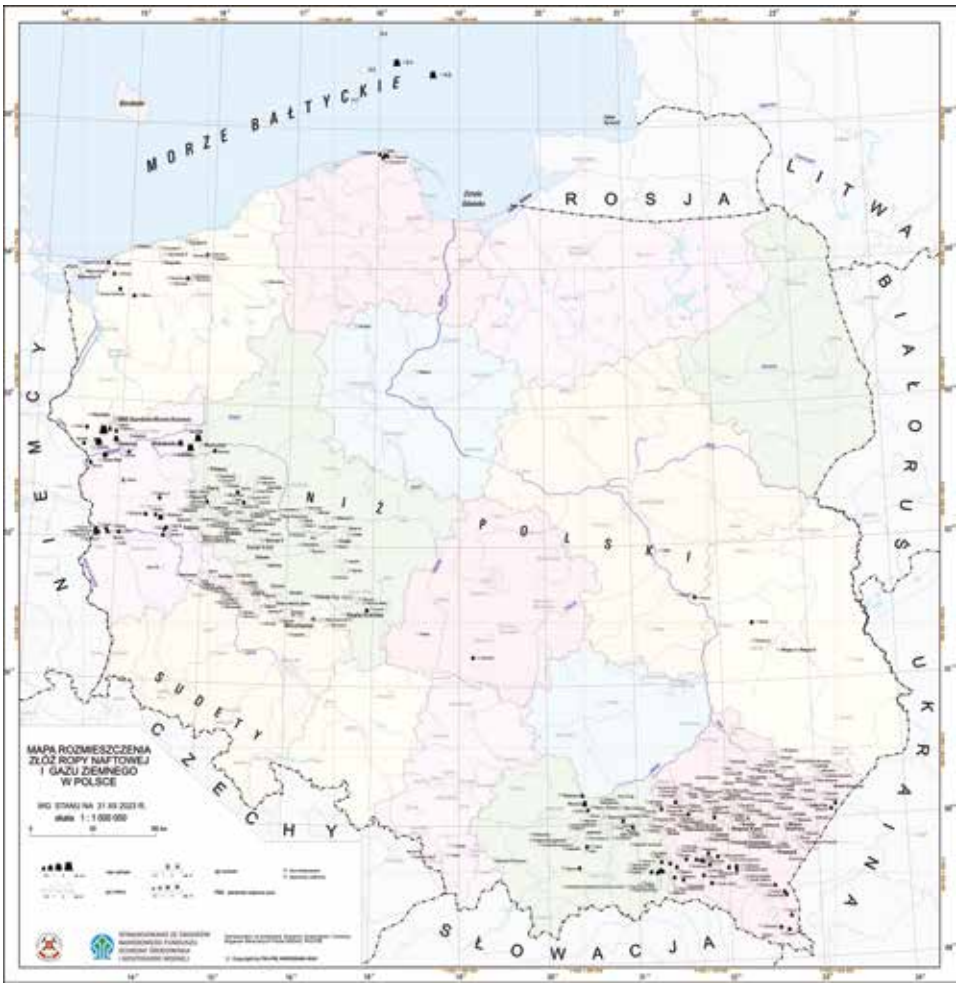


Fig. 28. Distribution of oil and natural gas deposits in Poland[76]

6.1.1. Raw material resources of the ocean floor and Poland's share in exploration and future exploitation

The existence of mineral resources on the ocean floor is being discussed more and more widely, including by organizations such as the IEA[79]. Opinions and expectations vary, but it is a fact that many metallic and non-metallic elements are found there. Many countries are beginning to realize that these resources could indeed secure their long-term demand for raw materials. Currently, some countries, such as Japan, Norway, Papua New Guinea, and China, are working intensively on the possibility of extracting them. Norway is even planning to issue concessions for deep-sea mining of metallic raw materials.

- In general, there are three main types of deposits found on the ocean floor:
- cobalt-manganese crusts (containing iron, cobalt, copper, nickel, and platinum);
- polymetallic nodules (rich in manganese, nickel, copper, cobalt, molybdenum, and REE); and
- massive seafloor sulfides (containing copper, gold, zinc, lead, barium, and silver), Table 7.

Table 7. Concentrations of different types of deposits found on the ocean floor (according to Cherkashov 2017 and Hein et al., 2023, in:[80])

Type	Description	Area, thickness of the deposit	Metals and their mean concentration[1]	Principal deposits
Polymetallic nodules	Concretions of layered iron and manganese oxides with associated metals from the water column or sediment	Up to thousands of km²; thickness generally up to 50 cm, rarely deeper	Mn (28.4%), Ni (1.3%), Cu (1.07%), Co (2098 ppm), Mo (590 ppm), Zn (1366 ppm), Zr (307 ppm), Li (131 ppm), Pt (128 ppm), Ti (199 ppm), Y (96 ppm), REEs (813 ppm)	Clarion-Clipperton Zone, Peru Basin, Central Indian Ocean, and Penrhyn Basin, Cook Islands
Seafloor massive sulfides	Concentrated deposits of sulphidic minerals (>50-60%) resulting from hydrothermal activity on the seabed	Up to several km²; several meters thick	Cu (0.8-17.9%), Au (0.4-13.2 ppm), Ag (64-1260 ppm), Zn (2.7-17.5%), Pb (0.02-9.7%), Co, As, Al, Si, REEs	Norwegian Sea, Red Sea, Central Indian Ridge, Mid-Atlantic Ridge
Cobalt-rich ferromanganese crusts	Layered manganese and iron oxides with associated metals on hard substrate rock of subsea mountains and ridges	Up to several km²; generally a few cm thick	Mn (21%), Co (6647 ppm), Ni (4326 ppm), Cu (573 ppm), Te (34 ppm), Mo (431 ppm), Zr (423 ppm), Ti (TiO_2 - 1.4%), Pt (0.273 ppm), W (68 ppm), REEs (1628 ppm)	Equatorial Western Pacific Ocean and Central Atlantic Ocean

For example**, in an area of 4.5 million square kilometers in the eastern Atlantic Ocean, polymetallic nodule reserves are estimated at 226 million tons of copper and, for example, 274 million tons of nickel or 44 million tons of cobalt, which for these two elements is a multiple of global land reserves** (Hefferman, 2019). [81]

However, the start of exploitation involves interference with the environment and the implementation of modern offshore mining technologies, which are constantly being improved to make the process profitable. The https:/www.isa.org.jm/ (ISA) is developing *a Mining Code* (regulatory framework) for deep-sea mining activities, but this process is ongoing as the code must take into account the interests of various parties.

Poland is also active in this area through its work in the ISA, but also through its concessions in the Atlantic (Fig. 29), where massive sulfides occur, and in the Pacific in the Clarion-Clipperton zone (Fig. 30), where, as a member of the international organization Interoceanmetal, it is conducting joint exploration work, which is at an advanced stage.

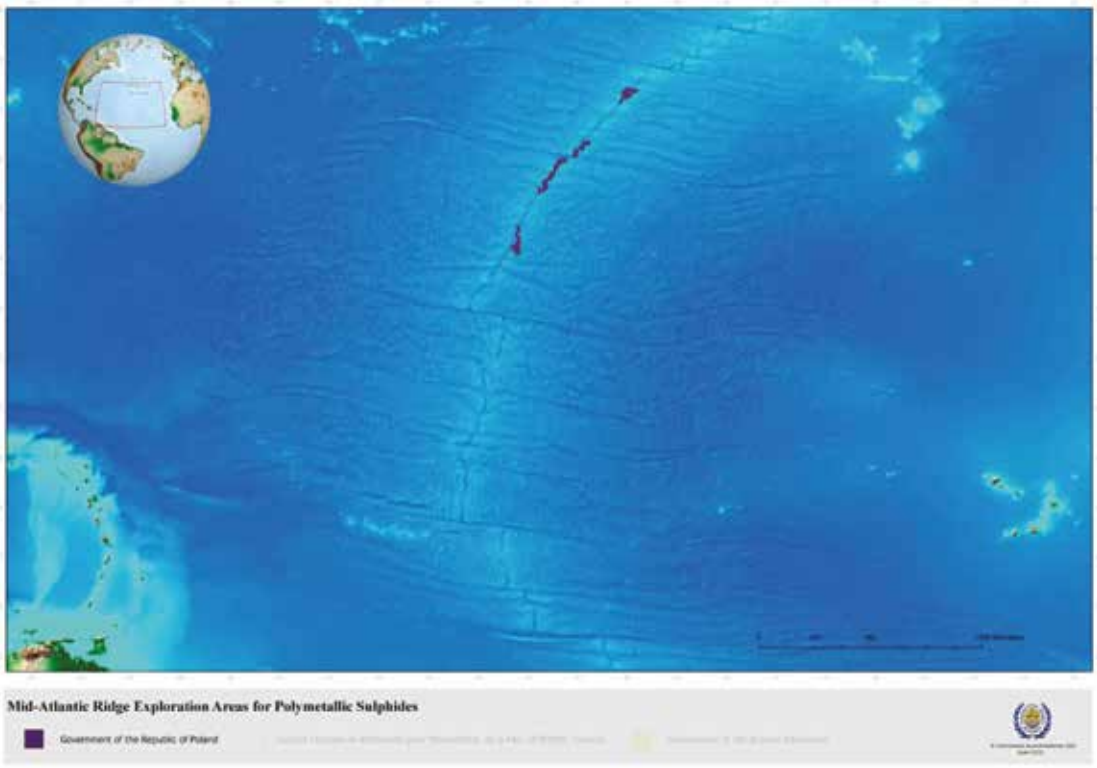


Fig. 29. Location of Polish, French and Russian concession blocks in the central part of the Mid-Atlantic Ridge[82]

Metal concentrations in the Clarion–Clipperton Zone in the northeast Pacific contain more Tl (6,000 times), Mn, Te, Ni, Co, and Y than the entire global onshore reserves for these metals. CCZ nodules also contain significant amounts of Cu, Mo, W, Li, Nb, and rare earth oxides (REO) compared to global onshore reserves[83] .

The total resources in the Interoceanmetal (IOM) concession area are estimated at 272.5 million tons of wet nodules (part of the area is excluded due to low content below 10 kg/m2, areas of volcanic activity, areas free of nodules, and areas with a slope of more than 7°). 12.2 million tons are measurable (proven) resources, 77 million tons are possible resources, and 183.3 Mt are probable resources. With Mn concentration at 30.58%; Ni at 1.33%, Cu at (0.18%) and REE at 697 (ppm)[84] .

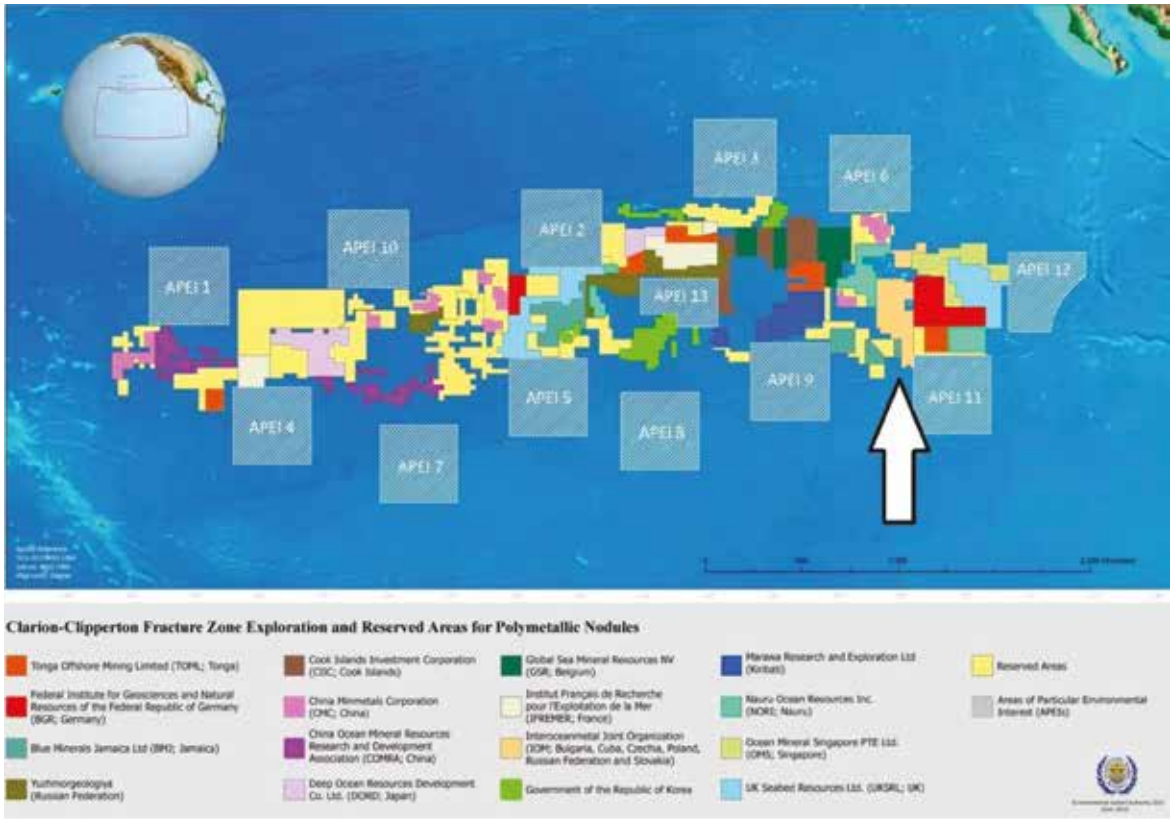


Fig. 30. Interoceanmetal concession blocks (indicated by arrows) in the Clarion-Clipperton zone [85]

Given the developing technologies of deep-sea mining, which are estimated to come into widespread use after 2030, **the exploitation of deep-sea deposits of metallic raw materials may revolutionize the supply and demand situation in many areas, also filling the supply gap.**

6.1.2. Geothermal energy and its potential

The geothermal potential associated with the presence of thermal waters in Poland has been known for years, even centuries. The history of the use of warm natural sources in Cieplice Zdrój dates back to the Middle Ages (1241). On an industrial scale, the development of geothermal energy in Poland began in 1992, when the first geothermal installation in Poland was launched in Podhale (Experimental Geothermal Plant of the Polish Academy of Sciences in Bańska – Biały Dunajec), currently PEC Geotermia Podhalańska SA. Subsequent installations were built in Mszczonów, Uniejów, Poddębice, Pyrzyce, and Stargard. Modern geothermal energy is an advanced field that includes both electricity production and the use of heat for heating purposes. In many countries, geothermal energy is an important part of the energy mix, contributing to the reduction of greenhouse gas emissions and increasing energy security. It is therefore necessary to exploit the available potential for its effective use, which can contribute to the achievement of climate protection and sustainable development goals.

Poland's geothermal potential covers over 50% of its area, Fig. 31, and concerns: the Polish Lowlands, where thermal water reservoirs are found in Lower Cretaceous and Lower Jurassic formations (temperature range 20-90°C, depth range approx. 700-4000 m); the Inner Carpathians (Podhale Basin), (temperature range 20-95°C, depth range approx. 650-3400 m); for which the Paleogene-Mesozoic formations are reservoirs. The occurrence of thermal waters is known in the Sudetes, and their possible occurrence is also possible in the Sudeten forede-basin (temperature range 20-45 (and even 90)°C, at a depth range of approx. (0-2500 m), where the reservoirs may be formations of the younger Paleozoic and Cretaceous. Lower, but possible potential exists locally in the zone of the Outer Carpathians and the Pre-Carpathian depression, but in the formations of their Mesozoic basement.

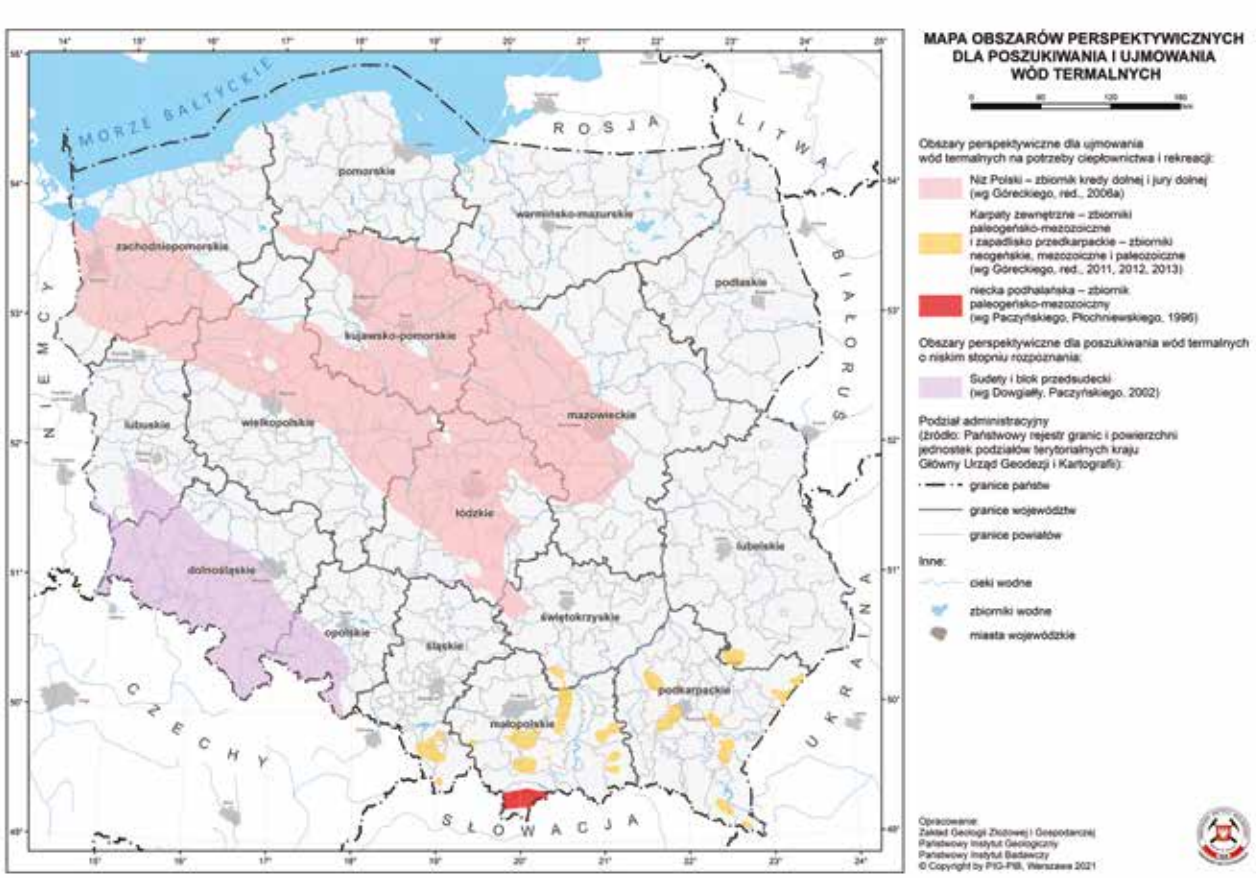


Fig. 31. Map of thermal water occurrence in Poland[86]

6.2. Key projects and resources – development opportunities in the context of the European Union's strategic objectives

Known raw material resources other than coking coal and copper do not make a significant contribution to the European economy. However, both **coking coal and copper ore are critical and strategic for the EU and Poland**. In both cases, EU countries have alternatives, but copper from Poland is of high quality and competitively priced. Polish copper, which is essential for the energy transition in its broadest sense, is also one of the country's export pillars and an important element of Poland's trade balance. The annual value of exports of copper and copper products from Poland ranges from EUR 3 to 5 billion, which is a significant contribution to the Polish economy[87] .

The development of KGHM is therefore both the foundation of Poland's and Europe's raw material security and a measurable driving force for the economy.

In order to maintain its market competitiveness**, KGHM must invest in modern technologies, improve efficiency, including energy efficiency, and develop new mining projects.** Therefore, the progress of the company's investments in domestic deposits **in the Copper Basin,** as announced in June, should be closely monitored, including plans to construct three new shafts: GG-2 „Odra" Retków and Gaworzyce[88] . At the same time, KGHM should not neglect its ongoing search for access to deposits located **outside Poland** and should develop its own foreign mining projects that have already been launched. Support from both the European Union and the Polish government will be essential in this regard, which should be expressed, firstly, in a far-reaching, pro-investment modification of the formula and reduction of the tax on the extraction of certain minerals (the so-called copper tax), secondly, political support, which is indispensable for effective operation on the global market, which is strongly influenced by geopolitical factors, and thirdly, the creation of formulas and tools at the European and national levels to support strategic mining investments.

When discussing Polish resources, it is also worth noting that new opportunities for copper extraction may also potentially be offered, under certain conditions, by a C_1 category deposit of copper and silver with resources of 848 million tons of copper and silver in the Nowa Sól region. However, the problem with its development may be both its depth (1,700-2,100 m) and the temperature prevailing at this depth (which can reach up to 70°C). Therefore, without significant financial outlays and very modern technologies, its exploitation may prove impossible or unprofitable.

The enormous **potential of coking coal** will also allow this segment of Polish mining to continue operating for decades to come. However, measurable obstacles include rising extraction costs (already very high) and the variable volume of pig iron production, reflecting processes in the global economy, to which the price of coking coal on the world market is directly linked. Therefore, any economic slowdown and halt in transformation processes may significantly affect domestic production. It is also worth remembering that the market position of Polish coal will always be affected by changes in production among the largest producers, e.g., Australia has a >60% market share, and the world leaders also include the US, Canada, Russia, and Mongolia, which is exploiting more and more of this raw material, but supplying it mainly to China. The emergence of a new player on this market, Mozambique, which is significantly increasing its production of this raw material, may also pose a threat. In Mozambique, in the northwestern part of the province of Tete (one of the largest in the world, rich in coal but still unexplored), new projects have been launched: Ncondezi Coal Mine – started in 2023 (resources of 4.7 billion tons) and Zambezi Coal Mine – a planned project (resources of approx. 1.7 billion tons)[89] .

Support for the Polish coking coal industry seems to be an important area, although from the point of view of green transition it seems completely incorrect, but from a rational point of view it should be taken into account. Firstly, the phasing out of mines is and will be very costly; secondly, maintaining mining expertise will be important for the development of other types of mining; thirdly, maintaining coking coal production will indirectly allow European economies to remain competitive in iron ore smelting. European ambitions for transformation can only be realized by taking into account currently used raw materials and with proper planning for the phased replacement of energy sources.

However, from the point of view of other raw materials, such as energy coal, lignite, rock salt, and hydrocarbon deposits, these are of significant importance for the Polish economy and should be developed and exploited as before. It is worth noting here the potential of deposits **of polihalit,** a potassium-magnesium salt particularly valuable in agriculture, located, for example, in the Puck region.

The existing **geothermal potential** in Poland should be given special attention[90] . Currently, the "Thermal Water Access Program" is being implemented and financed by the National Fund for Environmental Protection and Water Management (NFOŚiGW), under which (in its second edition) approximately 40 geothermal wells should be drilled (Fig. 32). Further development and support from local governments will be necessary in this area (they are beneficiaries of funds from the National Fund for Environmental Protection and Water Management). Renewable energy sources based on geothermal energy are becoming increasingly important in Polish heating. Geothermal energy provides "clean" emission-free energy, which is particularly important in efforts to protect the climate and improve air quality, as well as in the country's energy transition.



Fig. 32. Locations of wells subsidized under the Priority Program "Access to thermal waters" (based on a study by PIG-PIG and[91,92]

One of the most accessible ways to use geothermal energy is **shallow geothermal energy based on ground source heat pumps, which use heat from the shallow layer of the Earth.** A particularly important feature of this technology is the stability of the power obtained, which in Poland can reach up to 60-70 W/m of borehole. The stability of the lower heat source allows for a more precise determination of the electricity demand required to operate a ground source heat pump, which is lower than that of an air source heat pump – and therefore places less strain on the power grid at the most critical times. An additional advantage of using geothermal energy is the production of cooling in the summer, and consequently the thermal regeneration of the rock mass. The above-mentioned technology can be used not only in single-family housing, but also in public buildings such as schools, hospitals, and offices. **This energy is available in over 90% of Poland.** It is costly at the outset, but the return on investment will pay off from the point of view of the consumer and in terms of reducing electricity consumption, especially during periods of low and high temperatures, i.e., when demand is highest[93].

6.3. Poland as a European leader in raw materials – goals, potential, challenges

Two of the raw materials that are undoubtedly of critical and strategic importance to the EU and Poland are available in Poland. These are deposits with well-developed infrastructure and, importantly, a team of experienced miners, in the broad sense of the word. In addition, the large resource potential makes Poland a country of significant importance for the EU. The deposits and the aforementioned qualifications of the workforce are a huge national asset. What is more, Poland also has strong mining companies which, with the right support mechanisms in place, can perform tasks related to ensuring multi-resource security not only for Poland but also for the European Union.

Potential should also be seen in the development of technologies related to CO_2 capture and storage in rock formations, which may also contribute positively to the use of available fossil energy resources with the least possible damage to the natural environment. The potential associated with the possibility of storing

CO_2 both in depleted hydrocarbon deposits and in deep aquifers is also an important area of possible future activity for Poland. Appropriate legal regulations in this area are already largely in place[94] .

Undoubtedly, when looking at Poland's raw material potential, geothermal energy must also be mentioned among the challenges. This is a costly area, but with its existing potential, it can bring significant benefits in the energy transition. This is clearly stated, among others, in the European Resolution on geothermal energy.[95] Geothermal energy should also be a target for other EU countries , but not only deep geothermal energy, but also geothermal energy based on ground source heat pumps. This area should also be given special support. Although the technology is expensive, it should be considered very important from the perspective of the energy transition. Energy from this source is available 24/7/365, and its use significantly reduces the consumption of electricity generated, for example, from fossil fuels. This is particularly important in periods of extreme temperatures. The additional use of sources such as PV and energy storage facilities can significantly change the energy needs of Poland and many EU countries. Poland and EU countries have a lot of expertise in all these areas. These technologies should be widely promoted and used.

As many analysts point out, the future of energy may also be based on hydrogen. The production of 1 kg of hydrogen requires 7-9 liters of water and approximately 50 kWh of electricity, and 1 kg of hydrogen is approximately 33 kWh of energy, while 1 kg of hydrogen can power a vehicle for approximately 100 km. Today, the cost of 1 kg is about 70 PLN, or about 17 EUR. Compared to the 100 km that can be driven on gasoline for about PLN 50-70, this seems cost-effective, but even with renewable energy surpluses, the question must be asked whether it will be possible to produce enough hydrogen to meet the EU's social needs. Hydrogen can be used most effectively in commercial vehicle transport, replacing diesel fuel, and in heavy industry.

Considering that the European policy of moving away from fossil fuels should not be treated dogmatically, but should take into account the social, economic, and security dimensions, Poland can and should be treated as a key supplier of raw materials both necessary during the transition (e.g., coal) and those directly serving it (e.g., copper), and also, given the potential of the Polish mining industry, as one of the pillars of European raw material security policy.

7. Summary and recommendations

The situation on the global market for critical and strategic raw materials (as defined by the EU), in particular those necessary for the transition to modern technologies, renewable energy sources and the defense sector, is unprecedented. On the one hand, we are seeing intensive exploitation of these raw materials – often without regard for environmental and social standards – mainly in African and Asian countries. Countries with extensive access to resources or technological advantages in their extraction and processing are reaping tangible benefits. On the other hand, developed economies, heavily dependent on raw material supplies, have been trying for years to create legal and strategic frameworks to reduce their dependence on external stakeholders. Despite this, it is difficult to talk about an adequate increase in supply – there is a lack of new investment in exploration and exploitation of deposits. Administrative barriers, complex environmental procedures, lack of public acceptance, and insufficient funding mean that even documented deposits often remain unexploited.

New areas of potential exploitation, such as Greenland, Ukraine, and the Arctic region, although promising, will not ensure a rapid increase in the availability of raw materials. The development of projects in these locations requires years of preparation, analysis, consultation, and changes to the regulatory environment.

All forecasts cited in the Report point to dynamic growth in demand for critical raw materials. In the global economic race, the players who consistently ensure access to deposits and possess advanced raw material processing technologies—particularly with regard to rare earth elements, but not only—are leading and winning.

In view of the above, the European Union's ambitious goals for energy transition and the development of new technologies cannot be achieved without far-reaching changes in the way the entire mining industry is perceived. Only in Europe has it been possible to build up a negative image of mining and the entire industry surrounding it over decades, which is, first and foremost, an excellent business worldwide and, secondly, understood as one of the fundamental elements of economic sovereignty and national security. The European approach then implies problems with public acceptance of investments, access to financing for their initiation and development, as well as a progressive loss of competence due to shortcomings in education and training of personnel and the creation of technological innovations. In a difficult geopolitical race, Europe must change quickly if it is to have any chance.

Recommendations for the EU and Member States:

1. **Developing its own extraction projects** located within the EU by selecting projects of key importance for Europe's raw material security, for which a special procedural pathway will be provided, taking into account conflicts with environmental regulations and adequate financing mechanisms.
2. **Establish a European Raw Materials Fund (ERMF)**, modeled on the Japanese (JOGMEC) and Korean (KOMIR) models, financed by EU funds and EIB and EBRD capital. The main tasks of the ERMF:
   - accumulating and managing strategic reserves of raw materials,
   - co-investing in extraction and processing projects (within and outside the EU),
   - financing research and development, including in the field of substitutes and efficient use of raw materials, and supporting educational programs

in the field of raw materials,
- supporting projects at all stages of the mining cycle, from exploration to processing,
- acting as a coordinator between the public sector and private investors.

3. **Strengthening the European value chain** for critical and strategic raw materials, covering the entire cycle from exploration to extraction, recycling, and processing, including the development of research and development and mechanisms for technology transfer from science to business.
4. **Harmonizing environmental and social requirements** for mining investments in EU Member States aimed at creating a level playing field and transparent conditions for investment, and developing a code of good investment practices to facilitate public acceptance of investments.
5. **Expanding partnerships with democratic countries** rich in raw materials (especially with NATO member states and partners). At the same time, it is necessary to support the transfer of good practices and mining technologies to developing countries with the participation of European geological services and to link development aid to access to resources.
6. **Inclusion of European raw material projects in the list of strategic infrastructure subject to control in the event of acquisition by non-NATO entities**.
7. **Diversify import sources** to reduce dependence on selected third countries and increase the resilience of the supply system.
8. **Enhancing the capacity to monitor risks** related to supply disruptions and implementing mechanisms to mitigate them.
9. **Ensuring the free movement of raw materials** in the single market while increasing their sustainable use and recycling.
10. **Support the development of substitute technologies for critical raw materials**, including industrial implementations (e.g., sodium batteries as an alternative to lithium batteries), along with financing for the promotion and commercialization of the first implementations, using ESF instruments.
11. **Ensuring a system of budgetary compensation** for Member States that decide to introduce tax breaks for investments in the raw materials sector. These breaks should cover the entire value chain, from exploration to processing, and also be available in countries with weaker financial positions.
12. **Revision of the EU's energy transition strategy.** The new strategy should be tailored to the specific circumstances of each Member State.
13. **Support for the development of geothermal energy, clean coal technologies and CCUS (CO_2 capture and storage) technologies**, both through dedicated funds and by including these technologies in ESF activities.

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Manager with many years of experience working in large capital groups, government and local government administration. He has been involved in investment and legal consulting.

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He supervised large-scale infrastructure projects in the energy sector. As president of PGE, he initiated and implemented, in cooperation with the global offshore leader Ørsted, the largest project in the Polish energy sector to build offshore wind farms in the Baltic Sea. He coordinated the construction of a nuclear power plant with ZE PAK and the Korean KHNP.

He co-created the government's plan to spin off coal assets from energy groups as a necessary condition for the energy transition in Poland.

He managed the process of creating and implementing the PGE Group's strategy until 2030 with a view to achieving climate neutrality by 2050. Since 2024, he has been a member of the Council for Strategic Development Projects at the President of the Republic of Poland. He graduated from the Faculty of Law at the University of Warsaw.



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He obtained a master's degree in geology (1992) from the Jagiellonian University and a doctorate in Earth Sciences (1999) from the State Geological Institute. He also completed the National-Louis University School of Business in Nowy Sącz (2001) in business management. During his career, he has worked at the Polish Academy of Sciences – Institute of Geological Sciences, Polish Oil and Gas Company, Spółka Narzędzia i Urządzenia Wiertnicze Glinik Sp z o.o. (which he managed for 5 years), private companies involved in hydrocarbon exploration and production, and currently at the Oil and Gas Institute – National Research Institute in Krakow. He has been involved in the oil and gas industry since 1993. In 2019, he was appointed Secretary of State at the Ministry of the Environment – Chief Geologist of the Country, and then (2020-2023) Undersecretary of State – Chief Geologist of the Country and Government Plenipotentiary for State Raw Materials Policy at the Ministry of Climate and Environment. He has extensive knowledge of petroleum geology, raw materials geology, management, and public administration. He has held many positions in industry social organizations. He is the author or co-author of over 50 scientific publications in Polish and foreign journals.



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In 2015-2018, he was Undersecretary of State, then Secretary of State at the Ministry of the Interior and Administration, and Government Plenipotentiary for the Preparation of State Administration Bodies for Cooperation with the Schengen Information System and the Visa Information System. From January 2018 to April 2020, he was Secretary of State at the Ministry of National Defense, also serving as the Ministry's Plenipotentiary for Cyberspace Security. His responsibilities included the creation and implementation of the comprehensive CYBER.MIL.PL program. From April 2020 to August 2022, he was CEO of Poczta Polska S.A. From September 2022, he was Vice-President of the Management Board for Development at KGHM Polska Miedź S.A. From October 2022 to February 2024, he served as CEO of KGHM. He was also Deputy Chairman of the Supervisory Board of EXATEL S.A. From November 2021 to December 2023, he served as Chairman of the Social Advisory Team to the Minister of National Defense for Cybersecurity.

In December 2021, he was appointed by the President of the Republic of Poland, Andrzej Duda, to the Security and Defense Council within the National Development Council, and in July 2024, he was also appointed to the Council for Strategic Development Projects.

About the publisher

The SET Foundation "Security-Energy-Technology" is a Polish think tank whose main area of activity is Poland's national security: economic, military, energy, and digital. The SET Foundation supports the development of innovative technologies, works for economic development and the creation of sustainable cooperation mechanisms, combining science, business, and administration. Through its expert activities, including scientific and educational projects, initiating international cooperation, and providing professional reports and analyses, it builds a solid foundation for a future based on security and sustainable development. The SET Foundation brings together people with experience in business and administration, with extensive professional resources from the scientific, economic, legal, and media communities.

Mission

We strive to increase Poland's national security through the development of its economic, military, energy, and technological potential.

Areas of activity:

1. Supporting initiatives that strengthen Polish security in the economic, military, energy and digital spheres.
2. Creating platforms for dialogue between business, science, and administration in the field of broadly understood security and the development of new technologies.
3. Developing energy strategies, critical infrastructure protection, cybersecurity, and national defense.
4. Promoting best practices in security and cybersecurity, as well as the ethical and responsible development of artificial intelligence technologies.
5. Education for national security and sustainable development in Poland.
6. International cooperation and strengthening Poland's position. Supporting transatlantic partnerships, initiatives in the Three Seas region, and strengthening Poland's position in NATO and the EU.

How can we help you?

- ***Do you need a partner to implement initiatives in Poland and Central and Eastern Europe?***
  We can help with local implementation and reaching key stakeholders.

- ***Would you like to prepare a report or publication on security (economic, military, energy, digital) or new technologies?***
  Our experts will be happy to work with you.

- ***Are you looking for reliable analyses and data on security, energy, innovative economy, and finance?***
  Our research team will provide you with reliable and comprehensive studies.

- ***Are you looking for a partner to carry out research and development projects?***
  We cooperate with science, industry, and administration.

- ***Are you planning to organize events, workshops, conferences, or webinars?***
  We provide substantive and organizational support.

- ***Do you need a partner for educational, promotional, and social campaigns?***
  We have experience in effective communication, including infrastructure projects and cooperation with the media.

Footnotes

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