Critical Raw Materials and Industrial Competitiveness in Strategic Technologies

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1. Introduction

The European Union's pursuit of industrial competitiveness in the context of the green and digital transitions is increasingly shaped by a structural dependency on critical raw materials (CRMs). These materials, ranging from lithium, cobalt, and nickel to rare earth elements and graphite, are essential

inputs for strategic technologies such as semiconductors, batteries, renewable energy systems, and advanced digital infrastructure. As global supply chains become more fragmented and geopolitically sensitive, securing reliable and sustainable access to CRMs has emerged as a central pillar of the EU's industrial policy.

This section focuses specifically on the intersection between the EU's CRM strategy and its competitiveness in strategic technology sectors, namely **semiconductors**, **batteries**, and **clean** and **digital technologies**. These sectors represent the backbone of the EU's transition, yet they are also among the most exposed to upstream resource constraints and external dependencies. Unlike traditional manufacturing industries, which often rely on diversified input chains, **strategic technologies** depend on highly concentrated global supply networks, frequently dominated by a limited number of third countries. This creates significant vulnerabilities in terms of supply security, price volatility, and geopolitical leverage.

The EU has responded to these challenges through an increasingly coherent regulatory and industrial framework, including the Critical Raw Materials Act and complementary initiatives such as the European Chips Act and the Battery Alliance. These policy instruments aim not only to diversify external supply sources but also to strengthen internal EU capacities in extraction, processing, recycling, and substitution. In doing so, the EU seeks to reduce strategic dependencies while simultaneously enhancing its autonomy in key technological domains.

For European businesses, particularly those operating in high-tech value chains, CRM policies directly influence production costs, investment decisions, and innovation capacity. The availability and price of critical materials can significantly affect production costs, especially when supply chains are concentrated outside Europe and exposed to geopolitical tensions and export restrictions. At the same time, **supply uncertainty** can influence where companies invest and whether they expand production within Europe or seek alternative sources abroad.

Finally, secure access to CRMs is essential for innovation, as many advanced technologies depend on materials that are difficult to substitute without increasing costs or reducing performance. CRM policies therefore play an important role not only in strengthening supply security, but also in supporting European industrial competitiveness and technological development.

At the same time, the EU's CRM strategy creates significant opportunities for industrial upgrading. By promoting circular economy models, recycling infrastructure, and domestic refining capacity, European firms can potentially reduce import dependence and capture higher value-added segments of global supply chains. Moreover, the alignment between CRM policy and digital and green industrial strategies may foster new ecosystems of innovation, particularly in battery recycling technologies, semiconductor material engineering, and sustainable sourcing solutions.

Nevertheless, these opportunities are accompanied by persistent structural constraints, including high capital requirements, environmental trade-offs, permitting bottlenecks, and global competition from established resource-rich economies. As such, the effectiveness of the EU's CRM strategy will depend not only on regulatory ambition but also on its ability to translate policy frameworks into scalable industrial capacity.

This analysis therefore examines how the EU's approach to critical raw materials shapes the competitiveness of strategic technology sectors, with particular attention to semiconductors, batteries, and clean and digital technologies. It assesses both the constraints imposed by material dependencies and the industrial opportunities generated by the EU's evolving policy architecture, situating CRM policy as a key determinant of Europe's future technological sovereignty.

2. Critical Raw Materials and Strategic Technology Sectors

The dependence on CRMs is particularly evident in the sectors that are expected to drive Europe's future industrial development. Battery manufacturing, for example, requires large quantities of lithium, nickel, cobalt and graphite. These materials are necessary at different stages of the battery value chain, from cathode and anode production to the manufacturing of battery cells. The rapid expansion of electric mobility and energy storage is therefore directly increasing demand for these resources. The International Energy Agency (IEA) estimates that lithium demand for clean-technology applications could rise from 128 kt in 2024 to approximately 809 kt by 2040 under the Stated Policies Scenario.

A similar situation exists in the **clean-energy sector**. Rare earth elements such as neodymium, praseodymium, dysprosium and terbium are particularly important for permanent magnets used in wind turbines and electric motors. Yet their supply chain is highly concentrated. China accounted for around 91% of global rare-earth separation and refining production in 2024, illustrating the difficulty of rapidly developing alternative supply chains. Semiconductors also depend on specialised materials such as gallium and germanium, whose supply can be affected by geopolitical tensions and export restrictions. The importance of these materials therefore extends beyond individual products: disruptions upstream can affect entire industrial ecosystems downstream.

Beyond batteries and renewable energy systems, the semiconductor industry illustrates another important dimension of the EU's dependence on critical raw materials. Semiconductor manufacturing requires a range of specialised materials, including gallium, germanium, silicon and certain rare earth elements, which are used in different components and stages of the production process. These materials are particularly important for advanced electronics, telecommunications infrastructure, high-performance computing and artificial intelligence. As demand for digital technologies

increases, the availability of these specialised inputs becomes increasingly relevant to the competitiveness of European semiconductor manufacturers.

The semiconductor value chain is especially vulnerable because production requires highly specialised facilities, advanced technological expertise and reliable access to materials with extremely high purity levels. Unlike some other industrial inputs, these materials cannot always be replaced easily without affecting the performance or reliability of the final product. Furthermore, the concentration of processing capacity in a limited number of countries means that even relatively small disruptions can have consequences for downstream manufacturers. The introduction of export restrictions on gallium and germanium by China in 2023, followed by additional restrictions in 2024, demonstrated how trade policy can affect access to materials that are important for advanced electronics. The IEA has identified export controls as an increasingly significant risk for critical mineral supply chains.

This situation creates a direct connection between raw-material security and the EU's ambitions under the European Chips Act. While the Chips Act seeks to strengthen Europe's semiconductor ecosystem and expand its manufacturing capabilities, achieving these objectives also requires a stable supply of specialised materials. Investment in semiconductor fabrication facilities alone cannot guarantee industrial competitiveness if European producers remain exposed to shortages or price fluctuations in essential upstream inputs. Consequently, CRM policy and semiconductor industrial policy should be understood as complementary dimensions of the same broader strategy: strengthening Europe's technological capabilities while reducing vulnerabilities in the supply chains that support them.

This concentration is particularly problematic because diversification is difficult and time-consuming. Developing a new mine can require many years of exploration, permitting and investment, while establishing refining and processing capacity requires significant technological expertise and capital. Consequently, even if alternative mineral resources exist outside dominant producing countries, they cannot necessarily be brought to market quickly enough to respond to a sudden disruption.

3. The Impact on European Industrial Competitiveness

The dependence on CRMs has direct implications for the competitiveness of European companies. The first channel is **production costs**. When the price of critical materials increases, companies further down the value chain may face higher input costs. This is particularly relevant for batteries, where mineral prices can have a substantial effect on the final cost of production. The IEA estimates that a fivefold increase in the prices of lithium, nickel or graphite resulting from a supply disruption could increase average

battery pack prices globally by around 20%, while a tenfold increase could raise prices by 40–50%.

These effects are especially important for Europe because European battery manufacturing already faces a significant cost disadvantage compared with China. According to the IEA, the levelised cost of producing battery cells in Europe and the United States is currently around 40–50% higher than in China. A major increase in the price of critical minerals could therefore further widen this competitiveness gap. CRM dependency consequently represents not only a supply-security issue but also a potential structural disadvantage for European manufacturers competing in global markets.

A second channel concerns **investment decisions**. Companies are less likely to commit substantial capital to new production facilities when the availability and price of essential inputs are uncertain. This is particularly relevant for strategic sectors such as batteries and semiconductors, where establishing production capacity requires very high upfront investment. If European firms perceive that access to essential materials is more secure or cheaper elsewhere, they may have incentives to locate parts of their production outside the EU. CRM insecurity can therefore contribute to the relocation of investment and weaken the development of European industrial ecosystems.

A further dimension of this problem concerns the unequal distribution of market power along global value chains. Countries that dominate the extraction and processing of critical raw materials can exercise considerable influence over the availability and pricing of essential industrial inputs. This is particularly relevant when processing capacity is more concentrated than mining activity itself. The IEA's 2025 analysis found that the average market share of the three largest refining countries for key energy minerals increased from approximately 82% in 2020 to 86% in 2024. This demonstrates that the expansion of global mineral production has not necessarily resulted in more diversified supply chains. Instead, additional production has often reinforced the position of established suppliers.

For European companies, this concentration can create an uneven competitive environment. Manufacturers operating in countries with established refining industries may benefit from more integrated supply chains, lower input costs and easier access to processed materials. European firms, by contrast, may have to rely on imported materials that have already passed through several stages of processing outside the EU. This can increase transportation costs, create additional logistical risks and reduce their ability to respond quickly to changes in market conditions. The competitive disadvantage is therefore not limited to the price of raw materials themselves, but also concerns the geographical organisation of industrial production and the distribution of value added across international supply chains.

Furthermore, the economic consequences of CRM dependency are not necessarily restricted to periods of severe supply disruption. Even the possibility of export restrictions or sudden changes in trade policy can influence business expectations and investment strategies. Companies may respond by maintaining larger inventories, diversifying suppliers or accepting higher procurement costs in order to reduce exposure to supply risks. Although these measures can improve resilience, they also tie up financial resources that could otherwise be invested in research, technological development or production expansion. CRM insecurity can therefore generate additional costs even when physical shortages do not materialise.

Finally, CRM availability affects **innovation capacity**. Many advanced technologies depend on materials with specific physical and chemical properties that cannot easily be substituted. Substitution is possible in some cases, but it can involve higher costs, lower performance or significant redesign of production processes. At the same time, scarcity can also stimulate innovation by encouraging companies to develop more material-efficient technologies, alternative materials and recycling solutions. CRM policy therefore has the potential to influence not only the resilience of existing industries but also the direction of future technological development.

4. The EU's Policy Response: The Critical Raw Materials Act

In response to these vulnerabilities, the European Union has progressively developed a more strategic approach to raw materials policy. The central instrument is the **Critical Raw Materials Act (CRMA)**, which entered into force in 2024. Rather than focusing exclusively on securing imports, the Act seeks to strengthen the entire European CRM value chain, including extraction, processing and recycling.

The EU has established 2030 benchmarks according to which 10% of the EU's annual consumption of strategic raw materials should be extracted within the EU, 40% should be processed within the EU and 25% should come from recycling. Furthermore, the Act establishes that no more than 65% of the EU's annual consumption of each strategic raw material at a relevant processing stage should come from a single third country.

These targets represent an important shift in European industrial policy. Instead of relying predominantly on international markets, the EU is attempting to develop a more diversified and resilient supply structure. This does not imply complete self-sufficiency, which would be neither realistic nor economically efficient. Rather, the objective is to reduce excessive dependence on individual suppliers while maintaining access to international markets.

An important aspect of the CRMA is its emphasis on strategic projects, which are intended to accelerate the development of extraction, processing and recycling capacities within the EU and in partner countries. By identifying projects that contribute directly to European supply security,

the framework seeks to facilitate investment and improve coordination between public authorities, financial institutions and private companies. This approach recognises that regulatory targets alone are insufficient to transform the European raw-materials landscape. Achieving the 2030 benchmarks requires concrete industrial projects, access to financing, technological expertise and cooperation between Member States.

The designation of strategic projects is particularly relevant because the development of mining and processing infrastructure involves considerable financial and regulatory uncertainty. Projects often require substantial initial investment before generating commercial returns, while their profitability can be affected by fluctuations in international commodity prices. The CRMA attempts to address some of these difficulties by introducing more coordinated administrative procedures and supporting projects considered important for the EU's strategic interests. However, the effectiveness of this approach will ultimately depend on whether selected projects can attract sufficient private investment and become operational within the expected timeframe.

An additional development in the EU's policy approach is the RESourceEU Action Plan, presented by the European Commission in December 2025. The initiative seeks to accelerate the implementation of the CRMA and strengthen the EU's capacity to respond to geopolitical and economic risks affecting critical raw-material supply chains. Its approach places particular emphasis on reducing strategic dependencies, mobilising public and private investment and strengthening cooperation with international partners. This development illustrates that the EU's CRM strategy is evolving beyond the establishment of long-term production targets towards a more operational approach to economic security and industrial resilience.

Nevertheless, the relationship between the CRMA and other European industrial initiatives remains essential. The European Chips Act, the Net-Zero Industry Act and policies supporting battery manufacturing all depend, directly or indirectly, on the availability of critical raw materials. A fragmented approach could result in investments in downstream manufacturing without sufficient upstream supply, or in increased extraction capacity without corresponding demand from European processing and manufacturing industries. Effective coordination is therefore necessary to ensure that the different elements of the EU's industrial strategy reinforce one another and contribute to the development of integrated European value chains.

The CRMA is also intended to work alongside other industrial initiatives, including policies supporting batteries, semiconductors and clean technologies. This coordination is important because the value of CRMs ultimately derives from their integration into downstream industrial activities. Strengthening European mining or refining capacity without simultaneously developing competitive battery, semiconductor or clean-technology industries would have a limited impact on European industrial sovereignty.

5. Opportunities for Industrial Upgrading

Although CRM dependency represents a significant risk, the transition towards more resilient supply chains can also create opportunities for European industrial development. One of the most promising areas is **recycling and the circular economy**. Recycling can reduce the need for primary extraction while creating secondary sources of supply within Europe. This is particularly relevant for battery materials, where the rapid expansion of electric vehicles will generate increasing quantities of end-of-life batteries that can potentially be processed and reused.

The development of European processing and refining capacity could also allow European companies to capture a greater share of value added. Currently, the strategic importance of CRMs does not lie only in mining: processing and refining are often the most concentrated stages of the supply chain. The IEA estimates that China remains the dominant refiner for almost all major energy-related minerals, with particularly strong positions in graphite, rare earth elements, lithium and cobalt. Developing alternative processing capacity in Europe could therefore strengthen the continent's position in higher-value segments of the supply chain.

Moreover, CRM policy can stimulate innovation. Investments in material efficiency, recycling technologies, alternative battery chemistries and substitution can generate new markets for European firms. In this sense, reducing dependency does not necessarily mean simply reproducing existing production processes within Europe. It can also encourage technological transformation and the development of more resource-efficient industrial models.

6. Structural Constraints and Remaining Challenges

Nevertheless, the implementation of the EU's CRM strategy faces several structural obstacles. The first is the **high cost of developing new supply chains**. Mining and refining projects require large amounts of capital and often take many years to become operational. European projects may also face higher production costs than established competitors in resource-rich economies. The IEA's recent analysis shows that capital expenditure for mining and refining projects outside dominant producing countries can be significantly higher, making diversification economically challenging.

Environmental and regulatory considerations represent another challenge. Mining and processing activities can have significant environmental impacts, including land degradation, water consumption and emissions. The EU therefore faces a difficult balancing act between accelerating the development of domestic CRM capacity and maintaining its environmental standards. Lengthy permitting procedures can further delay projects, potentially reducing the effectiveness of policies aimed at rapidly increasing domestic supply.

Finally, Europe faces strong international competition. Countries such as China, Indonesia, Australia, the Democratic Republic of Congo and others have established positions in different parts of the mineral value chain. China in particular possesses significant advantages in processing, refining and downstream manufacturing. The EU must therefore avoid a situation in which domestic production becomes significantly more expensive without generating sufficient technological or strategic benefits.

7. Conclusion

Critical raw materials have become a fundamental determinant of Europe's industrial competitiveness. The issue is no longer limited to ensuring access to the resources required for the green and digital transitions. Increasing concentration in global supply chains means that CRM dependencies can directly influence European production costs, investment decisions, innovation and the ability of firms to compete internationally.

The Critical Raw Materials Act represents an important attempt to address these vulnerabilities by combining domestic production targets, supply diversification and recycling. However, the success of the strategy will depend on whether these regulatory objectives can be translated into actual industrial capacity. The EU will need to attract investment, accelerate permitting, strengthen recycling and processing capabilities, and develop partnerships with reliable international suppliers.

The central challenge is therefore to find a balance between **strategic autonomy and economic competitiveness**. Complete self-sufficiency is neither realistic nor necessarily desirable. Instead, Europe's objective should be to build sufficiently diversified and resilient supply chains while maintaining access to global markets. If successfully implemented, CRM policy could become more than a defensive response to geopolitical risks: it could serve as a catalyst for industrial upgrading, technological innovation and the strengthening of Europe's long-term technological sovereignty.