Critical Raw Materials and Open Strategic Autonomy in Europe: Targets, Resources and Geography

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Abstract

This paper examines the European Union (EU)'s strategy for securing Critical Raw Materials (CRMs) within the framework of Open Strategic Autonomy (OSA). As the green and digital transitions escalate global demand, the Critical Raw Materials Act (CRMA) establishes ambitious 2030 targets for domestic extraction, processing, and recycling to reduce reliance on concentrated foreign suppliers. The study critically evaluates the EU's main policy targets against the natural endowment of Strategic Raw Materials (SRMs) through global comparisons and subnational mapping at the NUTS-2 level. Findings indicate that European SRM resources are generally below global averages and highly concentrated in specific regions, predominantly in the Nordic countries and the Iberian Peninsula. We argue that CRMA's top-down approach risks overlooking regional capabilities, geological constraints, and social responses from the communities involved. The paper suggests that without integrating place-based approaches and fostering equitable international interregional partnerships, the current strategy may undermine the EU's pursuit of the targets of current industrial strategies for competitiveness and technological sovereignty.

1. Introduction

We live in an era increasingly characterised by the intensive use of complex metal combinations in a wide array of modern products. Critical and Strategic Raw Materials (CRMs/SRMs), in particular, are indispensable for technological progress due to their unique chemical and mechanical properties, finding applications in everything from semiconductors and solar cells to electric vehicle batteries and wind turbines. Consequently, these materials have become the backbone of the green and digital transitions.

However, the global supply of CRMs is characterised by extreme fragility and high concentration that exposes the European Union to considerable risks. To address these challenges, the EU has framed its policy response around the notion of Open Strategic Autonomy (OSA), expanding its focus from security and defence to encompass economic and technological resilience. A primary instrument in this agenda is the Critical Raw Materials Act (CRMA), which establishes specific 2030 targets for domestic extraction, processing, and recycling to reduce reliance on single-country suppliers. These initiatives aim to secure the EU's "technological sovereignty", that is the ability to provide and develop critical technologies without one-sided structural dependencies.

Despite these ambitious goals, the effectiveness of the CRMA remains debated. This paper provides a first critical assessment of the tensions between top-down EU policies and the reality of resource endowments and regional distribution. The paper attempts first of all to offer a comprehensive analysis of the EU's strategy regarding CRMs. The next section discusses the essential role of these materials in modern technological transitions. Section 3 examines the Open Strategic Autonomy (OSA) and the concept of technological sovereignty as the overarching policy frameworks behind current EU initiatives. Section 4 focuses on the identification of criticality, detailing how the EU defines and lists CRMs and SRMs. The fifth section explores the instruments for supporting CRM/SRM autonomy and fostering global linkages introduced by the CRMA, specifically "Strategic Projects" and international partnerships. Section 6 critically evaluates the quantitative independence targets set for 2030, offering a descriptive assessment of the EU's current baseline. Section 7 provides an analysis of mineral resources and their regional distribution, mapping the natural endowment of SRMs at the subnational level to highlight geographical concentrations. The paper concludes by summarising the structural and policy vulnerabilities of the current EU approach.

2. Critical Raw Materials (CRMs) and technological transitions

Contemporary times have been labelled as the "Rare Metal Age" (Abrahm, 2015). This reflects the growing usage of hard metals, in different and complex combinations, in a wide range of production and consumption goods. Technological progress has fostered new applications and markets for metals that were previously rarely used in response to evolving societal needs (Gunn, 2014). Unlike base metals, many rare metals and mineral raw materials are typically utilised in production processes in tiny amounts; yet, due to their irreplaceable chemical, electrical, and mechanical properties, they find extensive technological applications in a large variety of advanced products (Gunn, 2014; Abrahm, 2015; Bobba et al., 2020; Carrara et al., 2023; Li et al., 2024). For instance, gallium is used in semiconductors, and thin-film solar cells; magnesium is valued for its light weight and strength in aerospace and automotive alloys; some rare earth elements (REEs) are critical for permanent magnets, wind turbines, electric vehicles, and advanced electronics; cobalt is a key component in lithium-ion batteries, crucial for EVs and portable devices; and Platinum Group Metals (PGMs), including iridium, platinum, and rhodium, are known for their high resistance to corrosion and widely used in automotive catalysts, chemical processes, hydrogen technologies, and medical devices[1].

Governments have become increasingly aware of the importance of such natural resources, and certain mineral commodities have been referred to as Critical or Strategic Raw Materials (CRMs/SRMs)[2]. The concept of the criticality of a raw material is not a static one but varies depending on the factors considered relevant in determining its criticality (Glöser et al., 2015; Mayer & Gleich, 2015; Schrijvers et al., 2020; Zhang et al., 2023; Valverde-Carbonell et al., 2024). In this respect, the reports published by the USA National Research Council (NRC, 2008) and the European Commission (EC, 2008, 2010) are particularly important in establishing the conceptual

[1] https://scrreen.eu/crms-2023/

[2] IN this paper we use CRMs as a generic term: however, in the descriptive data analysis below we will differentiate between CRMs and SRMs, in line with the EU latest list.

and analytical foundations of CRM criticality assessment. Since the late 2000s, criticality assessment models have been mainly based on two-parameters: (1) supply risk; and (2) impact of supply disruptions (Gunn, 2014). Labelling a raw material as critical involves a selection process that places a commodity on an official list; these lists can differ across countries and over time due to differences in technical definitions and criticality assessment procedures. The EU has the longest history of public lists of CRMs (Zhang et al., 2023); but Canada, USA, United Kingdom, China, Japan, South Korea and Australia also rely on their own lists of CRMs[3] (Zhang et al., 2023).

The strong dependence of modern economies on CRMs is increasingly recognized in the academic and policy literature, as is the fragility of supply chains due to geopolitical risks, concentration of mineral deposits, low recycling rates, and social and environmental implications (e.g., Radetzki et al., 2008; Achzet & Helbig, 2013; Girtan et al., 2021; EC, 2023a; Draghi, 2024). A key source of vulnerability is the high concentration of CRM extraction and production in a relatively small number of countries, often characterised by low institutional stability. Such a concentration of supply generates two major risks (Draghi, 2024): 1) price volatility, making it harder for investors to commit to long-term projects; 2) use of CRMs as a retaliation tool on global markets. As reported by the European Commission (hereafter EC) (2023), China dominates the global supply of several key raw materials, accounting for 94% of gallium, 91% of magnesium, approximately 90% of REEs, and 60% of cobalt. The Democratic Republic of Congo (DRC) accounts for 63% of the world's cobalt extraction, highlighting a substantial reliance on a single country for this critical resource. Additionally, South Africa plays a leading role in the production of PGMs, supplying 93% of globally produced iridium, 71% of platinum, and 81% of rhodium. Figure 1 illustrates the leading supplier countries for CRM commodities worldwide[4] (Li & Iammarino, 2026).

[FIGURE 1 HERE]

As scholarly research and institutional reports point out, CRMs are fundamental prerequisites for achieving major goals such as the green and digital transitions (e.g., Bobba et al., 2020; Carrara et al., 2023; Li et al., 2024). Attaining decarbonisation goals and meeting the Paris Agreement targets depends significantly on the availability of critical mineral resources, whose demand – not only of notorious CRMs such as lithium, cobalt, or REEs, but also of base metals rather more widespread and available on the planet such as aluminium, copper, or nickel – is expected to increase dramatically, particularly driven by the renewable energy industry (e.g., World Bank, 2020; IEA, 2024). In general, mineral resource extraction is expected to increase by more than 60% by 2060 compared to 2020 levels, driven by rising demand for infrastructure, clean energy technologies, and industrial materials (Bruyninckx et al., 2024).

3. The EU Open Strategic Autonomy (OSA)

The EU Open Strategic Autonomy (OSA) (EC, 2020a; EC2021a) – announced for the first time in 2020[5] – emerges in a context of increasing global connectivity, multidimensional interdependence,

[3] Divergences across national and supranational CRM lists remain a relevant and understated issue.

[4] Production is generally intended of CRMs after processing, refining and metallurgy transformation, independently from the source of raw minerals and ores. Thus, extraction and production stages may not be geographically coincident, with many resource-rich countries not figuring on the map of producers as after extraction the commodities are shipped away for processing and refining.

and aggressive global competition. Although originally focused on matters of security and defence, OSA has since expanded to encompass a wide range of policies, including geopolitics and economics, technology, environment, social and governance issues (Cagnin et al., 2021): this lies behind the complexity of the OSA strategy, together with the inherently intricate nature of the concept of *open autonomy*. COVID-19, and subsequently the Russia-Ukraine war, highlighted the EU's dependence on third countries for essential inputs and showed how geopolitical instability can disrupt supply and global value chains (GVCs), trade and investment flows, and overall security. OSA also points to the importance of open and fair trade, and the need to reform global economic governance, develop mutually beneficial bilateral relations, while protecting against unfair and abusive practices to avoid future crises.

In the current EU's approach to OSA, security policy regulation and strategic partnership are central components. This also involves ensuring reliable access to critical resources and maintaining the resilience of supply chains essential to the EU's economic interests. The 2020 Action Plan on CRMs (EC, 2020b) and the most recent CRMA (EC, 2023b) are considered part of OSA. The role of OSA in addressing dependence on raw and processed materials is also highlighted in the 2021 update of the Industrial Strategy for Europe (EC, 2021b). Promoting economic competitiveness by diversifying CRM sources is one of the priorities of the EU Economic Security Strategy (EC, 2023c), also framed within the OSA agenda.

Four key themes are at the core of the OSA policy framework: (1) military and defence; (2) energy transition within the Green Deal; (3) microchip manufacturing; and (4) de-risking of CRM supply. These priorities are closely linked to the concept of *technological sovereignty*, which emerges as a cornerstone of the evolution of strategic security towards the notion of OSA. Similarly to open autonomy, technological sovereignty is difficult to define with precision, as it encompasses a broad spectrum of dimensions, ranging from control over what are considered strategic technologies to infrastructures and resilience against external dependencies. Its meaning varies depending on the geopolitical, economic, and sectoral context in which it is applied, making it a continuously evolving and debated notion (Couture & Toupin, 2019; Kelly et al., 2020). Edler et al. (2023: 1), refer to the concept of technological sovereignty as: "*the ability of a state or a federation of states to provide the technologies it deems critical for its welfare, competitiveness, and ability to act, and to be able to develop these or source them from other economic areas without one-sided structural dependency*".

This definition suggests that technological sovereignty goes beyond the mere concept of technological self-sufficiency. As March and Schieferdecker (2023) argue, Edler's definition – widely cited in numerous subsequent works such as Crespi et al. (2021), Schmitz & Seidl (2023) and Trippl et al. (2024) – emphasizes that technological sovereignty should primarily be seen as a capability. Specifically, it refers to the ability to autonomously generate technological and scientific knowledge, or to leverage technological capabilities developed externally through the establishment of reliable partnerships. As with the definition of OSA, the concept of technological sovereignty has evolved over time in response to contemporary challenges, and the term is increasingly used to describe different forms of independence, control, and autonomy.

ter the Brexit referendum, with the EU's release of "A Global Strategy for the European Union's Foreign and Security Policy" (EU External Action Service, 2016), fostered by growing international uncertainty, particularly in response to Trump's first presidency (Česnakas & Juozaitis, 2023).

Beyond the unexpected shocks of recent years, from the COVID pandemic to the latest attack to Iran, the debate on the EU's lack of technological sovereignty is driven in particular by the intensification of the trade competition and wars between the USA and China for technological, industrial and political leadership. At the same time, as in the EU the notion of sovereignty is necessarily shaped by the pursuit of shared objectives, strategic fields have been identified as those strictly interlinked with the EU's priorities for a sustainable, digital, and healthy society (Crespi et al., 2021).

A hot academic and political debate on OSA – and the pros and cons of the renewed industrial policy approach in the EU – has recently emerged[6]. Here we only mention the potential consequences in terms of the geography of linkages within and between the EU and the rest of the world. Trying to achieve the net zero economy and digital transitions through uncoordinated and place-blind policy instruments risks undermining the global and local benefits of climate action and digitalization. Macro-level conceived industrial policy approaches can lead to zero-sum games, fostering inequalities at different levels of geography. Too much emphasis on technological sovereignty without anchoring it in international and interregional innovation networks may lead to new forms of both closure and marginalization (Soete & Burgelman, 2023; Mariotti, 2024a,b; Trippl et al., 2024). The EU Commission has always been a front runner in stressing cross-border cooperation as essential for technological progress, post-crisis recovery, and long-term goals such as decarbonization and digitalization (EC, 2021a). Fragmentation and nationalistic approaches may undermine the EU's technological strength in frontier industries such as AI and biotechnology, which largely depend on international flows. Regions or nations that exit such networks risk becoming peripheral in technological trajectories (Binz & Truffer, 2017; Cagnin et al., 2021; Carrara et al., 2023; Boschma et al., 2026). Especially emerging green technologies depend on transnational ecosystems, and if the EU defensive and strategic policies set in motion autarkic approaches, the Union risks moving towards a treacherous "strategic decoupling" path (Hamore et al., 2021; Helwig & Sinkkonen, 2022; Kübek & Mancini, 2023).

With very few exceptions (e.g., Trippl et al., 2024), the debate has paid scant attention to the potential subnational/regional effects of such macro-policy schemes intended to promote technological sovereignty and strategic autonomy. OSA goals and measures have eminently supranational purposes, strengthening at the same time a governance centered on national member States. As emphasized by longstanding abundant economic geography research (e.g., Iammarino et al., 2019), EU regions differ widely in their industrial and innovation structures and capabilities, natural resource endowments, and institutional settings, determining their ability to benefit (or not) from OSA policies. The impacts of strategic industrial interventions are likely to be felt most strongly at the local level, with some regions able to grasp the opportunities for growth and innovation, and others failing to do so because of structural challenges related to lack of capabilities, restricted technology access, institutional weakness and competition for resources. Protective measures towards the rest of the world may pose serious risks also for regions highly dependent on GVCs, global innovation networks and foreign talent, such as urban innovation hubs and science-intensive areas (Trippl et al., 2024). With the ongoing dismantlement of the EU Cohesion policy and place-based sectoral approaches, and the rupture of the direct link between the Commission and the "Europe of regions", it is not only the periphery that will bear the costs (reinforcing populism and anti-EU movements: see Rodriguez-Pose & Bartalucci, 2026), but also

[6] See Dessì (2026) for a detailed survey of the academic literature on such debates.

those mid-size cities and regions with strong capabilities that can be diversified to facilitate the dual technological transitions.

4. CRMs in the EU strategy: identification of criticality

Strategies defined to reduce dependence on, and to differentiate sources of CRMs are essential elements in achieving the overall long-term objectives set by initiatives such as the European Green Deal and the new EU Industrial Strategy. The "EU Raw Materials Initiative" (EC, 2008) can be viewed as the starting point of the EU's concrete action regarding non-energy[7] raw materials. The initiative is a strategic and comprehensive approach designed to ensure a sustainable and secure supply of raw materials to the EU market; additionally, it underlines the importance of periodically defining and updating the list of materials considered "critical", with revisions every three years. Since 2010, the European Commission has commissioned periodic reports by ad hoc working groups aimed at identifying CRMs. The distinction between critical and non-critical materials was first made in the report "Critical Raw Materials for the EU" (EC, 2010), which set out the first criteria to assess material criticality. The global scarcity of a given material was not directly considered a significant factor in assessing criticality, which instead, depended on two main indicators: (a) an aggregate index of economic importance and supply risk; (b) an environmental risk indicator.

The first official list of CRMs was published in 2011 based on a study of 62 potential material candidates and included 14 CRMs[8]. The methodology established in 2010 for addressing criticality was also used for the first revision of the list in 2014, which included 20 elements. In 2017, the Commission significantly revised the methodology for establishing the third list of CRMs (EC, 2017), which is based on two parameters to assess a material's criticality: (a) economic importance and (b) supply risk[9]; the final decision is ultimately made by an ad hoc working group based on expert advice. This method continues to serve as the EU's official model (as at 2026). The number of elements present in the list has increased over time, with the most significant change brought in with the fifth list, which introduced a new category: Strategic Raw Materials (SRMs), including 27 individual materials. The SRM category represents both a major policy shift and a controversial novelty: indeed, since the fifth list, it is more appropriate to refer to a list of "CRMs and SRMs". Table 1 shows the evolution of the CRM and SRM lists up to 2023.

[TABLE 1 HERE]

[7] The definition of non-energy raw materials can be inferred from the Strategic Implementation Plan for the European Innovation Partnership on Raw Materials (2013), which is part of the European Innovation Partnership (EIP) on Raw Materials (https://single-market-economy.ec.europa.eu/sectors/raw-materials/eip/strategic-implementation-plan-sip_en#documents), and Hamor et al. (2021). These sources consider as non-energy raw materials: 1) industrial minerals (those with chemical and physical applications, such as phosphate rock, potash, magnesite, asbestos, silica sand, diatomite, perlite, zircon, peat, gemstones, etc.); 2) construction minerals; 3) metallic minerals (ferrous and non-ferrous metals, as well as precious metals). Fossil fuels, such as lignite, coal, anthracite, oil, and gas, oil shale, and certain minerals such as uranium and thorium ores, are considered energy minerals.

[8] Certain materials are usually aggregated into broader mineralogical groups. For example, REEs have been subdivided, starting with the second list of CRMs (2014), into LREEs (light rare earth elements) and HREE (heavy rare earth elements), which involve 5 and 10 elements respectively (see Table 1). Similarly, the PGM category includes 5 elements. During the EU's triennial criticality assessment, these materials are evaluated individually, but they are treated as groups in almost all other official EU communications.

[9] For a detailed description of the indexes see Dessì (2026).

Following the European Parliament's Resolution 2019/2712(RSP) on implementing the Paris Agreement (2015), initiatives proposed by the Green Deal (2019), and the 2022 Versailles Declaration, concerns over access to strategic resources have gained prominence. Special emphasis was placed on the circular economy and green technologies; the growing effects of climate change have further increased the EU's concerns about technological sovereignty and supply chain disruption (EC, 2018, 2022). As a result, the "Critical Raw Materials Act" (CRMA) is one of the flagship EU legislative initiatives under both the Green Deal Industrial Plan and the OSA framework. With the CRMA (Regulation (EU) 2024/1252), the Commission proposes a set of actions to ensure the EU's access to a secure and sustainable supply of CRMs and SRMs, consistently with existing programs and policy schemes such as the Net Zero Industry Act and REPowerEU. The plan's main ambitions include ensuring and reinforcing CRM supply chains, investing in research and innovation, and protecting the environment by improving the circularity and sustainability of CRMs.

With the CRMA, the strategic importance of input material demand in strategic sectors has become central to the EU action. From article 6 of the CRMA, it can be inferred that the EC considers SRMs to be the raw materials most needed to achieve the general goals of the CRMA. This rationale underpins the decision to establish independence thresholds for domestic consumption by 2030 exclusively based on this category: two of them (copper and nickel) are included in the list even though they do not meet the CRM thresholds. The identification of SRMs appears essentially political, as the designation of certain technologies as strategic has been driven primarily by policy considerations. Additionally, the Commission has considerable flexibility in determining and applying the assessment metrics used to select SRMs, particularly when evaluating the requirements of strategic technologies and forecasting global demand (Zhang et al., 2023; Tröster et al., 2024). The document states that the identification of strategic technologies is based on previous foresight studies (e.g., Bobba et al., 2020; Carrara et al., 2023), which apply a multi-stage approach to identify different materials in various parts of the supply chains relevant to the green and digital transition and the EU's economic and technological security.

The introduction of the SRMs is not the only innovation brought by the CRMA. As detailed in Section 6 below, the document sets explicit benchmarks for developing domestic capacities across the SRM supply chain and aims to diversify the EU supply by 2030. With the adoption of the CRMA (March 2024), the EU set the following objectives for each SRM by 2030:

- At least 10% of the EU's annual consumption must come from EU extraction;
- At least 40% of the EU's annual consumption must come from processing in the EU;
- At least 25% of the EU's annual consumption must come from EU recycling;
- Not more than 65% of the EU's annual consumption of each SRM unprocessed, and at any stage of processing, may come from a single third country.

5. CRMs in the EU strategy: instruments and global partnerships

5.1 Strategic Projects under the CRMA

In operational terms, the main novelty introduced by the CRMA is the instrument of the "Strategic Projects" (SPs), designed to attract investments within the EU, through which the independence targets listed above are supposedly achieved. To be recognized as a Strategic Project, an initiative must focus on extraction, processing, recycling, or substitution of at least one SRM and meet specific criteria, including technical feasibility, sustainable implementation, and the capacity to benefit the broader EU community[10].

By the 22 August 2024 deadline, the EC received 170 applications for SPs: 77 for extraction, 58 for processing, 30 for recycling and 5 for substitution. The latter category is the only one dedicated to research and development of new technologies, as it includes initiatives aimed at developing alternatives to SRMs, either through research of substitute materials or by leveraging technological innovation to reduce or eliminate dependence on SRMs. Geographically, 121 applications originated from within the EU, while 49 were submitted by entities outside the EU[11]. In March 2025, the EU published the list of approved projects located within the EU, amounting to a total of 47 (23 for extraction purposes, 23 for processing, 10 for recycling and only 2 for substitution[12]). These SPs are located across 13 EU Member States: Belgium, France, Italy, Germany, Spain, Estonia, Czechia, Greece, Sweden, Finland, Portugal, Poland, Romania, and cover 14 of the 17 SRMs listed in the CRMA considering REEs and PGMs as aggregate (no projects were submitted for bismuth and silicon metal). Cobalt, nickel, and, especially, lithium are the most targeted materials; 4 out of 10 recycling projects are based in Italy, which is the only country among the 13 mentioned that has not submitted any project beyond recycling. The selected projects are able to benefit from coordinated support by the EU Commission, Member States and financial institutions to become operational, notably regarding access to finance and support to connect with relevant stakeholders. They will also benefit from streamlined permit procedures, to facilitate project promoters. In fact, in line with the CRMA, the permit-granting process for SPs must not exceed 27 months for mining extraction, and 15 months for all the other typologies. In June 2025, also the list of SPs located outside the EU was published, adding 13 projects located outside the EU and covering 9 SRMs: boron, cobalt, copper, graphite, lithium, manganese, nickel, REEs, and tungsten. Table 2 summarises information on the SPs approved in 2025[13].

[TABLE 2 HERE]

Projects located outside the EU are not eligible for accelerated permitting procedures, as these measures can only be applied within the EU's jurisdiction. All other benefits remain applicable, as does the requirement that the project must deliver tangible benefits both to the host countries and to the EU. Taken together, the 60 initiatives have an expected overall capital investment of €28 billion (€22.5 billion[14] required for EU-based projects, and €5.5 billion for non-EU projects[15]).

The low number of submitted SPs concerning substitution is an illustration of the fact that the CRMA does not seem to be primarily focused on creating capabilities. The CRMA grants fast-track permits, but substitution projects are more research-driven and do not benefit from the same streamlined approval process. As pointed out by Findeisen and Wernert (2023), the CRMA document also reveals a structural weakness in EU funding mechanisms, particularly regarding the

[10] https://ec.europa.eu/docsroom/documents/59594

[11] https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials/strategic-projects-under-crma_en

[12] https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials/strategic-projects-under-crma/selected-projects_en. Note that a single project may fall under more than one category.

[13] For detailed information on SPs see Dessì (2026).

[14] https://ec.europa.eu/commission/presscorner/detail/en/ip_25_864

[15] https://www.spglobal.com/commodity-insights/en/news-research/latest-news/metals/060425-eu-identifies-13-new-strategic-critical-mineral-projects-located-outside-bloc

lack of a dedicated fund for CRMs, unlike the US CHIPS Act for semiconductors, which provides targeted financial support. Instead of establishing a new, centralized funding instrument, the CRMA merely references a range of fragmented, pre-existing funds, such as InvestEU, the European Regional Development Fund, and the Innovation Fund.

SPs are the most operational component of the CRMA, and they are intended to be the main instrument for achieving the 2030 targets. They attract investments in the mining and metallurgical industries: only projects related to extraction and processing have received a significant number of applications. Many of such SPs were started before the call, and sometimes even before the CRMA[16]. Thus, doubts arise on the role of SPs as drivers for radically new projects, especially considering the short deadlines given in the calls the lack of access to dedicated funds.

For non-EU projects, the issue is even more complex: these may benefit from having an EU-based sponsor and from EU-backed credit guarantees, which in effect means that the EU is supporting projects led by extra-EU multinational enterprises in third (and sometimes, developing) countries (no EU company has proposed extraction projects outside the EU). This may also pose a risk, as even though SPs are subject to evaluations by an EU ad hoc committee, there are no sanctioning mechanisms in place to address moral hazard on the side of project owners if the projects later turn out to be non-compliant with environmental and social standards (EC, 2023b). Greater concerns in this regard arise in the mining sector, due to its significant local impacts in resource-rich developing economy.

5.2 Global partnerships under the CRMA

The rest of the operational strategy primarily draws on coordination provisions among the Member States, and on applicable principles and guidelines. References to the CRMA's international policy are limited to broad statements of intent and vague references to strategic partnerships. Support for extraction and processing SPs in non-EU countries can be seen as an attempt to establish cooperative relations with companies and communities in resource-rich countries, but the absence of specific strategies for CRM-based international relations and the lack of projects led by EU companies limits the potential for building direct long-term ties with extra-EU territories. Moreover, SPs stem from private initiatives, not including international agreements between EU public institutions and host countries' governments. This is not surprising from a global trade perspective, considering that current trade policies can offer very low incentives to diversify imports, as the EU already applies low tariffs on CRMs (Rietveld et al., 2022).

Although the document repeatedly refers to the need to enhance international partnerships, in practice, the new developments in this area are limited. Many of these initiatives are in fact simple non-binding Memorandum of Understanding (MoU)[17] rather than formal trade or partnership agreements. Among the most structured CRM arrangements those embedded in the following should be noted: the EU–Mercosur framework, signed in January 2026; the EU–Indonesia CEPA, for which negotiations were finalised in September 2025; and the updated EU–Mexico Global Agreement, for which negotiations were concluded in January 2025. The 2021 EU-Canada Strategic Partnership on Raw Materials can also be mentioned: it does not constitute a fully-fledged trade agreement, but rather a structured cooperation framework established within the framework of the Comprehensive Economic and Trade Agreement (CETA) between Canada and

[16] E.g. Aguablanca project: https://denariusmetals.com/project/spain/alto-minerals/aguablanca-project-overview/

[17] The list of MoUs can be found here: https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/raw-materials-diplomacy_en

the EU, signed in 2016. Yet, the rest of the international strategy consists in promoting bilateral agreements and encouraging provisions on CRMs in existing agreements, through the use of the Global Gateway[18] (an initiative in place since 2021) to support projects along the raw materials value chain and improve connectivity.

To find additional references to the EU's stance on international relations and CRMs, other sources outside the CRMA must be considered. One of the main intentions, even though not explicitly stated in the CRMA, is the attempt to establish a "Critical Raw Materials Club" to collaborate with "like-minded countries" (EC, 2023d). The definition of "like-minded" is not provided in the EU documents, and it is unclear whether it refers to the intention of other parties to strengthen CRM global supply chains, or rather to specific political, economic, and social characteristics. However, the concept of a CRM Club has been taken up in more concrete form through the creation of the Minerals Security Partnership (MSP)[19], a policy dialogue group and a multilateral cooperation platform. In this context, the 30 like-minded[20] countries are broadly understood as those aligned with the objective of promoting secure, resilient, and sustainable critical mineral supply chains. This approach may prove risky, strengthening polarizations rather than widening and upgrading international partnerships and multilateral cooperation. These cooperative relationships could be undermined by some of these countries' ties with China, that has built over time solid economic relationships with strategic partners through international policy instruments like the Belt and Road Initiative (BRI) (Liu et al., 2018; Wang et al., 2023), in which several members of the MSP also participate. In addition, many international partnerships of the EU have been characterized by a technocratic tendency and, at times, a paternalistic attitude. This is particularly evident in relations with African countries, where the EU is often perceived as an actor imposing its own model or priorities without adequately involving local counterparts[21]. For instance, the Namibian government implemented a ban on the export of unprocessed critical minerals, including lithium, cobalt, manganese, graphite, and REEs, just eight months after a MoU signed in November 2022 with the EU. Namibia's decision aligns with a broader trend among resource-rich African nations, such as Zimbabwe, which implemented similar bans to retain more value from their natural resources[22], and others like Nigeria and Ghana in banning unprocessed mineral ores exports[23]. The EU's strategic approach, entirely based on bilateral negotiations and aimed at safeguarding what it defines as "strategic" interests, risks clashing with the interests of resource-rich countries which, in the absence of serious proposal of alternative models of mutually beneficial collaboration and economic development, are inclined to adopt protectionist policies to safeguard their own interests.

[18] The Global Gateway is the EU's strategy to mobilize up to €300 billion by 2027 for sustainable infrastructure projects in partner countries, aiming to promote high standards and strengthen the EU's global influence, supporting the goals of the UN 2030 Agenda and the Paris Agreement: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/stronger-europe-world/global-gateway_en

[19] https://policy.trade.ec.europa.eu/help-exporters-and-importers/accessing-markets/raw-materials/minerals-security-partnership-forum_en

[20] Argentina, Australia, Canada, DRC, Dominican Republic, Ecuador, Estonia, EU, Finland, France, Germany, Greenland, India, Italy, Japan, Kazakhstan, Mexico, Namibia, Norway, Peru, Philippines, Republic of Korea, Serbia, Sweden, Türkiye, Ukraine, UK, US, Uzbekistan, and Zambia.

[21] https://www.gisreportsonline.com/r/eu-africa-strategy/

[22] https://www.reuters.com/markets/commodities/namibia-bans-export-unprocessed-critical-minerals-2023-06-08/

[23] https://www.globalpolicywatch.com/2024/05/african-raw-material-export-bans-protectionism-or-self-determination/

6. CRMs in the EU strategy: assessing the targets

6.1 CRMA independence targets

To appraise mechanisms and novelties introduced by the CRMA, it is now crucial to clarify that the four targets set by the CRMA discussed in Section 5 above are non-binding. This means they are not embedded within a legal regulation that would not only define the targets but also impose requirements and enforcement mechanisms, including sanctions for non-compliance[24]. All four independence targets are based on the domestic consumption of SRMs, which have been selected ad hoc by the EC on the basis of their strategic importance for three broad areas: green transition, digital transition, and defence & aerospace.

According to the terminology most used in the mining and metallurgical industry, the more upstream stages of the supply chain are those carried out by the mining sector and consist of extraction and processing. In the extraction stage, material is removed from the ground, while the processing stage refers to ore separation and concentration, typically carried out in smelters and concentrators operated by mining companies and classified under NACE Rev. 2, Section B (Mining and quarrying). The more downstream stages instead begin with processed ore and culminate in the production of tradable metals. These activities fall under the manufacturing sector, specifically NACE Rev. 2, Division 24 (C24): Manufacture of basic metals. After this stage, tradable mineral commodities are available on the market and are used by manufacturing firms as material inputs. This nomenclature is also used by Daly et al. (2019) to refer to the technologies related to the different stages in the production of mineral commodities. However, in the CRMA the EC adopts a different classification, in which the mining stages of extraction and processing described above are grouped together under the label "extraction", while refining is included under "processing". Here we use the terms extraction and processing according to the terminology adopted by the EU, where the extraction stage refers to the production of unrefined primary materials (e.g. ores, concentrates, raw mineral forms), whilst the processing stage implies the transformation of such raw materials into refined or semi-refined commodities (e.g., cobalt sulphate for batteries, cobalt powder, aluminium sheets, copper cathodes). This distinction is essential for understanding what the four targets are actually intended to achieve, since all the thresholds are expressed as percentages of consumption: the notion of consumption to which they refer, however, is not the same across all four targets. More specifically, the extraction target refers to the consumption of ore and raw materials from mining (hence, unrefined materials), whereas the processing and recycling targets refer to the consumption of finished commodities (refined materials). More detailed information on the different stages and processes of the production chain of each material can be found through the factsheets of the SCRREEN project[25], which provide a clear sense of how the extraction, processing and refining involve a far more complex set of activities than is generally assumed[26].

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[24] An example of legally binding targets is the European Climate Law (Regulation (EU) 2021/1119). This law sets a mandatory goal to reduce greenhouse gas emissions by at least 55% by 2030 and to reach climate neutrality by 2050. Unlike the CRMA, which only sets voluntary targets, this regulation makes it legally compulsory for EU countries to act, with their progress monitored and enforced at the EU level.

[25] The SCRREEN project operates within the Horizon 2020 Programme and compiles factsheets for each specific raw material, relying on data from multiple sources, including the British Geological Survey (BGS), the United States Geological Survey (USGS), World Mining Data (WMD), and the UN COMTRADE and PRODCOM (Eurostat) databases (https://scrreen.eu/crms-2023/).

[26] Relying on such information, for instance, cobalt is predominantly extracted as a by-product from copper and nickel mining, with 56% of the global primary cobalt supply coming from copper mines and 37% from nickel mines.

Target 4 on supply independence represents an even more distinct case. Although it is the clearest and most ambitious of all the targets, Regulation (EU) 2024/1252 explicitly states that the maximum threshold of 65% import reliance on a single country applies to both the extraction and the processing stages. As a result, this target must be assessed both upstream, on the consumption of unrefined materials, and downstream, on the consumption of finished commodities.

6.2 Independence targets: a descriptive assessment

Although the CRMA sets very specific quantitative targets, as of May 2026 no official evaluation of progress towards these targets has yet been published. By collecting and systematising the scattered and fragmented data contained in various EU documents, it is possible to identify the 2023 baseline against which the objectives were defined. We report our own elaboration in Table 3 to assess the EU's position with respect to the CRMA targets for each SRM. Data on Table 3 are manually gathered and harmonized from the information available in the 2023 factsheets by the SCRREEN Project, the 2023 Final Report on CRMs (EC, 2023a) and the Raw Materials Information System (RMIS)[27].

[TABLE 3 HERE]

It is important to emphasize that none of these sources constitutes a proper database. Rather, they are textual files from which we extracted the information. Starting with targets 1 and 2, Extraction and Processing, we rely on the indicator Input Reliance (IR). This indicator is directly provided by the EU and calculated according to the official methodology of the Commission (2017). It is defined as the ratio of net imports (imports - exports) to apparent consumption[28] (domestic production + imports – exports) for each SRM[29], and can range from 0 to 100, but it cannot take negative values when exports exceed imports. The IR indicators are computed on the basis of different consumption measures, according to whether Extraction or Processing is being considered: the consumption of unrefined SRMs for Extraction, and the consumption of refined SRMs for Processing, since they refer to two different stages of the SRM supply chain. Target attainment for these first two objectives is derived from the inverse of this measure (1–IR) which, in economic terms, captures the share of domestic consumption satisfied without recourse to net imports. For Recycling, the target attainment is instead calculated using the End-of-Life Recycling Input Rate (EoL-RIR), which is also provided in the EU official documents. It measures the share of total material inputs into the EU economy that originates from end-of-life recycling. As such, it provides a suitable proxy for assessing the CRMA recycling target. In this case, the consumption used to calculate the indicator is the consumption of refined SRMs. The main supplier for target 4 is also provided in the official documents consulted and as previously discussed, must refer to the supply of both unrefined and refined materials.

However, despite our considerable efforts, Table 3 remains incomplete. In some cases, an attainment level of 0% for the extraction target may reflect either a negative trade balance (exports-

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Only 7% of the global cobalt supply originates from mining operations where cobalt is the primary product, such as the Bou Azzer mine in Morocco and the Lubumbashi project in the DRC (SCREEN, 2023a).

[27] RMIS (https://rmis.jrc.ec.europa.eu/) was set up in the Circular Economy Action Plan (2015) and is led and maintained by the JRC. It provides knowledge on raw materials and associated value chains in the context of sustainability, including supply risks and circularity.

[28] The EC constructs apparent consumption using data from PRODCOM, Eurostat, and World Mining Data (WMD), based on averages for the 2019–2023 period.

[29] Note that an IR value of 0 does not imply the absence of imports for a given SRM. Rather, it indicates that net imports are zero or that the EU is a net exporter.

imports) when IR = 100, or the absence of extraction. In other cases, however, such as for the REEs, combining multiple sources allows us to be more precise and state that no materials were extracted during the five-year period considered. Looking at Table 3, six SRMs were above the 10% threshold for extraction (aluminium, cobalt, copper, lithium, nickel, tungsten); 7 met the 40% threshold for processing (aluminium, cobalt, copper, germanium, silicon metal, titanium), while only 3 SRMs met the 25% threshold for recycling (aluminium, copper, tungsten). Given that the CRMA targets were set in 2023, they represent the most up-to-date figures available from the EC at the time the targets were established. Nevertheless, consumption data were available only up to 2020, so the averages were based on the 2016–2020 period. Low recycling rates may stem both from technical, chemical, and engineering challenges in reprocessing certain materials, and from the difficulty of retrieving end-of-life products in which these materials are embedded. For instance, the high *EoL-RIR* values of some materials, such as tungsten and cobalt, can largely be attributed to high end-of-life collection rates. Tungsten is mainly used in machine tools typically managed by industrial actors and therefore collected efficiently at the point of end-of-life. Similarly, cobalt is primarily used in batteries, which benefit from targeted waste legislation that ensures high collection rates (Blengini et al., 2019). For other materials, however, such as PGMs, current performance remains well below the technical potential that could be achieved. PGMs are highly suitable for recycling, and up to 95% of their content can be recovered from industrial and automotive catalysts. However, the recycling input rate for platinum and palladium was only around 10% over the 2016–2020 period (EC, 2023a). This mainly depends on the fact that a large amount of PGMs is embedded in long-lived products, or to sub-optimal collection of waste containing these specific materials (Blengini et al., 2019).

For target 4, on the processing side, 16 materials were below the maximum threshold of 65% dependence on a single supplier required by the target. The label "No import or production" in the fourth column indicates that there was neither domestic mine production nor imports of unrefined SRMs. Therefore, no main source country can be identified for that specific SRM. This may look rather intricate but follows logically from the structure of the mineral commodity supply chain. In principle, mine production of unrefined commodities constitutes the input demand of metallurgical firms for materials to be refined. For some materials, the IR is 100%, but we also find that the EU share of global refined production for a specific SRM is 0%. This means that, according to the data consulted, there was neither mining nor metallurgical production in the EU, nor any imports of unrefined materials; therefore, in this case, the EU was fully dependent on imports of finished commodities already refined abroad. From this perspective, target 4 about import independence from a single supplier is certainly more achievable for processing than for extraction.

Much of our work consisted in keeping the sources up to date, which still present some gaps and are continuously being updated. In this regard, new factsheets for some of the SRMs included in Table 3 were released at the end of 2025, although only for the IR indicator and no recycling data were available. Table 4 compares the previously reported values with the updated ones. The indicators are again calculated as five-year averages for the 2019–2023 period. Comparison is possible only for those materials comparable with 2016–2020 data: a comparison can be carried out for 11 SRMs. The new figures reported in Table 4 therefore provide a more accurate picture of the situation in 2023, when the CRMA was adopted. For some materials, the update reveals substantial changes, pointing to a situation that is worse than that suggested by the earlier data. This is the case, for example, for aluminium, copper, boron, and nickel extraction. For others, such as tungsten and nickel processing, a slight improvement can be observed compared to the 2016–2020 period. An increase can also be noted in the share of some materials, such as refined cobalt, aluminium and copper, supplied by EU or European countries such as Norway. At the same time, there is less reliance on Russia and a greater dependence on China in the case of refined tungsten and gallium.

[TABLE 4 HERE]

What emerges from this sketched analysis is that, when adopting a more granular approach that looks at minerals and targets, the CRMA suffers from several weaknesses. First, data collection remains difficult and, even in the new 2025 data, often partial. Second, the Act establishes the same deadline for all four targets discussed earlier, focusing on the different stages of the supply chain and on each SRM. Yet, the EU's starting points at the baseline differ substantially across extraction, processing, and recycling. The latter appears particularly problematic, as the share of consumption met by secondary raw materials is below 5% for most SRMs. Third, the top-down approach works less precisely for those materials for which extraction and processing are still at an early stage (or entirely absent), and therefore where the EU is exposed to greater risks. It would be more effective, for example, if the extraction target was instead measured on the basis of the extractive capacity of the mining sector, taking into account the natural endowment, or the material input demand of the metallurgical sector for the production of refined mineral commodities. Similarly, the recycling of SRMs is closely linked to the metallurgical industry and it should not be disconnected from existing refining capabilities in the EU. Furthermore, the SPs do not cover all materials efficiently. For instance, bismuth, titanium, and silicon metal have no SPs of any kind, while for magnesium there is only one extraction project, despite the fact that 100% of the consumption of this commodity between 2016 and 2020 was met through imports of refined commodities, 97% of which came from China. For other materials, such as lithium, the SP appear to be a more interesting tool, as 8 processing SPs are currently underway, and the EU extraction activities (although mainly confined to Portugal) already exist.

Even more importantly, the whole operative approach is based on reducing dependencies through increases in domestic supply, while lacking concrete strategies to diversify risk via fair and mutually beneficial partnerships with resource-rich countries. Another form of inconsistency arises between the operative content of the CRMA and its overall purpose. The CRMA's general aim is the creation of a stable and secure supply of CRMs at every stage of the supply chain. However, the only likely effect of the SPs is to attract investment in the extraction and processing of SRMs in the short to medium term. This approach does not align well with the objective of building and strengthening stable supply chains: the lack of a long-term perspective becomes problematic when considering the actual and expected rise in demand for some of these commodities, as well as the efforts that other countries such as China, Canada, Australia, and the USA are already undertaking through their respective programs.

7. CRMs in the EU strategy: the resources and the regions

7.1 Mineral resources: definitions and framework

In this section, the focus shifts to the extraction of SRMs and, in particular, to the extent to which the EU endowment and distribution of such natural resources add further complexity to the assessment of the European strategy. Mineral natural resources are unevenly distributed across the Earth's crust. The location of deposits results from geological processes that have occurred over millions of years, and cannot be easily modified through policy interventions.

We report a descriptive analysis of the EU's natural mineral resource endowment, seeking to highlight both potential strengths and weaknesses of the EU in relation to its known SRMs resources. To have a tool as coherent as possible with the analytical and policy framework of the EC, all the geological and mining technical definitions provided in this section are aligned with the EU INSPIRE Directive (2007/2/EC)[30], the most updated INSPIRE technical definitions and the INSPIRE Registry.

Two concepts are crucial and well established in the mining literature: Resources and Reserves. In short, a mineral resource is defined as a mass of naturally occurring mineral materials (mineral occurrences) with a potential economic viability. A reserve represents the portion of a mineral resource that has been evaluated as both economically and technically feasible for extraction under current socio-economic conditions (US Bureau of Mines & USGS, 1980). Thus, although both measures are usually expressed in metric tonnes, while resources refer to a concentration of material of economic interest and are quantified on the basis of geological criteria and methodologies, reserves quantify the portion of those resources that is economically extractable.

Another useful concept is that of a Mineral Deposit, defined by the INSPIRE Registry as a mass of naturally occurring mineral material, e.g. metal ores or non-metallic minerals, usually of economic value, without regard to mode of origin. When a stakeholder, whether a public actor or a private firm, carries out a geological survey in a specific area, the presence or absence of a given mineral in that area may be established. This finding is technically referred to as an Occurrence and may consist either of a few traces of the mineral or of an actual concentration of resources of that material. In the latter case, in the presence of mineral resources, we have a mineral deposit. Yet, the presence of some resources in a mineral deposit does not necessarily mean that such a material is exploitable in the short term. An example in Europe is that of REEs, for which there are some geological concentrations but, to the best of our knowledge, there are no significant operating mines extracting REEs from the soil of the EU (although several projects are in progress, particularly in Sweden and Norway)[31]. Finally, according to INSPIRE, a Mine can be also referred to the natural mineral endowment as it can be simply defined as an excavation for the extraction of mineral resources from mineral deposits. A mine therefore exploits mineral properties where reserves are located, acquired or licensed from one or more mining companies for the development of their own projects. Figure 2 summarises the mineral resource framework.

[FIGURE 2 HERE]

7.2 Data

The availability of large-scale geolocated data on mineral resources and mining production is a well-known problem, and the EU is no exception. Partial territorial and mineral coverage, difficulties in retrieving from metadata detailed information on the techniques used for data collection, and issues of temporal consistency are widespread. On the basis of the framework reported in Figure 2, here we rely on the proprietary database "Metals & Mines Database" by S&P Global. We use this dataset both to obtain a quantitative representation of resources in mineral deposits and to map SRM mines. In fact, S&P Global provides a wide range of information on both mining projects – including their activity status, mining properties, production from mining activities, nationality and financial information of project owners – and resources and reserves in

[30] https://inspire.ec.europa.eu/registry

[31] https://www.bbc.com/news/world-europe-64253708,https://www.reuters.com/markets/commodities/companies-forging-rare-earths-industry-eu-2024-06-27/

with global coverage. The identification and geolocalisation of mines is carried out by geolocating "mining properties", defined by S&P Global as "*an area that has been legally acquired or claimed for the extraction of mineral resources*" and identified through latitude and longitude coordinates[32]. Through S&P Global data, we can also retrieve information on the mining projects to which these properties belong, thereby highlighting, for example, whether an active extraction project is still in place for a given mine[33]. We consider 17 SRMs: nickel, bauxite, bismuth, cobalt, copper, graphite, lithium, magnesium, manganese, titanium, tungsten, REEs, and PGMs treated as single elements: platinum, palladium, rhodium, ruthenium, and iridium. Due to data granularity, however, REEs can only be considered as the lanthanide group[34].

A second data source, not analysed here, should be mentioned: the European Geological Data Infrastructure (EGDI[35]), which harmonizes data from multiple sources collected by official national providers, such as the Italian Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA), the British Geological Survey (BGS), the French Bureau de Recherches Géologiques et Minières (BRGM), etc. EGDI has three strengths: 1) it is the only source providing, with a sufficient level of accuracy, information about a wide range of raw materials including almost all the CRMs in the EU 2023 list; 2) it is an official EU database which follows specific notions, structures, and definitions adopted by the EC, and is therefore fully aligned with its programs and objectives (among which, the CRMA); 3) it is a dataset based on mineral deposits rather than on mining properties, which means it geolocates resources in both exploited and non-exploited deposits. Unfortunately, the weaknesses of EGDI are multiple and significant, and it only allowed us to geolocate the resources of CRMs and SRMs within Europe, without any quantification. It also suffers from lack of metadata, missing values concerning the date when a specific dimension was either updated or recorded, the source from which it was taken, and geographical coverage relative to mines[36]: these and other limitations forced us to rely mainly on S&P Global for the mining component.[37]

7.3 The European SRM endowment

One of the main tasks in assessing the EU's natural endowment of critical mineral resources is to develop a consistent method for comparing resources across geographies in order to identify relative advantages. Figure 3 is an example of the kind of representation S&P Global allows to do,

[32] Thus, when we geolocate mining properties, we are not locating the headquarters of a firm, but rather the geographic point where the resources are physically situated.

[33] Although data on reserves and annual production are included, the high number of missing values, compared to resources in mining projects classified as active or at an advanced development stage, led us to exclude these variables.

[34] The lanthanide group is an aggregate of REE that includes lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium. Some of these do not appear on the list of SRMs, but it is impossible to further disaggregate.

[35] EGDI is a geological database assembled by the EuroGeoSurveys (EGS), a not-for profit organization providing European Institutions with experts and services

[36] For the use EGDI to build a dataset on all CRMs/SRMs and resources embedded in unexploited deposits, see Dessì (2026).

[37] Other databases were identified as potentially suitable for a resource analysis, but they resulted to be incompatible with EGDI, S&P Global or INSPIRE technical guidelines. The most important is the Mineral Resource Data System (MRDS) provided by the USA Geological Survey (USGS), which offers data at the global level for a wide set of different materials. The information is based on deposits, as in EGDI, which allows identification of resources in both exploited and non-exploited deposits. However, when comparing European deposits and occurrences, the USGS database turned out to be significantly less informative than EGDI.

in this case considering 4 SRMs (lithium, cobalt, REEs and platinum)[38] for a set of world macroregions including Europe, US, Canada, China, Latin America, Africa and Russia

[FIGURE 3 HERE]

In the radars, the amount of resources is computed as the sum of mineral resources (in tonnes[39]) for each SRMs contained in mining properties of all mining projects in that region of the world. The feasibility of extracting mineral resources through mining activities clearly depends not only on the amount of economically recoverable resources, but also on geological characteristics, regulatory constraints, social and political resistance, and associated risks. For example, it is highly unlikely that a titanium mine would be opened in a UNESCO World Heritage natural park or in the middle of an urban area, even if the deposit were one of the largest in the world.

From Figure 3, the distribution of mineral resources does not appear favourable to Europe for the SRMs considered. Though, considering each material individually is useful for obtaining a general representation of the distribution of resources worldwide, but it is not an easy way to evaluate the global natural endowment of CRMs and SRMs. Absolute values of resources of different commodities cannot be summed together, since each occurs in different concentrations within mineral deposits. For example, a deposit containing 1 million tonnes of REE oxide resources has a completely different economic and strategic relevance compared to a deposit with 1 million tonnes of aluminium resources. To address the problems of incomparable absolute values and heterogeneous resource distributions, and to enable international comparisons of resource endowments, we compute z-scores for each SRM in every country. The amount of resources in a given country is thus expressed in terms of standard deviations from the mean resource level for that specific commodity. In Figure 4, absolute values are aggregated by world macro-regions and then standardized in z-scores to provide a comparative representation of the European position.

[FIGURE 4 HERE]

Values toward red indicate a comparative advantage in the mineral resource endowment for the area considered. A value of 0 corresponds to the mean, as z-scores follow a standard normal distribution $Z \approx N(0,1)$. Negative values in blue represent a resource endowment below the world average. When the number of resources is 0, meaning the complete absence of that specific SRM in the world region, we denote it as NP (Not Present). The heatmap highlights the highly uneven global distribution of SRMs. Africa shows strong comparative advantages in several CRMs, including bauxite, cobalt, graphite, manganese, PGMs, and REEs. Latin America stands out with a particularly high concentration of copper and significant resources of lithium and graphite. Australia holds advantages in bauxite, nickel, copper, and palladium, while China is prominent in bismuth, nickel, and especially REEs. Russia shows relative strength in nickel and palladium, whereas the United States has notable advantages in copper and titanium. Canada presents a more balanced profile, with strengths in lithium, manganese, and PGMs. In contrast, Europe generally appears below the global average, with only limited relative advantages, such as copper and tungsten.

7.4 SRM resources in the European regions

We finally provide a preliminary attempt to map the natural endowment of mineral resources across European subnational regions. The EU's criticality assessment model for CRMs, together

[38] Radars for all 17 SRMs are available from the authors upon request.

[39] Note that for PGMs, which are treated as precious metals, the unit of measure is ounce (oz).

with the CRMA top-down approach, fails to adequately account for the geographical distribution of resources and the potential socio-economic and environmental implications of the regional concentration of CRM resources. By identifying where critical resources are concentrated, it is possible to highlight regions with untapped potential and classify critical materials for which, based on current knowledge, diversifying domestic supply may be feasible (or not) in the short-medium term due to the presence and size of natural endowments, costs and risks assessments, and local communities' reactions.

We use S&P Global for quantitative representation of SRM resources in mining projects at the NUTS-2 level. A total of 210 projects was identified, from which we consider the mineral resources contained within the deposits under the ownership or license of a project. We classify deposits by size – small, medium/small, medium/large, and large – based on the quartiles of each material's global resource distribution[40]. Figure 5 maps the distribution of SRM resources across European regions (27 EU members + Switzerland, Norway and UK)[41].

[FIGURE 5 HERE]

Figure 5 reveals a strong concentration of SRM resources in projects located mainly in two areas: the Nordic countries and south-western Europe (Portugal and Spain). A notable cluster of deposits classified as "large" containing substantial resource volumes is also evident in parts of Central and Eastern Europe. Yet, aggregating all SRMs can yield an overly optimistic picture that obscures the actual concentration of specific resources within regions. As previously stressed, these materials must be analysed individually rather than as a single bundle, because they are extracted and processed at different concentrations, and refined and used for distinct production purposes. Figure 6, as an example, reports on a subset of materials that, at the baseline period (2016–2020), did not meet the 10% domestic-extraction threshold set by CRMA, underlining an even more limited number of regions in which resources of such materials are embedded.

[FIGURE 6 HERE]

Mineral resources in mining properties may be exploited at very different pace, but rarely very swiftly. The further the project licensed for using the resources advances toward a production stage, the sooner these resources may be utilized. In Figure 7, we reproduce the map shown in Figure 5 but report the operational status of the SRM mining projects, using the macro-classification provided by S&P Global, which summarizes the possible stages of activity of a project into Closed Project, Early Development, Late Development, and Mine Stage; the latter is the only one actually in an operational extraction phase, either intermittent or continuous. Late and Early Development stages are gathered into a single category, Under Development, with the exclusion of projects for which no quantified resources are available. It should be noted that the recording of project status in S&P Global often refers to dates even earlier than the past decade. A manual check on each individual project was performed, drawing on information from producer websites and local government agencies, and updated project status whenever it was dated prior to 2023[42]. Out of a

[40] Note: resources of different SRMs may be contained within the deposits of individual projects; therefore, the count of deposits for each material does not match the total number of projects.

[41] The integration of resources from these countries is strongly aligned with the EU CRMA framework (with the UK as a EU Member State until 2020).

[42] The update was carried out following a logic aimed at avoiding inconsistencies with S&P Global's classification approach. Projects originally in the Under Development or Mine Stage categories, where the license had expired without renewal and no new ongoing feasibility studies, were reclassified as Closed. Projects in Under Development that had begun extraction activities for at least one year were reclassified as Mine Stage. Finally, projects previously

total of 210 mining projects containing at least one of the considered SRM resources, 36 (17%) are classified as Closed, 134 (63%) are Under Development, and 40 (19%) are in the Mine Stage.

[FIGURE 7 HERE]

Overall, Figure 7 highlights that while many projects are still under development, 80% of them are active or potential mining sites, with strong geographic concentrations in the Nordic regions and those of the Iberic Peninsula. Active mine stage projects are again primarily located in regions in Finland, Sweden, Portugal, and Spain, with a markedly lower presence in Greek and Romanian regions. In this representation, it is important to note that the presence of resources of a given SRM within the mining properties of a project does not necessarily mean that the material is being extracted, but only that the licensed area contains such resources. This is the case, for instance, of REEs, which, although present in certain quantities, are not yet being extracted in the territories considered as of August 2025.

8. Conclusions

The CRMA represents a bold attempt to secure a stable supply of critical and strategic raw materials in Europe. Our descriptive analysis suggests that the strategy outlined in the CRMA – and more generally in OSA – is not without significant uncertainties, which could prevent it from achieving its ambitious independence targets.

The EU approach risks overestimating the capacity of broad industrial policy tools to reshape mineral supply chains while underestimating geological constraints, territorial governance and capabilities' challenges, and the inherently global nature of raw material supply chains. The analysis identifies and discusses the major areas of vulnerability: the inadequacy of the policy instruments designed so far to reduce European dependency; the inward-looking orientation of the OSA strategy and the CRMA in a context where mineral supply is fundamentally global; the mismatch between policy targets and Europe's geological endowments; and the insufficient integration of regional environmental and social territorial constraints affecting extraction and production of critical and strategic raw materials.

The CRMA prioritizes increasing domestic supply, but the reality is that critical mineral resources are relatively scarce and geographically concentrated in a few subnational European regions. The regional dimension and the capabilities for a functioning and technologically advanced European mining sector have been overlooked: it is uncertain whether and where the geographical distribution of natural resources for various CRMs and SRMs meet the capabilities needed for their extraction, processing and transformation (Dessì, 2026).

Even in the case the EU achieves its domestic extraction targets, it would still be heavily dependent on imports for most of its supply. The lack of a structured trade strategy and solid, inclusive and equitable international, and multilateral, partnerships could increase supply risks and jeopardise GVCs based on CRMs and SRMs. The uncertainty surrounding mineral reserves and availability of accurate geological data – signalling structural weaknesses per se – may only foster these issues making more difficult to predict whether specific regions can truly support large-scale mining

classified as Mine Stage but subsequently closed, and later acquired under license or feasibility studies by another operator, were reclassified as Under Development operations. Furthermore, without better data and investment in exploration, European policymakers risk misallocating resources and failing to develop truly resilient supply chains.

Additionally, the implementation of the CRMA excessively depends on strategic projects that are subject to regulatory fast-tracking and public funding support. The lack of binding obligations and clear enforcement mechanisms raises concerns about whether these projects will be sufficient to meet the CRMA's targets. Firms may hesitate to commit to large-scale projects without stronger incentives and clearer long-term commitments from policymakers. In the EU's SP framework MNEs seems to have a clear advantage in meeting the requirement to present SPs as they have greater access to capital and financial networks, extensive experience in managing complex extraction operations, which allow them to address permitting processes and influence decision-making more effectively. These dynamics may create barriers to entry for smaller, local firms, limiting competition and reinforcing the dominance of a few key players in the mining sector.

Furthermore, the uneven geographical distribution of mineral resources includes the risk of excessive pressure on certain regions particularly rich in rare and highly concentrated raw materials. This could result in environmental degradation, social conflicts, and obstacles to obtaining Social License to Operate (SLO)[43]. Without a governance that integrates the top-down approach with bottom-up actions and involvement of the regions and communities concerned, the concentration of strategic projects around MNEs, combined with the clustering of SMRs in a few regions, could foster social tensions that may hinder the exploitation of the scarce natural resources available in Europe. In areas where extraction and processing are heavily concentrated, local communities may see these activities as unfairly impacting their environment and economy, leading to resistance and opposition. Without gaining SLO, many SPs could face delays or even fail. If these structural issues remain unaddressed, the CRMA may lead to an inefficient exploitation of resources, failing to achieve its ambitious goals.

[43] The (SLO) refers to the ongoing acceptance/approval of a company's standard business practices by stakeholders and local communities.

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TABLES

Table 1: EU lists of CRMs and SRMs

Materials	1st list (2011) *- 14 CRMs (33 individual elements)* *-62 screened*	2nd list (2014) *-20 CRMs (37 individual elements)* *-71 screened*	3rd list (2017) *-27 CRMs (44 individual elements)* *-78 screened*	4th list (2020) *-30 CRMs (47 individual elements)* *-83 screened*	5th list (2023) *-34 CRMs & SRMs (51 individual elements)* *-87 screened*
Antimony	✓	✓	✓	✓	✓
Arsenic	X	X	X	X	✓
Baryte	X	X	✓	✓	✓
Aluminum/Bauxite	X	X	X	✓	✓
Beryllium	✓	✓	✓	✓	✓
Bismuth	X	X	✓	✓	✓
Boron/Borate	X	✓	✓	✓	✓
Chromium	X	✓	X	X	X
Cobalt	✓	✓	✓	✓	✓
Coking Coal	X	✓	✓**	✓	✓
Copper	X	X	X	X	✓*
Feldspar	X	X	X	X	✓
Fluorspar	✓	✓	✓	✓	✓
Gallium	✓	✓	✓	✓	✓
Germanium	✓	✓	✓	✓	✓
Hafnium	X	X	✓	✓	✓
Helium	X	X	✓	X	✓
HREE	included in REE	✓	✓	✓	✓
Lithium	X	X	X	✓	✓
LREE	included in REE	✓	✓	✓	✓
Magnesite	X	✓	X	X	X
Magnesium	✓	✓	✓	✓	✓
Manganese	X	X	X	X	✓
Natural Graphite	✓	✓	✓	✓	✓
Natural Rubber	X	X	✓	✓	X
Indium	✓	✓	✓	✓	X
Nickel	X	X	X	X	✓*
Niobium	✓	✓	✓	✓	✓

Platinum Group Metals (PGM)	✓	✓	✓	✓	✓
Phosphate Rocks	X	✓	✓	✓	✓
Phosphorus	X	X	✓	✓	✓
REE (LREE +HREE+ Scandium)	✓	-	-	-	-
Scandium (former REE)	included in REEs	X	✓	✓	✓
Silicon metal	X	✓	✓	✓	✓
Strontium	X	X	X	✓	✓
Tantalum	✓	X	✓	✓	✓
Titanium metal	X	X	X	✓	✓
Tungsten	✓	✓	✓	✓	✓
Vanadium	X	X	✓	✓	✓

Source: European Commission (2010, 2014, 2017, 2020c, 2023a).

Note: SRMs in italic. * Non-critical but strategic materials. ** Cocking coal was just below the criticality thresholds in the 2017 assessment. However, it was included in the 3rd list of CRMs due to its borderline position. The screened materials refer to the number of individual materials examined.

Table 2: Strategic Projects approved under the CRMA (2025)

EU-based Strategic Projects				
	Extraction	**Processing**	**Recycling**	**Substitution**
No. of projects	23	23	10	2
EU countries involved	France, Spain, Portugal, Czechia, Finland, Greece, Sweden, Romania, Germany	France, Czechia, Estonia, Germany, Belgium, Finland, Spain, Portugal, Greece, Sweden, Poland	Italy, Spain, France, Sweden, Poland, Finland	Germany, Belgium
Non-EU countries involved		Namibia (main location: France)		
SRMs	REE, Tungsten, Lithium, Magnesium, Manganese, Nickel, aluminum, Cobalt, PGM, Copper, Graphite	Aluminum, Gallium, Cobalt, PGM, Nickel, Copper, Germanium, Graphite, Lithium, Manganese, Tungsten, REE	Copper, Cobalt Nickel, PGMs, Lithium, Manganese, REE	Graphite, Germanium
Extra-EU-based Strategic Projects				
	Extraction	**Processing**	**Recycling**	**Substitution**
No. of projects	10	3	0	0
Non-EU countries involved	Ukraine, Greenland, Norway, Canada, Serbia, Madagascar, Kazakhstan, Malawi, UK, South Africa	New Caledonia, Greenland, Norway, Zambia, Brazil		
SRMs	Graphite, Nickel, Lithium, Copper, REE, Tungsten, Manganese	Nickel, Graphite, Cobalt, Nickel		

Source: https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials/strategic-projects-under-crma/selected-projects_en

Note: a single project may fall under more than one category.

Table 3: CRMA target assessment: 2016-2020 averages

Strategic Raw Material	**Extraction** (Threshold ≥ 10% of domestic consumption)	**Processing** (Threshold ≥ 40% of domestic consumption)	**Recycling:** (Threshold ≥ 25% of domestic consumption)	**External supply independence** (Threshold ≤ **65%** of domestic consumption)	
	Target attainment *(1-IR)*	**Target attainment** *(1-IR)*	**Target attainment** *(EoL-RIR)*	**Main source country for the EU** *(Extraction)*	**Main source country for the EU** *(Processing)*
Bauxite/Aluminium	12%	42%	32%	Guinea (61%)	Russia (19%)
Bismuth	0%	29%	0%	**-**	China (51%)
Boron/Borate	0%	28%	1%	Turkey (99%)	Turkey (47%)
Cobalt	19%	99%	22%	Russia (25%)	Finland (62%)
Copper	52%	83%	55%	Poland (20%)	Germany (18%)
Gallium	0%	2%	0%	-	China (71%)
Germanium	0%	58%	2%	-	China (45%)
Lithium	19%	0%	0%	-	Chile (79%)
Magnesium	0%	0%	13%	**No imports or production**	China (97%)
Manganese	3%	34%	9%	South Africa (42%)	Norway (32%)
Natural Graphite	1%	-	3%	China (41%)	-
Nickel	69%	25%	16%	Canada (59%)	Russia (38%)
Silicon metal	-	40%	0%	-	Norway (33%)
Titanium	0%	82%	19%	Norway (23%)	Germany (35%)
Tungsten	79%	20%	42%	Austria (35%)	China (32%)
PGMs*	*** 0%**	***4%**	**-**	**-**	**-**
Platinum	-	-	11%	-	UK (51%)
Palladium	-	-	10%	-	USA (31%)
Iridium+Ruthenium	-	-	-	-	South Africa (31%)
Rhodium	-	-	24%	-	South Africa (37%)
REEs	**0%**	**0%**	**-**	**-**	-
Cerium	0%	0%	1%	**No imports or production**	Russia (85%)
Praseodymium	0%	0%	10%	**No imports or production**	China (85%)
Neodymium	0%	0%	1%	**No imports or production**	China (85%)
Samarium	0%	0%	1%	**No imports or production**	China (85%)
Gadolinium	0%	0%	1%	**No imports or production**	China (100%)
Terbium	0%	0%	0%	**No imports or production**	China (100%)
Dysprosium	0%	0%	0%	**No imports or production**	China (65%)

Source: own elaboration on European Commission (2023), SCREEN, RMIS data. (*) Data are only available in aggregate form and not for individual materials. 1−IR is the inverse of the Import Reliance (IR) index and captures the share of domestic consumption met without relying on imports. The EoL-RIR is the End-of-Life Recycling Input Rate, which measures the share of total material input into the economy that comes from end-of-life recycling.

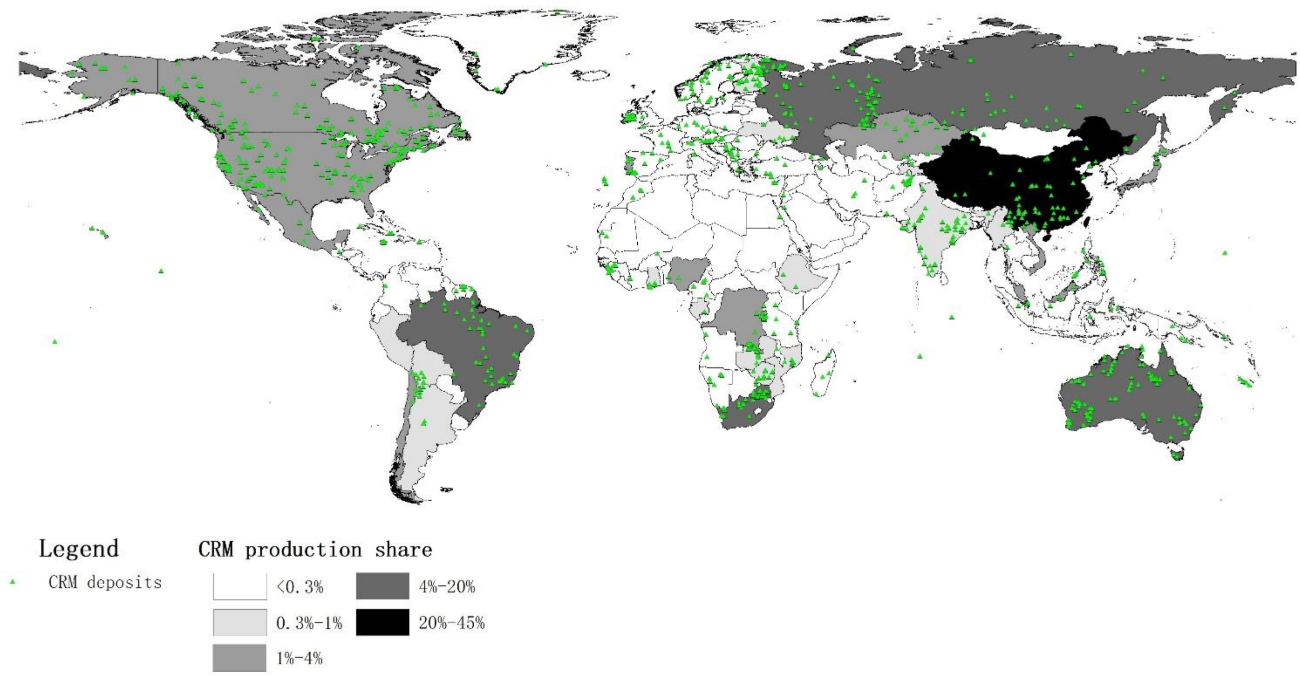
Table 4: CRMA target assessment: averages 2016-2020 compared to 2019-2023 for selected SRMs

Strategic Raw Material	**SCREEN 2023: 2016-2020**				**SCREEN 2025: 2019-2023**			
	Extraction Target attainment *(1-IR)*	**Processing** Target attainment *(1-IR)*	**Main source country for the EU** *(Extraction)*	**Main source country for the EU** *(Processing)*	**Extraction** Target attainment *(1-IR)*	**Processing** Target attainment *(1-IR)*	**Main source country for the EU** *(Extraction)*	**Main source country for the EU** *(Processing)*
Bauxite/Aluminium	12%	42%	Guinea (61%)	Russia (19%)	10%	23%	Guinea (64%)	Norway 16%
Boron/Borate	0%	28%	Turkey (99%)	Turkey (47%)	0%	0%	Turkey (99%)	Turkey (68%)
Cobalt	19%	99%	Russia (25%)	Finland (62%)	15%	100%	Russia (22%)	Finland (72%)
Copper	52%	83%	Poland (20%)	Germany (18%)	49%	85%	Poland (20%)	Germany (20%)
Gallium	0%	2%	-	China (71%)	-	0%	-	China (87%)
Lithium	19%	0%	-	Chile (79%)	100%	0%	Portugal (100%)	Chile (63%)
Manganese	3%	34%	South Africa (42%)	Norway (32%)	5%	22%	Gabon (46%)	Norway (21%)
Natural Graphite	1%	-	China (41%)	-	-	0%	-	China (25%)
Nickel	69%	25%	Canada (59%)	Russia (38%)	59%	28%	Finland (42%)	Russia (28%)
Silicon metal	-	40%	-	Norway (33%)	-	35%	-	Norway (38%)
Tungsten	79%	20%	Austria (35%)	China (32%)	100%	44%	Austria 41%	China 34%

Source: own elaboration on SCREEN projects 2023 and 2025 factsheet.

FIGURES

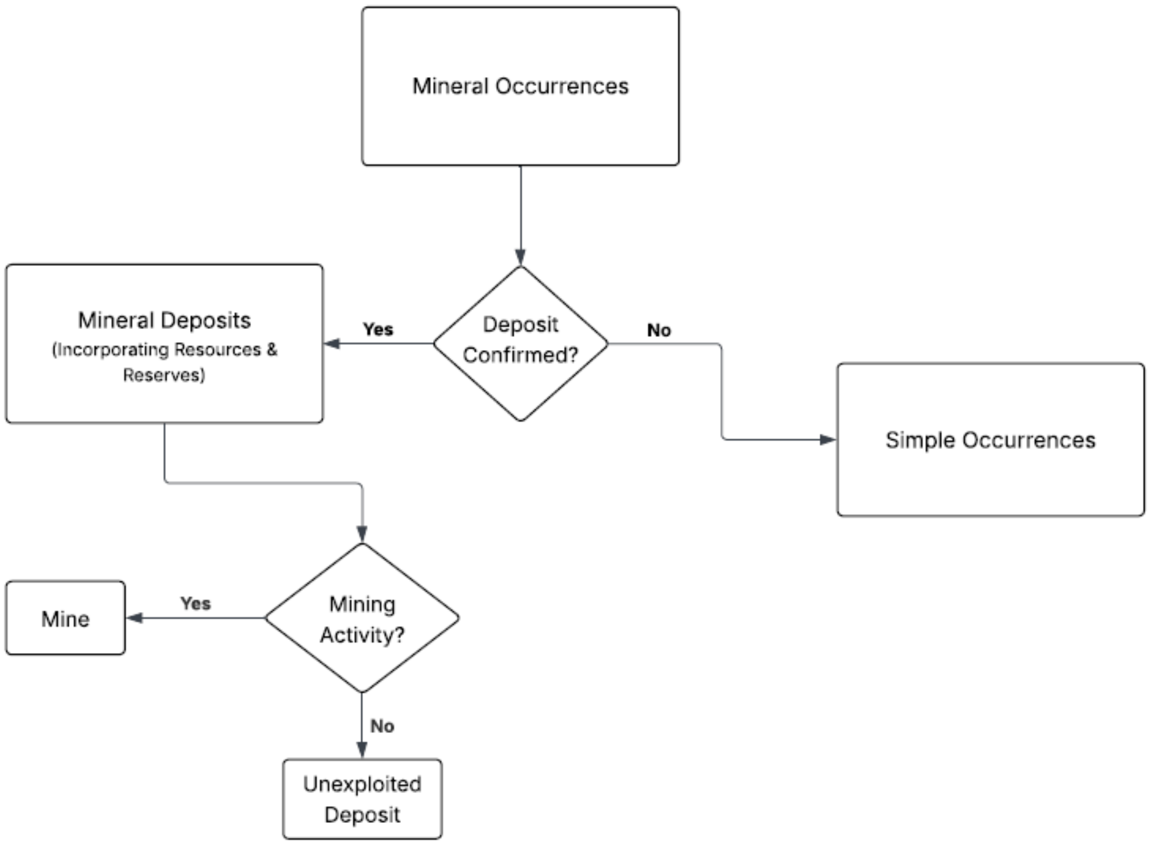
Figure 1: The geography of CRMs: deposits vs largest shares on global production



Source: country-level production data from the British Geological Survey (BGS) and the United States Geological Survey (USGS).

Note: CRMAs included here: antimony, bismuth, cobalt, gallium, germanium, lithium, magnesium, manganese, niobium, tantalum, tungsten, vanadium, as well as heavy and light rare earth elements (REEs) and platinum group metals (PGMs).

Figure 2: Mineral resource framework and key concepts



Key Concepts:

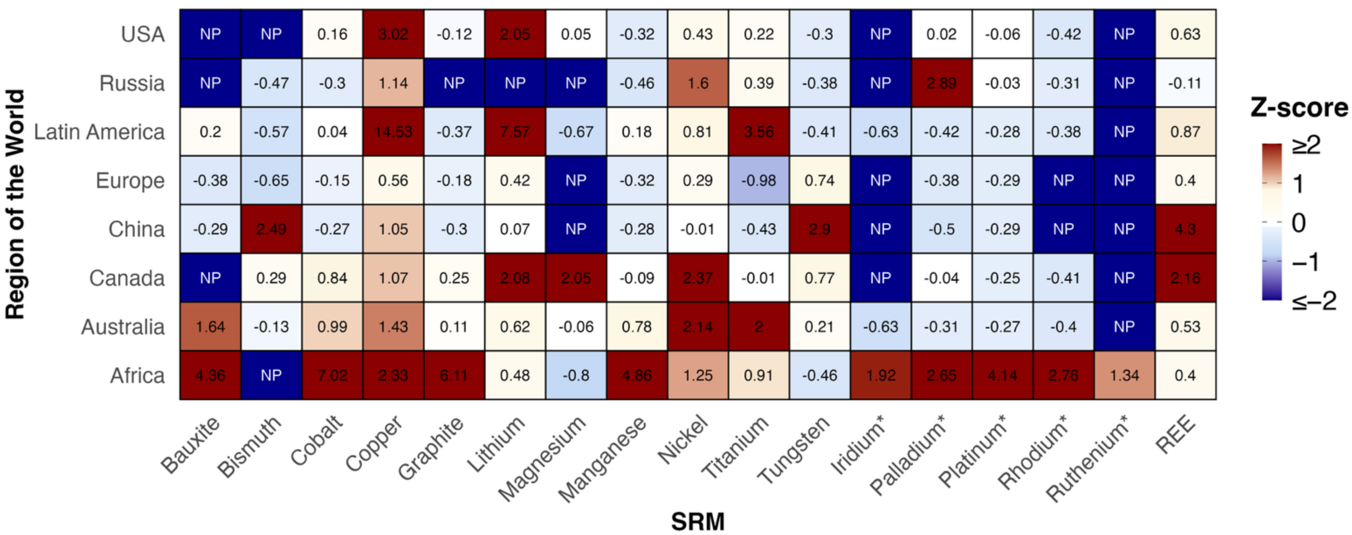
- *Mineral Occurrences*: presence of minerals or rocks in an area under examination
- *Mineral Deposits*: a mineral occurrence of sufficient size that it might, under favorable circumstances, be considered to have economic potential
- *Mineral Resources*: concentration of minerals identified and measured with reasonable certainty
- *Mineral Reserves*: part of mineral resources evaluated as both economically and technically feasible for extraction under current socio-economic conditions
- *Simple Occurrences*: occurrences that are not deposits
- *Unexploited Deposit*: mineral deposit not exploited for extraction purposes
- *Mine*: mineral deposit exploited (or previously exploited) for extraction purposes

Figure 3: Share of global resources for selected SRMs

Source: own elaborations on S&P Global data (2025).

Note: shares are computed on global endowment of resources (tonnes), across mining properties in mining projects.

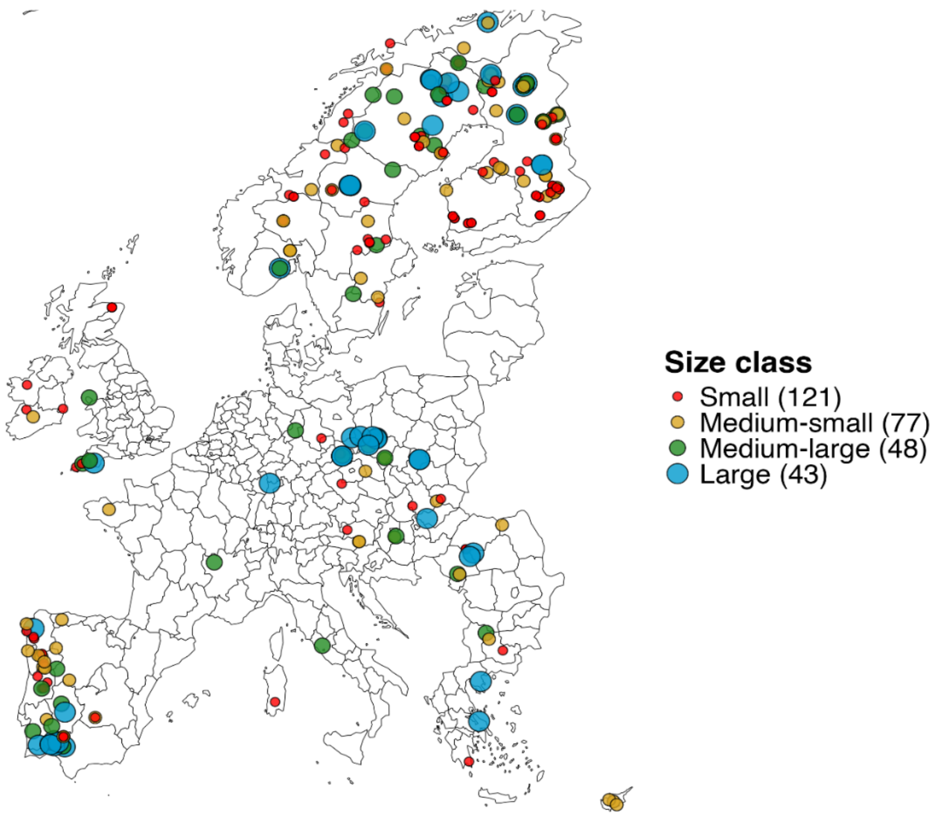
Figure 4: SRMs Resources in mining properties across world regions (z-score)



Source: own elaborations based on S&P Global data (2025).

Note: z-scores are computed at the country level based on mineral resources and subsequently aggregated by world regions. NP values indicate cases where resources for a given SRM are equal to zero. (*) PGM.

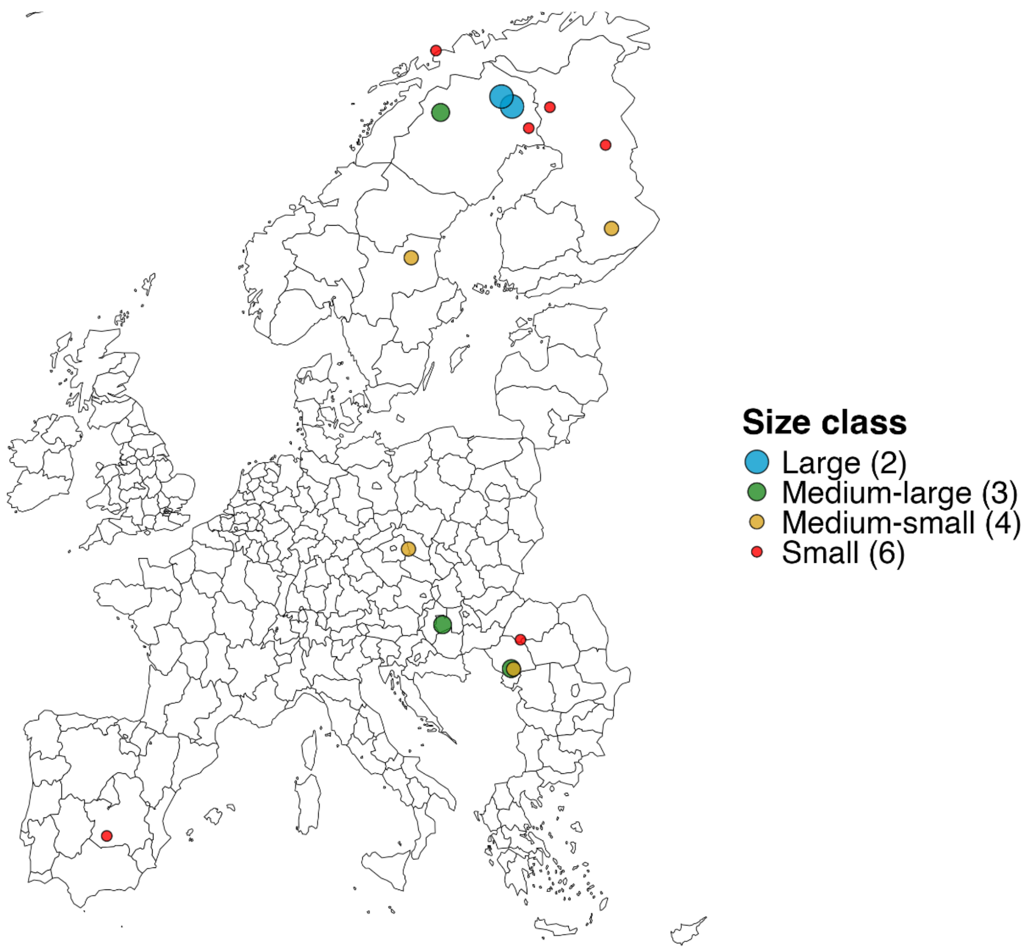
Figure 5: SRM Resources in European regions mining properties by size (NUTS 2)



Source: own elaboration based on S&P Global (2025) data.

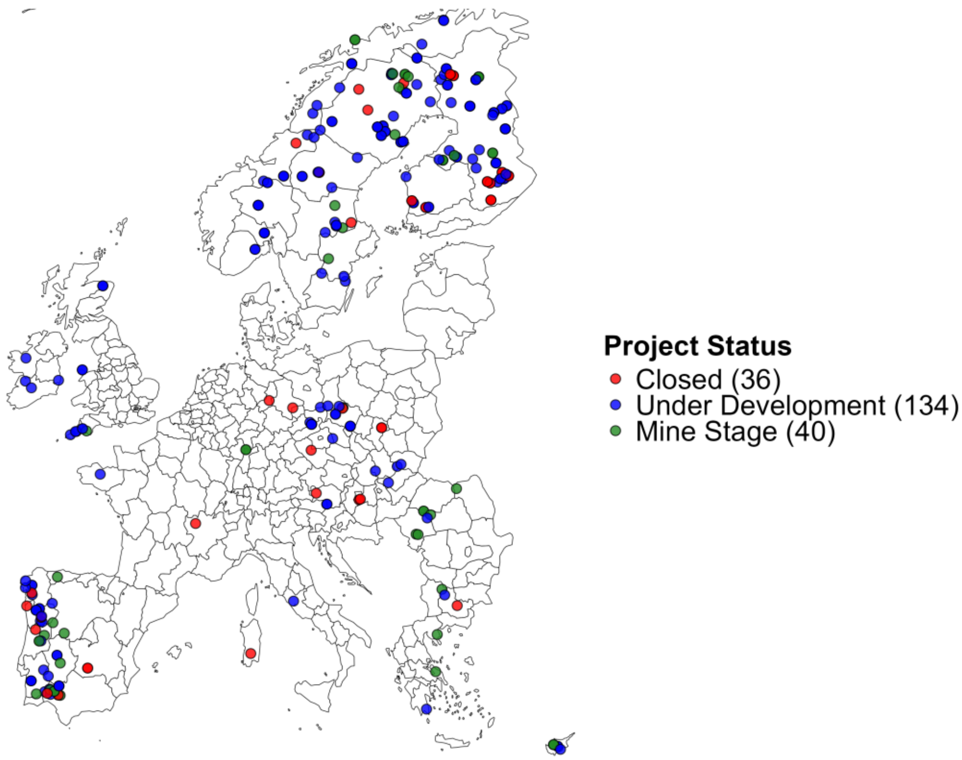
Note: 17 SRMs included. Countries: 30 (27 EU members + Switzerland, Norway and UK). Size classes are computed based on the mineral resources (t) embedded in mining properties, by quartiles of the world distribution for each SRM.

Figure 6: Resources of bismuth, magnesium, manganese, titanium in European regions mining properties, by size (NUTS 2)



Source: own elaboration based on S&P Global (2025) data.
Note: Countries: 30 (27 EU members + Switzerland, Norway and UK). Size classes are computed based on the mineral resources embedded in mining properties, by quartiles of the world distribution for each SRM

Figure 7: Mining projects including SRMs in European Regions, by status (NUTS 2)



Source: own elaboration based on S&P Global (2025) data.

Note: 17 SRMs included. Countries: 30 (27 EU members + Switzerland, Norway and UK). Size classes are computed based on the mineral resources (t) embedded in mining properties, by quartiles of the world distribution for each SRM