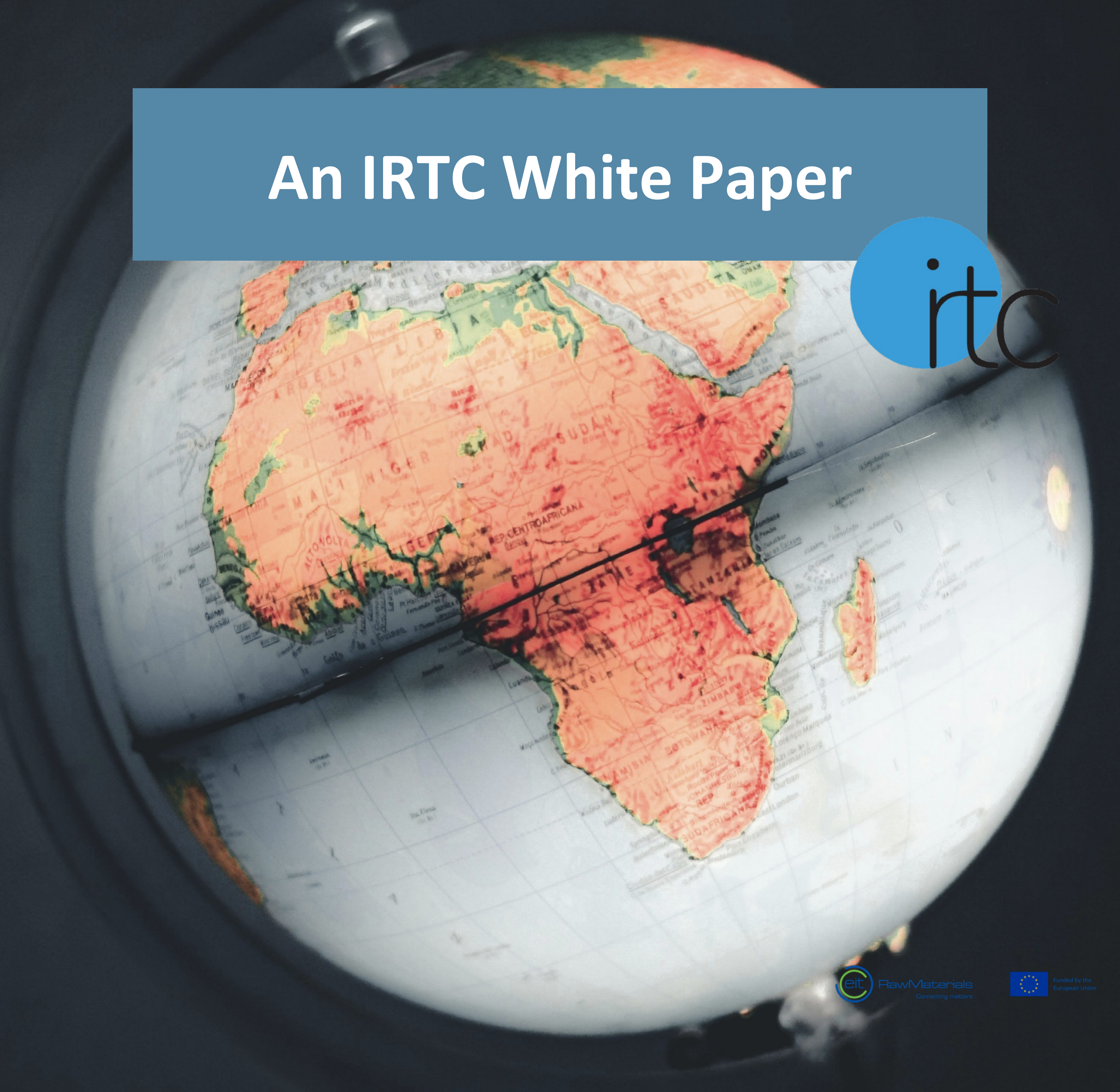
Global Assessments and Strategies for Critical and Strategic Raw Materials: The State of Play in 2025

An IRTC White Paper



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Executive Summary

Critical and strategic raw materials (CSRMs) have shifted from a largely technical concern to a core pillar of economic, climate, industrial, and security policy. The IRTC 2025 round table on "Global Assessments and Strategies for Critical and Strategic Raw Materials" higlights an international convergence: countries now prioritise materials that are simultaneously hard to secure and indispensable for clean energy systems, digital infrastructure, and defence – domains whose material needs increasingly overlap. At the same time, CSRM debates are being reshaped by heightened geopolitical tension, the concentration of processing and refining in a few jurisdictions (above all China), and shortening political time horizons that demand faster cycles between analysis and policy action.

Across jurisdictions, most CSRM frameworks share a dual structure that combines some notion of "importance" (economic, energy, strategic) with "supply risk," yet they differ markedly in scope, indicators, and governance linkages. The European Union employs a rules-based hierarchy between critical and strategic raw materials tied to 2030 capacity and diversification benchmarks. The United States complements a macroeconomic risk model (USGS) with technology-specific supply chain assessments (DOE) and a defence-focused list (DoD). France emphasises material form and processing stage; Japan and South Korea integrate criticality into economic security strategies with strong state–industry coordination; India links criticality to a push for domestic value chains and overseas assets; Canada and Brazil adopt supplier-oriented perspectives anchored in resource potential and export strategies; the United Kingdom uses a transparent, "policy-service" approach. Despite these differences, actors operate under similar structural constraints: capital-intensive and slow-moving projects; complex and contested permitting; infrastructure and skills bottlenecks; and a rapidly shifting geopolitical context that makes it difficult for analytical frameworks to keep pace.

First, there is no single "best practice" model. CSRM lists, thresholds, and policy instruments are inherently context-specific, shaped by differing resource endowments, industrial structures, and political economies. Countries apply distinct lenses (end-user, manufacturer, supplier) to assess largely overlapping sets of materials and technologies. Second, assessment and strategy are now closely intertwined. Criticality exercises no longer function as neutral diagnostics; they directly shape public support, industrial prioritisation, and international partnerships. As feedback loops between assessments and policy decisions intensify, and time horizons shorten, questions of data quality, methodological transparency, and the integration of geopolitical change are becoming both more salient and more politically contested. Third, systemic vulnerabilities are increasingly geopolitical and extend to mid- and downstream parts of the value chain. High concentration of mining, processing and refining capacity creates exposure that cannot be addressed through mine development or unilateral action alone. This is pushing many actors to integrate components, sub-systems, and entire value chains into their assessments and mitigation strategies.

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Looking ahead, participants highlighted a set of priorities for strengthening CSRM governance. A first priority is to tighten and accelerate the link between assessments and concrete policy tools – such as R&D support, de-risking finance, strategic stockpiles, and diplomatic engagement – while avoiding purely inward-looking or protectionist reflexes that displace risks onto partners. A second priority is to accelerate responsible project development across the value chain, recognising that time to market and control over midstream segments have become strategic assets. This implies credible but streamlined permitting, coordinated infrastructure planning, and wider use of financial instruments, underpinned by criteria for designating and supporting "strategic projects." Third, the round table underlined that effective CSRM governance will ultimately depend on the quality of international cooperation. While some degree of strategic competition is unavoidable, an unmanaged race for control over critical minerals risks fragmenting markets, amplifying price shocks, and undermining the very energy transition and security goals that CSRM strategies are meant to support. Plurilateral initiatives and new supply alliances and strategic partnerships offer vehicles for coordinated investment, information sharing, joint early-warning systems, and collaboration on standards, ESG, and traceability. Countries already track one another's CRM and SRM lists to understand evolving risk perceptions and to identify opportunities to position themselves as suppliers of materials that partners deem strategic; turning this practice into a more structured exchange on lists and methodologies could make it a constructive element of cooperation rather than competition. In this context, friend-shoring and "club-based" supply arrangements will need to be embedded in cooperative frameworks if they are to enhance, rather than fragment, global resilience.

Beyond supply expansion, there is a need to strengthen demand-side and circularity measures – including material efficiency, design-for-recycling, and substitution – to reduce structural exposure. Building robust data infrastructures and improving the quality, comparability, and timeliness of metrics will be essential for evidence-based policymaking and for aligning public and private investment decisions. Particular gaps remain for data on midstream processing, component-level use, and secondary flows. Skills, innovation, and social licence to operate also emerged as critical enablers: without a qualified workforce, technology development, and trusted engagement with affected communities, even well-designed strategies will struggle to deliver.

Perspectives from the round table, complemented by wider policy debates, also point to a potential divergence of priorities between advanced and developing economies. Many resource-rich and lower-income countries are likely to focus more on CSRMs linked to food security, basic infrastructure, and diversified industrialisation. This raises the question of how "transition minerals" and "development minerals" can be managed in a more integrated way, so that reducing risks for high-tech and clean energy sectors does not inadvertently increase vulnerabilities in essential services. While this perspective was only partially represented at the round table itself, it suggests that future CSRM dialogues should more systematically include producer- and developing-country voices.

The IRTC community aims to support these efforts by advancing methodological dialogue, enabling cross-regional exchange on emerging risks, and exploring scenarios that move beyond zero-sum logics. Well-designed CSRM strategies should not only safeguard national interests, but also contribute to a more resilient, transparent, and sustainable global raw materials system that can contribute to deep decarbonization, inclusive development, and shared prosperity.

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1. Introduction

This white paper presents the key approaches, insights, and strategic considerations that emerged from the IRTC 2025 round table "Global Assessments and Strategies for Critical and Strategic Raw Materials: A 2025 Update." The round table brought together international experts and institutions on October 24, 2025, to exchange approaches for identifying critical and strategic raw materials (CSRMs) and to discuss strategies for securing, diversifying, and governing CSRM supply chains in a secure, resilient, and sustainable manner. It serves as a snapshot of current practices and debates among a group of active policy, industry, and research actors.

Securing CSRM supply and strengthening strategic positions related to these materials – and the technologies that depend on them – has become a top priority for many countries and supranational entities, attracting heightened political and policy attention worldwide. At the same time, intensifying geopolitical and geoeconomic tensions are intersecting with the urgent need to safeguard the raw material base required for key technologies, a global clean energy transition, and the attainment of climate and sustainable development goals. CSRMs thus sit at the intersection of industrial policy, climate policy, and security policy, and decisions in one domain increasingly have immediate effects in the others.

The evaluation of risks linked to CSRMs plays a central role in informing decision-makers about their nature, magnitude, and urgency. Only on this basis can targeted and effective mitigation measures be designed. Consequently, the methodologies, tools, and indicators used to assess CSRM-related risks are crucial, as their results directly shape policy and industrial strategies. It is therefore essential to understand their underlying logic and functioning, and to be aware of which methods exist, how they differ, and in which contexts they are most appropriate. The round table discussions confirmed that assessment frameworks are no longer purely analytical exercises, but are increasingly used as direct inputs into policy design, project selection, and international cooperation.

This white paper has three main objectives. First, it documents the current assessment frameworks and policy approaches used by participating jurisdictions to evaluate CSRMs and manage associated risks. Second, it highlights key sectors, methods, and challenges of the different entities related to their unique position in the supply chain and discusses commonalities and differences in their approaches. Third, it distils convergences and lessons to inform future research priorities, policy development, and international cooperation. Across these objectives, the paper aims to make methodologies more comparable and to clarify how they translate into concrete instruments and decisions.

This paper does not aim to provide an exhaustive or definitive account of all CSRM strategies worldwide; rather, it captures the state of play in 2025 among actors that participated in the IRTC event and points to areas where further dialogue, cooperation, and methodological innovation are needed. In that spirit, IRTC continues to invite researchers and organisations globally to share their insights on methodologies and policy approaches and engage in our international conversation.

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What is IRTC?

The International Round Table on Materials Criticality (IRTC) is a collaborative initiative supported by EIT RawMaterials that brings together experts and stakeholders from various countries and sectors to address issues related to the criticality of materials.

IRTC focuses on discussing and analyzing the concept of material criticality, sharing knowledge and best practices on assessing and managing critical raw materials, exploring strategies to mitigate supply risks and environmental impacts, and promoting international cooperation on sustainable resource management.

IRTC involves participants from academia, industry, government agencies, and non-governmental organizations. The round table format allows for open dialogue and exchange of ideas among diverse participants, aiming to create a more comprehensive approach to addressing materials criticality on a global scale.

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2. Overview of approaches[1]

Brazil

Strategic Context and Supply Chains

Brazil has substantial geological endowments. Main reserves include Fe, Cu, Li, Mn, Nb, Ni, Sn, V, and Zn. REEs and cobalt are missing from the main reserves list of the latest Brazilian Mineral Yearbook, although there are large known reserves. Brazil has a world dominance in niobium reserves and production, with 98.8% of global reserves and 93.7% of global production.

There is a high import dependency on minerals for agriculture and protein production. Policy alignment includes the National Fertilizer Plan 2022-2050 and the National Policy for Energy Transition. The National Mining Plan is being updated and put to public discussion in January 2026.

Current CSRM Assessments

Brazil's CSRM assessment is based on domestic production, trade numbers, and economic and business domestic needs. CSRMs are categorized into three groups: group 1 includes minerals with high import dependency for agriculture and protein production, as well as coal for steelmaking. Group 2 covers minerals that are globally critical for technologies in the forefront of energy transition, IT, communications, and defence industrial sectors. Future enlargement is focused on digital components/IT supplies, the defence industry, and the bioeconomy. Group 3 represents key minerals Brazil has large amounts of and a potential for strategic advancement ("premium minerals"). Niobium, graphite, and copper are classified both in groups 2 and 3. REEs could be added to group 3, too, since considerable large reserves sites are already known, some in the preoperational stage.

The current list was not set by any mathematical methodology. The concepts of "criticality assessment" and "strategic interpretation" are not clear-cut.

Policy and Regulatory Developments, Trade Cooperation

Brazil has a number of plans touching critical/strategic minerals, spread across the Ministry of Mines and Energy (MME), the Ministry of Development, Industry, Trade and Services (MDIC), the Ministry of

[1] The report covers developments up to the end of 2025 and therefore includes information and references that became available after the round table took place.

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Science, Technology and Innovation (MCTI), the Ministry of Environment, the Ministry of Finance, and others.

A draft law (PL 2780/2024) proposes the creation of a National Policy on Critical and Strategic Minerals (PNMCE), seeking to transform Brazil's mineral wealth into prosperity, jobs, and income. The undertaking includes tax incentives for exploration and incentives for infrastructure development.

The Brazilian Development Bank issued calls for special loans aiming at technology upgrade and product development. It seeks to promote research, extraction, and processing of key minerals essential for the energy transition and technological development, ensuring security of supply and fostering sustainable economic development.

There has been an effort to foster and speed up licensing (mining permits and environmental) for listed minerals mining projects under way during the previous Brazilian government (2018-2022), but only a few projects were analysed and received special support.

Brazil plays a central role in attracting and shaping FDI flows in the Latin America and the Carribean (2025 ECLAC/UN). There is currently no agreement on minerals trade privileges or special conditions among the BRICS 6 nations.

Anticipated Developments

The government is expected to update the National Mining Plan and set a special policy to foster CSRM exploration/processing by law. Brazil seeks to speed up the signature of agreements involving critical and strategic minerals (trade and tech transfer) through bilateral or trade block agreements, such as the EU-Mercosur Association Agreement.

Sources

Bill proposing the establishment of the PNMCE (2024):
https://www.camara.leg.br/proposicoesWeb/fichadetramitacao?idProposicao=2447259

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Canada

Strategic Context and Supply Chains

Critical minerals are foundational to Canada’s Green and Digital economy. Priority sectors are clean energy technologies (i.e., batteries, wind, solar, nuclear), ICT/semiconductors, and advanced manufacturing inputs.

Canada is a mineral-rich country. Policy goals focus on positioning Canada as a sustainable and strategic partner within global supply chains. The vision is to grow the supply of responsibly sourced critical minerals and develop domestic and global value chains. Value chains are intended to benefit clean technologies and defence.

Imports are vulnerable due to high geographical concentration in production and processing (e.g., REEs). Canada is also dependent on exports.

Current CSRM Assessments

Canada’s updated Critical Minerals List was published on June 10, 2024, listing 34 minerals. The updated list includes high purity iron, phosphorous, and silicon metals. In Canada, a mineral is designated as “critical” where its supply chain is threatened and there is a reasonable likelihood that it can be produced domestically. In addition, the mineral must be essential to Canada’s economic or national security, required for the transition to a low-carbon and digital economy, or position Canada as a sustainable and strategic partner within global supply chains.

Policy and Regulatory Developments, Trade and Cooperation

The Major Projects Office (MPO) was established in August 2025 to coordinate financing and streamline the federal regulatory approval process for "national interest projects," aiming for a two-year decision window for such projects.

Supporting Indigenous participation, partnerships and reconciliation is a key element of Canadian policy (e.g., Indigenous Natural Resource Partnerships Program).

During Canada’s 2025 G7 Presidency, G7 leaders launched the Critical Minerals Action Plan in June 2025 and the Critical Minerals Production Alliance. The Production Alliance fosters non-concentrated supply chains by aggregating demand and coordinating offtake arrangements. Canada has strategic partnerships with the U.S., EU, Japan, South Korea, UK, and others.

Anticipated Developments

Focus areas include Indigenous equity participation, infrastructure development, and a permitting reform.

Sources

The Canadian Critical Minerals Strategy (2023): https://www.canada.ca/en/campaign/critical-minerals-in-canada/canadian-critical-minerals-strategy.html (updated June 2024: https://www.canada.ca/en/natural-resources-canada/news/2024/06/government-of-canada-releases-updated-critical-minerals-list.html)

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European Union

Strategic Context and Supply Chains

The EU is highly reliant on imports of CSRMs. It distinguishes between Critical Raw Materials (CRMs) important for the overall EU economy and Strategic Raw Materials (SRMs), which are key for strategic technologies relevant for the green and digital transition, and defence and aerospace. Strategic technologies include lithium-ion batteries, wind turbines, electric motors, PV panels, hydrogen-DRI, data transmission networks, servers and storage technology, robotics, drones, satellites, and rocket launchers.

The EU exhibits significant vulnerability along key supply chains, with its share in global production at the raw materials extraction step never exceeding 7% for strategic technologies. The core goal of the EU strategy is ensuring a secure and sustainable supply of CSRMs. Quantitative 2030 benchmarks for SRMs aim for extraction capacity to cover at least 10%, processing capacity at least 40%, and recycling capacity at least 25% of EU consumption. Diversification targets state that not more than 65% of SRM consumption should come from a single third country.

Current CSRM Assessments

The latest criticality assessment in 2023 covered 87 individual materials. Important CRM assessment indicators are economic importance (importance per sector, value added, substitutes' cost-performance ratio) and supply risk (market concentration via HHI, governance performance, import reliance, end-of-life recycling input rate, substitutes' criticality and co-production).

The assessment of SRMs includes strategic importance (relevance for green/digital/defence&aerospace, amount needed for strategic technologies), difficulty of increasing production, and forecasted demand growth (2030 demand forecast vs. global annual production).

The 2023 assessment defined 34 materials as critical of which 17 are strategic. SRMs include lithium, cobalt, battery-grade nickel, gallium, germanium, tungsten, magnet Rare Earth Elements (REEs), and copper. A bottleneck analysis shows the raw materials step as systematically critical for all 16 strategic technologies analyzed.

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Policy and Regulatory Developments, Trade and Cooperation

Regulation 2024/1252 (the Critical Raw Materials Act, CRMA) entered into force on May 23, 2024. It prescribes risk mitigation including monitoring, coordinating strategic stocks and establishing a joint purchasing platform and stress-testing of SRM supply chains. Strategic projects contributing to European SRM supply benefit from faster permitting and judicial procedures as well as coordinated access to finance. Policies promote programmes to reuse, collect and recycle and encourage the use of secondary raw materials.

CSRMs are important in EU international diplomacy and trade, facilitated through trade agreements and Foreign Direct Investment. The EU participates in G7/G20, MSP, CCMM, and IEA. It has established Strategic Partnerships on Raw Materials with numerous countries, including Canada, Norway, Australia, Chile, Argentina, DRC, and Ukraine.

Anticipated Developments

A ReSourceEU Action Plan deepens and speeds up CRMA implementation and was adopted in December 2025. The Commission will set up a dedicated EU Critical Raw Material Centre by 2026 to coordinate stockpiles, joint purchasing, and supply chain monitoring. The CSRM lists will be revised by May 2027.

Sources

Study on the critical raw materials for the EU 2023: https://op.europa.eu/en/publication-detail/-/publication/57318397-fdd4-11ed-a05c-01aa75ed71a1/language-en

Critical Raw Materials Act (2024): https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials/critical-raw-materials-act_en

ReSourceEU Action Plan (December 3, 2025): https://single-market-economy.ec.europa.eu/document/download/01c448d6-dc93-40d7-9afe-4c2af448d00c_en

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France

Country/Entity Overview & Strategic Context and Supply Chains

The French Observatory of Mineral Resources for Industrial Sectors (OFREMI) supports French action to comply with the EU CRMA, bringing expertise from various scientific institutes (BRGM, CEA, IFPEN, ADEME, IFRI). Their risk evaluation shall help decision-makers to find the best mitigation strategies for specific vulnerabilities.

Current CSRM Assessments

OFREMI's goal is to assess criticality with more granularity (on global and national level) and focus on specific forms of a substance – from minerals and concentrates to more advanced stages, such as sulfates and oxides. The approach uses three dimensions: supply risk, vulnerability, and ability to cope with. ESG impacts are assessed separately, to emphasize them and avoid dilution within the main assessment dimensions.

Indicators vary in their data foundation (e.g., calculation e.g. of HHI, but also expert opinion) and have each a value from 1 (not critical) to 5 (very critical). The supply risk dimension comprises commercial risk (trade barriers and logistic issues), economic risk (supply-demand evolution and price volatility), technical risk (by-production, impacts of OPEX increase, reserves), and socio-environmental risk (political risk, social crisis risk, environmental risk).

Results of the assessments show that the criticality of transformed/more proecessed forms of the raw materials is often more important than the one of concentrates.

Anticipated Developments

Future work includes data updates and further methodology development, including the refinement of thresholds and a criticality ranking. The assessment of CRSMs in their various forms will be continuously revised. A prospective evaluation based on defined scenarios is planned (e.g., impact of the development of a new factory).

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Mineral intelligence and criticality of raw materials: https://www.brgm.fr/en/solutions/mineral-intelligence-criticality-raw-materials

The French Observatory for Mineral Resources: https://www.ofremi.fr/en

French portal for non-energy mineral resources (in French): https://www.mineralinfo.fr/fr/substances

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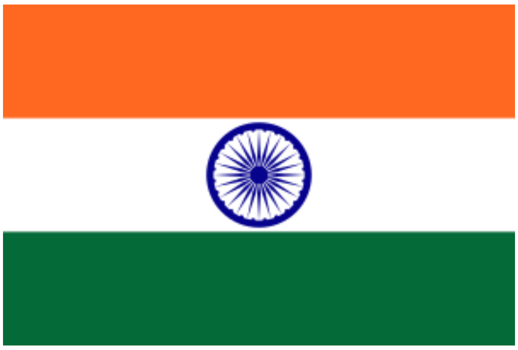

India

Strategic Context and Supply Chains

India is highly dependent on imports for critical minerals. Only 7 minerals that are critical for India (e.g., Cu, REE, graphite) are produced domestically, each with a global share of less than 1%. Active exploration since 2015 has identified 11 deposits of 8 different critical minerals (including lithium and REEs). The overall CSRM policy goal is to build self-reliant and globally integrated supply chains and strengthening value chains.

Domestic demand for materials like lithium, neodymium, and nickel in India is estimated to increase significantly until 2045. Key use sectors are clean energy (solar PV, battery storage, wind energy), electronics/semiconductors, electric mobility, defence, fertiliser, and space/aeronautics.

Current CSRM Assessments

The Ministry of Mines identified 24 minerals as critical and strategic to India in 2023. The assessment distinguishes minerals based on whether they fall into high economic importance, high supply risk, or both. The goal of the assessment is to enhance the competitiveness of the materials-parts-equipment system and stabilize the supply chain.

CEEW categorised 49 non-fuel minerals as most critical, moderately critical or least critical for India in 2016; the method and indicators used were based on the EU method for CRM assessment. The study compared a base year (2011) with assumptions for 2030.

Policy and Regulatory Developments, Trade and Cooperation

The National Critical Minerals Mission (NCMM), launched in January 2025 with an outlay of more than 4 billion USD, comprehensively covers the entire supply chain. The Mines and Minerals Development and Regulation (MMDR) Act amendments (2023) declassified six minerals that were initially classified as essential for the development of nuclear energy, reserving mining exclusively for government agencies: lithium, beryllium, niobium, titanium, tantalum, and zirconium. The declassification opened them up for private exploration and mining through auctions.

India launched a Critical Minerals Recycling Scheme (~180 million USD) to build domestic capacity. The goal is to quadruple annual recycling capacity to 400 kt by 2030. India established Khanij Bidesh India Limited (KABIL) to secure overseas critical minerals. KABIL also signed an MoU with Argentina to develop lithium reserves.

Like many countries, India has very limited capability to process critical minerals. The government is planning to launch an incentive scheme to promote critical minerals processing. It also launched a

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scheme to promote manufacturing of sintered rare earth permanent magnets with a financial outlay of 800 million USD. The scheme aims to establish 6’000 metric tonnes per annum of integrated rare earth permanent magnet manufacturing capacity in India, covering the full chain from rare earth oxides to finished magnets.

India joined the Minerals Security Partnership (MSP) and the Indo-Pacific Economic Framework (IPEF). Under this partnership, Indian companies (e.g., ALTMIN) are building vertical integration models, such as investing in a lithium refinery in Brazil to secure a steady stream of refined lithium for India's domestic battery manufacturing.

Anticipated Developments

A National Critical Mineral Mission (NCMM) is set to commence end of 2025 with a budget of 1.9 billion USD, plus an expected 2.1 billion USD from public sector undertaking. This mission targets a comprehensive overhaul of India's CRM supply chain by 2031. Key goals include auctioning 100 mineral blocks, acquiring 50 foreign mines, and launching 1’200 domestic exploration projects, supported by an ecosystem of 4 processing parks, 100 R&D projects, and a target of 1’000 patents and 10’000 skilled workers to secure national mineral sovereignty. Furthermore, Centres of Excellence (CoEs) have been established under the NCMM to advance R&D and scale innovations via pre-commercial demonstration projects.

Sources

Ministry of Mines India (2023): Addressing Vulnerabilities in the Supply Chain of Critical Minerals: https://www.ceew.in/sites/default/files/addressing-critical-minerals-supply-chain-vulnerabilities-india.pdf

CEEW (2025): India’s Critical Mineral Resources. https://www.ceew.in/publications/indias-critical-mineral-resources

CEEW (2025): Making India a Hub for Critical Minerals Processing: https://www.ceew.in/publications/how-can-india-transform-its-critical-and-strategic-minerals-sector-with-domestic-processing-strategy

Government of India (2025): Powering India’s Next Tech Leap through Rare Earth Permanent Magnet Manufacturing Ecosystem: https://www.pib.gov.in/PressNoteDetails.aspx?NoteId=156753&ModuleId=3®=3&lang=1

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Japan

Strategic Context and Supply Chains

Japan's critical raw materials strategy is steered by the Ministry of Economy, Trade and Industry (METI) together with JOGMEG, a government-affiliated organization which was created in 2004 as merger of the former Japan National Oil Corporation with the former Metal Mining Agency of Japan. The primary goal of Japan's critical raw materials strategy is securing a stable and economical supply of natural resources. Critical minerals are those that are promising for GX (Green Transformation) & DX (Digital Transformation). Key products include batteries for Electric Vehicle (EV), solar generation, motors, and semiconductors. High priority metals under Japan's Economic Security Act include Mn, Ni, Co, Li, graphite, REEs, Ga, Ge, and U. Japan began to diversify its CSRM supply base after the REE shock in 2010. Today, it has transitioned towards safeguarding economic security. The government focuses on supply chain and data analysis to support securing supply to industries.

JOGMEC supports investment across the entire mining value chain, including exploration, development, refinery, smelting, and recycling. Policy is aimed at supporting private activity to secure supply to industries. Information regarding the national stockpiling system (volume, duration, amount, price, location) is not disclosed.

Current CSRM Assessments

The goal of Japan's CSRM assessment is to identify critical minerals and affected industries, quantify the impact of supply disruptions, and identify mitigation actions for companies.

Models utilize economic importance and supply risk. Advanced models aim to categorize risks based on whether they can be addressed by market mechanisms and incorporate indicators for internal supply risks (e.g., ratio of self-owned mine production) and external supply risks (e.g., by-production rates). Target metals for JOGMEC financial support include a long list covering base metals, ferro-alloys, and critical metals. Detailed determination methods and lists are not made public.

Policy and Regulatory Developments, Trade and Cooperation

Post-2023 policy highlighted economic security, including subsidies for CAPEX on critical minerals projects. Japan plans to establish an "Economic Security Thinktank". JOGMEC supports industries through financial and technical support for recycling. Japan maintains a national stockpiling system since 1983. Recent policy emphasizes alliance with like-minded countries.

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Anticipated Developments

The refinement of the CSRM assessment methodology is being continued to clarify the direction of strategy for each mineral. Recent policy developments also include initiating traceability studies for critical and strategic raw materials.

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https://www.enecho.meti.go.jp/en/category/special/article/detail_158.html

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https://www.jogmec.go.jp/metal/metal_10_00001.html

METI Policy on initiatives for ensuring stable supply of critical minerals (2022, in Japanese):
https://www.meti.go.jp/policy/economy/economic_security/metal/torikumihoshin.pdf

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Türkiye

Strategic Context and Supply Chains

Türkiye holds the world's largest boron reserves, generally estimated at around 70-73% of global boron resources, and produced by the state company Eti Maden. Beyond boron, Türkiye also has significant reserves of other raw materials often classed as critical or strategic, including chromite, bauxite and other aluminum raw materials, important deposits of REEs, plus various base metals and industrial minerals.

CSRM policy in Türkiye is coordinated by the Ministry of Energy and Natural Resources. The ministry's affiliated and relevant bodies include the General Directorate of Mineral Research And Exploration (exploration), the Eti Maden Operations General Directorate (operation and stockpiling), the General Directorate of Turkish Coal Enterprises and the Turkish Hard Coal Enterprise (operation), the Turkish Energy, Nuclear and Mineral Research Agency (R&D), and the General Directorate of Mining and Petroleum Affairs (incentives and stockpiling).

Priority sectors focus on heavy industry: turbine engine superalloys, steel and other alloys, laser applications, and military applications (defense industry super alloy development projects).

Current CSRM Assessments

Critical raw materials for Türkiye are defined as having an input on industrial production, facing a high supply risk, and creating an economic problem in case of a disruption. Strategic raw materials are those that are important for national security.

A quantitative criticality assessment is used, with a weighted score system: risk score (70%), import score (20%), and export score (10%). Risk indicators include supply risk (depletion time, reserve concentration, ore production concentration, country reserve concentration, country production contentration), price risk (price change, price volatility), demand risk (mine production change, domestic demand growth), recycling restriction (stockpiles, recyclability), and potential risk (possibility of usage restrictions).

Minerals are categorized as potentially critical (e.g., Be, Cr, Pt), significantly critical (e.g., Ni, Co, REEs), and highly critical (e.g., Li, Cu, Al). The SRM list includes amongst others rhenium, tantalum, and tungsten.

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Policy and Regulatory Developments

Goals on circularity include reporting the ore content in waste dumps and tailings by Q2 2026.

Anticipated Developments

Türkiye aims to establish a detailed and specific database for critical minerals by Q2 2026.

Sources

2025 Critical and Strategic Minerals Report:
https://enerji.gov.tr//Media/Dizin/TKDB/tr/Belgeler/Critical_and_Strategic_Minerals_Report_Eng.pdf

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South Korea

Strategic Context and Supply Chains

South Korea's CSRM policy goal is to establish a stable rare metal supply chain to support industrial competitiveness and carbon neutrality. The current expansion of Chinese export controls affects Korean firms trading materials used in the telecom, IT, and energy sectors. Korean firms using Chinese materials or technology need permits for third-country trade.

Under Law No. 19438 (2023), rare metals are treated explicitly as an issue relevant to national securty. The law mandates 5-year cycle policies to enhance competitiveness, considering the national security characteristics of rare metals. Policy prioritizes impact assessment and response for semiconductors, EVs, batteries, and IT devices.

Current CSRM Assessments

Since 2010, South Korea conducts regular demand-supply analyses of criticality by the Korea Institute for Rare Metals (formerly KIRAM; now KORAM) endorsed by the Korean government through the Ministry of Trade, Industry and Energy (MOTIE). In 2025, 35 of 56 screened elements are defined as critical for Korea, based on high industrial demand and difficulty of extraction, while they do not exist abundantly in the earth's crust; the number has elevated from 33 critical minerals in 2023.

The class of "core strategic minerals" was defined by MOTIE for the first time in 2023 and updated in 2025. Core stratetic minerals are those relevant to Korean key industries, namely mobility, semiconductors, machinery and tools, as well as energy, electricity, and electronics: REEs, vanadium, chromium, tantalum, molybdenum, silicon, tin, tungsten, magnesium, titanium, niobium, PGMs, lithium, manganese, and cobalt. They are determined by analyzing the CRMs relevant to of each sector regarding import dependence, domestic production, and recycling rates.

Systematic company support through monitoring and database establishment is currently being implemented. An interagency rare earths supply chain task force was founded in October 2025 to address China's recent export measures.

Policy and Regulatory Developments, Trade and Cooperation

Korea's national supply of strategic minerals shall be stabilized by reducing import dependence on them from 80 to 50 percent and increasing recycling rates from 2 to 20 percent by 2030.

A comprehensive response plan established a rare metals supply chain task force led by the Vice Minister of MOTIE. Amongst others, a Supply Chain Stabilization Fund and Committee will be established. The response framework emphasizes strengthening international cooperation, such as through the Mineral Security Partnership MSP. South Korea utilizes dialogue channels with China (Export Control Dialogue, Supply Chain Hotline) for faster export permits. Overseas development funding for mining and refining projects is being increased (from 25 million USD to 48 million USD).

Key plans to strengthen small business competitiveness include fostering 15 global top-tier small and medium-sized enterprises by 2030, long-term R&D support of 13 million USD per company, the establishment of 10 to 20 specialized small business complexes by 2030, and private enterprise investment in specialized complexes expanded from 7.6 billion USD to 20.6 billion USD.

Mid- to long-term strategies include R&D funding (2024–2028, 27 million USD) for recycling, substitution, and material efficiency. A core focus is the promotion of waste resource recycling. The public stockpile will include a broader range of items and has been extended from the current 100 days to a maximum of one year. Furthermore, an early warning system will be established.

Anticipated Developments

Priorities include strengthening information sharing and global cooperation to build supply chains that are more resilient against external shocks. Impact assessment on semiconductors, EVs, and batteries shall be prioritized. information sharing and global cooperation are planned to be intensified.

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United Kingdom

Strategic Context and Supply Chains

The UK is an import-reliant nation, making it vulnerable to global supply risks. It is almost entirely dependent on other countries for most critical minerals, typically importing processed materials and components. The UK has resources of lithium, tungsten, and nickel, but – in contrast to some industrial minerals – to date no active mining of these. Geopolitics remains the biggest risk.

Critical minerals for the UK are those considered important to economic prosperity, national security, and environmental resilience. The Critical Raw Materials Intelligence Centre (CMIC) at the British Geological Survey (BGS) primarily focuses on minerals needed for UK decarbonization and the energy transition. It is funded by the Department for Business & Trade and provides intelligence to inform strategy development.

Current CSRM Assessments

The UK assessment has the goal to provide a quantitative criticality assessment for the UK, representing a "snapshot in time". Almost all information about it is publicly available. CMIC developed a methodology using two primary dimensions – UK economic importance and UK supply risk – that aggregate various indicators, providing a comprehensive risk management approach.

The methodology is similar to the EU's with some differences. Supply risk indicators are production concentration adjusted by ESG factors, global trade concentration, companionality, and recycling rate. Economic vulnerability indicators are UK apparent consumption, UK net import reliance, and gross value added. 34 critical minerals were identified for the UK in the 2024 assessment.

Policy and Regulatory Developments

A strategic focus is on increasing circular economy efforts: the UK has excellent circularity expertise in platinum group metals (PGMs), with growing expertise in REEs and lithium. Also other risk mitigation approaches are being developed, including domestic production (tungsten, lithium), continued investment in clean energy & net-zero technologies, international partnerships and agreements, R&D, a proactive role in global affairs, and maintaining analytical capacity. In late November 2025, the UK released Vision 2035: Critical Minerals Strategy, which includes a growth minerals list to align critical minerals with needs for the UK's Industrial Strategy and government missions such as economic growth.

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Anticipated Developments

A new study including foresights of secondary material flows from decarbonisation technologies and new research on additional methodologies and data sources for a UK criticality assessment areforeseen to be published in April 2026.

Sources

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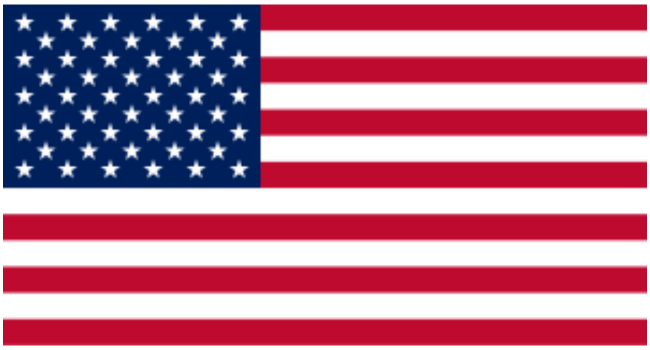

United States

Strategic Context and Supply Chains

The United States approaches CSRMs through a combined economic security, energy transition, and defense lens. Its exposure arises less from lack of geological potential than from a long period of offshoring mining, processing, and manufacturing, which has left many supply chains heavily dependent on foreign sources, particularly at midstream stages. The latest assessment from the U.S. Geological Survey (USGS) shows that production concentration in a few countries is a key risk: China is the leading contributor to the probability-weighted net decrease in U.S. GDP for 46 of the 84 minerals examined, including all rare earth elements (REEs), gallium, germanium, tungsten, and magnesium metal.

The U.S. CSRM strategy is increasingly organized around entire supply chains rather than individual commodities. For a subset of priority value chains – such as lithium-ion batteries, permanent magnets, power electronics, and semiconductor manufacturing – the United States aims to expand domestic and allied capacity from upstream extraction through midstream processing and material transformation to downstream component and equipment production. Vulnerabilities are most acute in midstream steps (e.g., rare earth separation, battery-grade materials refining, high-purity silicon and specialty alloys), where China and a small number of other countries currently dominate.

Current CSRM Assessments

The U.S. Critical Raw Materials list draws on the outcomes both of the US: Geological Survey (USGS)/Department of the Interior (DOI) assessment of critical minerals, as required at least once every three years by the Energy Act of 2020, and the Department of Energy (DOE) assessment of critical materials for energy, as authorized by the same Act.

The USGS evaluated over 1’200 scenarios for 84 mineral commodities based on 2023 data for the 2025 critical minerals list. The USGS methodology uses two criteria: economic effects assessment (quantifying the potential net decrease in U.S. GDP across disruption scenarios), and Single Point of Failure (SPOF): if a reliance on a sole domestic producer exists. The economic effects assessment quantifies risk as the probability-weighted net decrease in U.S. GDP. The USGS recommended in the 2025 assessment the addition of six mineral commodities (potash, silicon ferroalloys, refined copper, silver, rhenium, and lead) and the removal of two (arsenic and tellurium) from the list of critical raw materials. The USGS assessment includes separate results for different forms or stages of mineral commodities. The quantitative risk is statistically categorized into five classes.

The U.S. DOE focuses on materials serving an essential function in one or more energy technologies (producing, transmitting, storing, and conserving energy). In the 2023 assessment, priority technologies include EVs, various battery chemistries, fuel cells, wind, solar, nuclear, and semiconductors. It weighs importance to energy (70%) (including substitutability limitations) and supply risk (30%) (including producer diversity and political, social, & regulatory factors). The recent U.S. DOE assessment identified vulnerabilities across 11 energy supply chains. The results influenced federal strategy, DOE research and development (R&D) strategy, tax credits, and other policy to build resilient energy supply chains.

In addition, the U.S. Department of Defense (DOD) maintains a list of strategic materials of intersest. This list of 63 alloys, metals, miscellaneous non-metals, rare earths, ores and compounds, and precious metals represents materials determined to be both at risk and essential for defense and essential civilian needs in time of national emergency. Some chemical elements are included more than once, given that this list focuses on specific material forms and is not based solely on chemical elements.

Policy and Regulatory Developments, Trade and Cooperation

The DOE Policy is guided by the Energy Act of 2020. Domestic capacity is built through tax incentives, grants, loans, and stockpiling. The DOE prioritizes R&D and deployment strategies to develop alternatives and invest in circular economy approaches.

Via the Inflation Reduction Act (IRA) of 2022, EV tax credits are tied to critical minerals sourcing requirements (minimum shares from the U.S. or FTA partners, or recycled in North America, with phased-in thresholds). However, the One Big Beautiful Bill Act from July 2025 repealed many IRA provisions.

The U.S. is actively building strategic stockpiles of CSRMs like cobalt, antimony, tantalum, rare earths, and battery materials (lithium, graphite, nickel) to reduce dependencies for defense and high-tech needs, with the Pentagon leading a 1 billion USD purchasing initiative alongside efforts to boost domestic production and recycling.

The U.S. government also supports projects outside national boarders, such as an Australian company's heavy rare earth separation facility in Malaysia, and partnerships to accelerate the domestic rare earth mine-to-magnet supply chain. Critical minerals cooperation is embedded in trade and strategic frameworks with the EU, Japan, Canada, Australia, South Korea, and the UK. Third-country projects are implemented via DFC, EXIM Bank, and development partnerships, aiming to diversify global supply away from highly concentrated sources.

Anticipated Developments

The 2025 final list of U.S. Critical Minerals was published in November 2025.

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Sources

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3. Sectors of interest

The CSRM approaches of the presented countries and regions all prioritize sectors that are essential for the green and digital transition and for economic and military security, but each does so with a different emphasis. Across these approaches, “critical” or “strategic” can be interpreted in at least three ways: (i) raw materials needed in products and technologies that are desired because of their functionality (end-user perspective); (ii) raw materials needed in products and technologies that countries want to manufacture because of their contribution to economic growth (manufacturer perspective); and (iii) raw materials that countries want to supply because of growing international demand and associated opportunities (supplier perspective). These three lenses recur throughout the paper and shape how different jurisdictions interpret risks and opportunities along the same value chains.

In the **European Union**, strategic raw materials (SRMs) are linked to specific technological needs and distinguished from broader critical raw materials (CRMs), with a strong focus on green and digital transition technologies such as lithium-ion batteries, fuel cells, electrolysers, wind turbines, electric motors, solar PV, heat pumps, hydrogen-based steelmaking, and a wide range of digital and aerospace applications including data networks, servers, mobile devices, 3D printing, robotics, drones, satellites, and launchers. **France**, operating within this EU framework, uses OFREMI’s granular assessments to differentiate between concentrates and more advanced material forms and to inform national industrial strategy, with particular attention to the exposure of national key sectors such as automotive, aerospace, nuclear, and chemicals.

The **United Kingdom** puts a focus on minerals needed for decarbonization and the energy transition, and more broadly, on those underpinning economic prosperity, national security, and environmental resilience.

In the **United States**, the Department of Energy concentrates on materials essential to energy technologies for production, transmission, storage, and efficiency – covering EVs, multiple battery chemistries, fuel cells, wind, solar, nuclear, electrolysers, grid infrastructure, lighting, and semiconductors – while the U.S. Geological Survey defines critical minerals more broadly as those essential to the economy or national security across energy, defense, agriculture, consumer electronics, and healthcare. The Department of Defense focuses on national emergencies and idenfities materials that are – while being at risk – essential for defense and civilian needs in such times.

Canada’s critical minerals strategy identifies minerals as foundational to both green and digital economic development. It prioritizes value chains in clean technologies (batteries, wind, solar, nuclear), ICT and semiconductors, and advanced manufacturing, while also recognizing defence as an important beneficiary of secure domestic value chains.

Brazil organizes its strategic minerals around two main pillars: those critical for agriculture and protein production (key export sectors) due to high import dependency, and those tied to cutting-edge global technologies in energy transition, IT, communications, and defence. Future Brazilian policy aims to expand domestic capabilities in electronics, digital components, defence, and the bioeconomy.

Japan frames critical minerals around Green Transformation (GX) and Digital Transformation (DX), focusing on batteries for EVs and solar power, motors, and semiconductors, and assigns high priority to metals such as manganese.

South Korea’s approach is similarly centered on industrial competitiveness and high-tech manufacturing, assigning special focus on Korean core industries: mobility, semiconductors, machinery and tools, and energy, electricity, and electronics. As in the EU, the “core strategic raw materials” needed for these industries form a special class besides the more broader CRMs.

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India identifies critical minerals across clean energy technologies (solar PV, batteries, wind), high tech and transport sectors (EVs, electronics, semiconductors, space and aeronautics), defence, and agriculture via fertiliser inputs.

Türkiye defines its strategic minerals primarily through a national security lens, emphasizing inputs for heavy industry and defence manufacturing. Strategic minerals feed into steel and advanced alloys, turbine engine superalloys, laser technologies, and a range of military applications.

Taken together, these sectoral priorities show an overall trend: critical raw materials are no longer treated merely as inputs to generic industrial growth, but as levers for managing intertwined transitions. Each country or region frames its priorities through its own institutional lens: the EU and Korea with technology-specific SRMs, the U.S. with an energy and security emphasis, Japan through GX/DX and industrial competitiveness, Brazil with export-led development, Türkiye with a defence focus, Canada and the UK through green industrial strategies, and India with a mix of a development and a security focus. However, they are all effectively mapping criticality onto the same three broad domains: low-carbon energy systems, defence technologies, and advanced information – the latter being itself a necessary condition both for effective decarbonization as well as modern defense systems. This "stacking" of demand across multiple strategic sectors for the same group of minerals (e.g. battery and magnet materials) is a key driver of anticipated pressure on selected value chains.

This convergence has several implications. First, competition for certain minerals – especially those used in batteries, permanent magnets, and semiconductors – is likely to intensify, as governments pursue overlapping goals with similar material bases. Second, the securitization of mineral supply is becoming increasingly normalized: what began as climate or industrial policy is now increasingly articulated in terms of national security, resilience, and strategic autonomy. Third, even where development or export competitiveness remains central, these agendas are being re-anchored in global value chains transformed by decarbonisation, digitalisation, and security priorities.

This alignment also highlights important divergences that are relevant to international cooperation. Resource-rich countries like Canada and Brazil tend to frame critical minerals as an opportunity for value-added development and upgraded positions in global value chains, whereas resource-dependent manufacturing powers such as Japan and Korea emphasize securing access to inputs for existing or planned industrial bases. Countries such as the United States sit somewhat between these positions, combining domestic extraction ambitions with a broad security-led conception of criticality. These differences shape attitudes toward instruments like export restrictions, local content rules, strategic stockpiles, and friend-shoring (i.e. deliberately concentrating trade, investment, and supply relationships among a subset of "trusted" partners to reduce exposure to perceived geopolitical rivals). They also influence preferences for long-term offtake contracts versus spot markets, and for open multilateral regimes versus more exclusive "clubs".

Another emerging feature is the deep entanglement of industrial, climate, and security policy between different global actors. Because the same technologies appear across all common key sectors and, subsequently, policy strategies, measures taken in one jurisdiction – export controls, subsidies, ESG requirements, or investment screening – can have immediate cross-border impacts. This raises the risk of fragmented policy frameworks and "mini-blocs" of mineral trade, particularly around U.S.-China competition and the central role of China in extraction, processing and midstream segments. At the same time, the shared recognition of vulnerability and the common focus on similar technologies could also create a basis for cooperation on standard setting.

Within low-carbon energy systems, nuclear power and its upstream material base seem to be re-emerging as areas of strategic interest in several jurisdictions. It also has to be noted that developing countries – which were underrepresented at the round table discussed in this White Paper – are likely to place greater emphasis on CSRMs linked to food security and basic infrastructure, for example fertiliser minerals (such as Brazil) and inputs to water, nationwide energy coverage, and improved transport systems. Reflecting these priorities more fully in future work will be important to avoid shifting scarcity and vulnerability from high-tech sectors to essential services.

4. Methodologies

Across all examined jurisdictions, CSRM assessments are built around a broadly similar architecture, but with distinct methodological choices that reflect national contexts and priorities. Almost every approach combines some notion of "importance" (economic, energy, or strategic) with some measure of "supply risk," yet the way these dimensions are defined, quantified, and linked to policy differs. Time horizons are typically short- to medium-term, reflecting concerns about exposure to concentrated suppliers, trade restrictions, and other near-term geopolitical risks; long-run resource depletion and deeper structural transition risks are considered less explicitly and more unevenly across methods. A further source of divergence is how far assessments extend beyond mine output to refined products, components, and downstream technologies.

In the **European Union**, the Commission's methodology to determine CRMs is a clear-cut dual-criteria, indicator-based framework. It evaluates a large set of materials using economic importance and supply risk, relying on quantitative indicators such as sectoral value added, substitutability, market concentration, governance quality, import dependence, and recycling input rates. An important feature is the explicit hierarchy between CRMs and SRMs: strategic raw materials are not defined by criticality scores, but by their role in a predefined list of "strategic technologies" and by forward-looking indicators such as projected demand growth and difficulty of ramping up supply. The EU then translates these results into binding 2030 benchmarks for SRMs (domestic extraction, processing, recycling, and diversification targets), making the EU approach one of the clearest examples of how an assessment framework is directly coupled to quantitative policy objectives.

France, operating within this EU architecture, has chosen to increase granularity rather than expand scope. OFREMI's framework extends the dual-logic structure by adding the dimension "ability to cope" alongside supply risk and vulnerability, disaggregates materials into specific forms (ores, concentrates, oxides, sulfates, etc.), and evaluates them separately. Each indicator is scored from 1 to 5 and covers commercial, economic, technical, and socio-environmental risk. ESG aspects are assessed in a dedicated dimension rather than being diluted into generic risk scores. This form- and stage-specific perspective reveals that transformed materials often exhibit higher criticality than primary concentrates, and it is designed to feed directly into targeted industrial, trade, and stockpiling decisions.

The **United Kingdom's** methodology is intentionally transparent and "policy-service oriented." It mirrors the EU's two-dimensional logic (economic importance vs. supply risk) but tailors indicators to the UK context and data availability. Supply risk reflects production and trade concentration adjusted by ESG factors, companionality, and recycling rates; economic vulnerability incorporates apparent consumption, net import reliance, and gross value added. The outcome is a periodically updated, publicly documented "snapshot in time" that supports the UK government and industry in risk monitoring, rather than a legally binding trigger for quotas or benchmarks.

India's methodologies have evolved from adapting international frameworks toward more tailored approaches. Early work by CEEW adapted the EU scheme to the Indian context, applying economic importance and supply risk indicators to a broad set of minerals in a 2011–2030 horizon. More recent assessments by the Ministry of Mines define 24 minerals as "critical and strategic" based on high economic importance, high supply risk, or both, with particular attention to India's import dependence and projected domestic demand growth in sectors such as clean energy, electronics, mobility, and fertiliser. The Indian approach is tightly coupled to policy initiatives such as the National

Critical Minerals Mission (NCMM), auctioning of mineral blocks, overseas asset acquisition through KABIL, and targeted recycling schemes.

Japan's CSRM assessment, steered by METI and JOGMEC, uses economic importance and supply risk as core dimensions, but explicitly differentiates between risks that markets can absorb and those that require government intervention. Advanced models incorporate internal supply indicators (e.g., share of self-owned mine production), external supply risks (e.g., by-production, concentration), and sectoral exposure in key GX/DX applications. A broad list of target metals – including base, ferro-alloy, and critical metals – can qualify for financial and technical support from JOGMEC. While detailed methodologies are not publicly available, the Japanese approach stands out for its integration with an economic security framework and for its emphasis on value-chain-wide risk mapping (from mines and smelters to downstream manufacturers).

South Korea combines periodic supply-demand analyses with a legal framework that embeds rare metals into national security planning. The government screens elements based on high industrial demand, extraction difficulty, and limited crustal abundance. The Ministry of Trade, Industry and Energy (MOTIE) designates a narrower list of strategic minerals linked directly to semiconductors, mobility, machinery, and energy and IT. The assessment look at the CRMs of each sector and analyses import dependence, domestic production, and recycling rates. Quantitatively, Korea attaches explicit benchmarks to this group: for example, targets to reduce import dependence from 80% to 50% and to raise recycling rates from 2% to 20% by 2030. Assessments are embedded in monitoring systems, an interagency rare earths task force, and early-warning mechanisms, making Korea's framework one of the most operationally integrated into supply chain management.

Türkiye applies one of the most explicitly weighted quantitative systems. Its assessment distinguishes between critical and strategic minerals and aggregates risk through a composite score: risk (70%), import exposure (20%), and export exposure (10%). Within the dominant risk component, factors such as depletion time, reserve and production concentration, price volatility, domestic demand growth, recyclability, stockpiling, and potential usage restrictions are all included. Minerals are then grouped into categories such as potentially, significantly, or highly critical. This heavy weighting of inherent supply and price risk, and the explicit split between "critical" (economic impact) and "strategic" (national security) materials, reflects Türkiye's focus on industrial and defence vulnerabilities.

In the **United States**, the methodological landscape is split between the USGS and the DOE, and complemented by the DOD. The USGS employs one of the most macroeconomic risk-based approaches, evaluating a broad range of foreign trade disruption scenarios and quantifying risk as the probability-weighted net decrease in U.S. GDP. Minerals are classified into five quantitative risk classes. In addition, a SPOF criterion allows inclusion of minerals that rely on a single domestic producer, even if their modelled GDP impact is below the general threshold. This combination of macroeconomic modelling and structural vulnerability analysis is unique among the surveyed methods. The DOE assessment narrows the lens to energy technologies. It evaluates minerals according to energy importance and supply risk, where "importance" captures functional indispensability and substitutability constraints in technologies such as EVs, batteries, fuel cells, wind, solar, nuclear, electrolysers, grids, and semiconductors. Supply risk indicators include producer diversity and political, social, and regulatory factors. DOE's forward-looking horizon and its tight coupling to R&D priorities, industrial incentives, and tax credit design distinguish it from predominantly backward-looking or static assessments. The DOD, in addition, focuses on raw materials, ores, and compounds essential for defence systems and ammunition.

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Canada's emerging criticality framework is comparatively selective in scope. The official list of 34 critical minerals is defined by three conditions: either essentiality to economic or national security or relevance for the transition to a sustainable low-carbon and digital economy, and a "reasonable chance" of domestic production. This last criterion is distinctive: it filters out materials that, while domestically or globally important, are unlikely to be produced in Canada, thereby aligning the list with realistic industrial and investment opportunities. Parallel academic work (e.g., the Canadian Criticality Assessment Framework, see the list of further methods) reflects this logic by combining supply risk (demand-supply imbalance, concentration, geopolitical risk, substitutability) with "strategic significance," explicitly tying criticality to Canada's clean energy and defence transitions and to domestic feasibility.

Brazil's current approach is more qualitative and structurally oriented. Rather than relying on a formal multi-indicator criticality index, it organises CSRMs into three groups based on domestic production, trade patterns, and economic strategy: group 1 comprises minerals with high import dependence that are essential for agriculture and protein production, group 2 covers minerals that are globally critical for frontier technologies in energy transition, IT, communications, and defence, and group 3 includes "premium minerals" where Brazil has substantial reserves and potential for strategic advancement. These groups are not yet supported by a harmonised quantitative criticality index; instead, they reflect a strategic segmentation of minerals according to Brazil's development model and trade profile.

Taken together, these methodologies reveal several common trends. First, a dual structure – some form of importance (economic, energy, strategic) combined with some form of supply risk – is now near-universal, even where terminology differs. Second, there is a gradual shift from static, commodity-level indicators toward more granular and dynamic perspectives: France disaggregates by material form and processing stage; the USGS distinguishes multiple stages within key supply chains; Korea and the EU attach explicit time-bound benchmarks; and Japan and the U.S. DOE integrate forward-looking technology scenarios. Third, assessments are increasingly designed not as neutral diagnostics, but as gateways to specific policy instruments. The EU's SRM list is tied to capacity and diversification targets and to "strategic project" status; Korea's strategic minerals are linked to import-reduction and recycling objectives; India's list underpins NCMM investments, auctions, and overseas ventures; Japan's and Canada's frameworks guide JOGMEC support and Canadian project prioritisation; and U.S. USGS/DOE results inform stockpiling, R&D, and industrial incentives. Finally, most systems are beginning to integrate trade dynamics, circularity potentials, and midstream vulnerabilities more explicitly, moving beyond a narrow focus on mine-level supply risk toward a more systemic understanding of how CSRMs shape energy, digital, and security transitions across interconnected global value chains. This also reflects a gradual recognition that competition is not only for raw materials but increasingly for downstream and processed forms, where extending CRM methodologies to refined products, components, and intermediate materials will require dealing with more complex multi-stage value chains and significant data-access constraints that need to be addressed in the near term. Differences in indicator choice, weighting, and disclosure also mean that results are not always directly comparable across jurisdictions, underlining the value of methodological dialogue.

Across many of the presented frameworks, China features both as a benchmark and as a central source of perceived risk, given its dominant role in the mining, processing, and manufacturing of numerous CSRMs. China itself has implemented regulatory tools for managing material supply chain risks – including export controls, industrial policy guidance, and planning for secure access to overseas resources – which in turn shape how other countries design their own methodologies. As a result, the position of China in global supply chains is now explicitly or implicitly embedded in most CSRM assessments, not only as a supplier to be diversified from, but also as a strategic actor whose policy choices can rapidly alter risk profiles worldwide.

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5. Key challenges

CSRM policies across major economies face a common tension: governments want secure, sustainable supply chains, but the projects that deliver them are capital-intensive, slow to develop, and politically and environmentally sensitive. Each country's challenges reflect its institutional, economic, and geological context, but several cross-cutting themes recur: regulatory and permitting bottlenecks, infrastructure and technological constraints, governance and ESG expectations, geopolitical uncertainty, and insecurities in investment and long-term planning.

In the **European Union**, the key challenges lie in mobilizing sufficient investment for strategic CSRM projects and overcoming slow, complex permitting processes. The EU maintains high environmental and social standards, as well as extensive consultation obligations, which are essential for legitimacy but tend to lengthen procedures. However, actual project deployment can lag behind ambitions because project initiation and rollout takes too long, and developers struggle to secure finance under regulatory, permitting, and market uncertainty. Investors are particularly cautios when regulatory requirements are perceived as unpredictable or fragmented across Member States. A further challenge is to ensure that imported materials do not become systematically more competitive than EU production, as they often benefit from weaker environmental and social safeguards. Strategically, the EU must also navigate a geoeconomic environment increasingly shaped by U.S.-China rivalry, where its leverage over value chains can be constrained by decisions taken in Washington and Beijing. It must do so while competing with large subsidy schemes in other jurisdictions for a limited pool of viable CSRM projects. The core policy challenges are to streamline and accelerate permitting, de-risk investments, and internalize ESG costs for imports without lowering standards or jeopardizing democratic processes, while not overburdening companies with regulation.

In **France**, the central challenges lie less in defining criticality than in translating OFREMI's granular assessments into timely, coordinated industrial and policy responses. First, France must bridge a data-to-decision gap: while OFREMI distinguishes between different forms of a material (across its transformation stages along the value chain) and reveals that transformed forms are often more critical, industrial policy, trade diplomacy, and stockpiling instruments are still largely structured around broader material categories. Aligning these instruments with form-specific vulnerabilities is analytically and institutionally complex. Second, France operates within the EU CRMA framework but must still develop national-level levers (e.g., support for midstream processing, targeted R&D) that complement EU-wide tools without duplicating or fragmenting them. This coordination challenge is heightened by the need to manage CRM exposure of key French industrial champions (automotive, aerospace, chemicals, nuclear) whose supply chains are global. Third, prospective analysis (e.g. scenario-based evaluation of new factories or technologies) requires robust, up-to-date data and the ability to anticipate abrupt demand shifts; maintaining this capacity over time, and ensuring that ministries, agencies, and firms actually use it in investment and permitting decisions, is a demanding governance task. Turning OFREMI's socio-environmental risk insights into concrete conditions for procurement, financing, and industrial support – without shifting risk offshore – also remains a challenge. Ensuring that OFREMI's continuous updates and scenario analyses feed into real-time decisions on investment support, supply diversification, and crisis response will be key to reducing vulnerabilities in practice.

In the **United Kingdom**, geopolitics stands out as the dominant strategic risk in CRM policy. The UK is heavily exposed to global supply chains and depends on imports for many critical materials used in energy transition technologies, defense, and advanced manufacturing. While the UK may be affected by EU CRM policy, as a non-EU member, it does not have access to EU joint mitigation actions. Because domestic reserves and production capacity are limited for many CRMs, the UK cannot rely on self-sufficiency and instead must manage risk through diversification and resilience. Policy therefore focuses on advancing multiple fronts simultaneously: modestly expanding domestic extraction and

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processing where feasible; strengthening circular economy measures such as recycling, remanufacturing, and material substitution; deepening international partnerships and strategic alliances to secure reliable supplies; and investing in research and development to reduce dependence on the most vulnerable materials over time. The central challenge is to build a resilient CRM strategy in a context where external geopolitical shocks are the primary source of risk.

In **India**, critical raw materials policy is developing as domestic capabilities grow quickly, but the country still relies heavily on imported equipment, reagents, and process know-how for advanced processing. Technologies such as HPAL and sophisticated solvent extraction – crucial for producing battery-grade and other high-purity materials – are in the early stages of domestic deployment, with pilot and first commercial projects underway but not yet at the scale anticipated by India's long-term demand projections. Scaling these technologies would enable India to move further up the value chain from raw ore to refined, high-value products, reduce exposure to external supply and price risks for critical processing inputs, and strengthen strategic autonomy. At the same time, India has significant potential to recover critical materials from tailings, slag, industrial ash, and other secondary sources. Harnessing these streams can simultaneously cut import dependence, lower environmental footprints, and create domestically controlled supply for selected CSRMs. Realising this potential will depend on coordinated policy support, targeted R&D, and the industrial scaling of recycling and reprocessing technologies – areas that India's National Critical Minerals Mission and related initiatives are increasingly prioritising.

Japan's CSRM strategy is sophisticated but also faces several structural challenges. First, Japan is highly import-dependent for key GX/DX metals, making it exposed to geopolitical tensions, export controls, and supply concentration in a few producer countries. Second, the shift toward an economic-security lens demands advanced supply chain and risk analysis. Third, Japan must coordinate public backing (subsidies, guarantees, JOGMEC finance) across the entire value chain and a long list of priority metals, while distinguishing between issues that can be solved by markets and those that need intervention. Finally, deliberate non-disclosure of stockpile details and critical mineral designations aids security but limits transparency for markets, researchers, and international partners. These dynamics are embedded in a long-standing model of close state-industry coordination, where government agencies play an active role in shaping firm-level strategies and overseas resource investments. Japan's long history of observing and managing CSRM supply risk and its strong state-firm collaboration is a strategic asset in navigating these hurdles.

South Korea's critical raw materials policy is constrained above all by high dependence on Chinese rare metals and the concentration of these inputs in strategic sectors like semiconductors, EVs, batteries, and IT devices. As in Japan, strong government engagement with industry – through planning mandates, public corporations, and targeted support instruments – is a defining feature of Korea's approach to CSRM risk management. Law No. 19438 mandates five-year policies that treat rare metals as a security issue, but rapid shifts in technology and geopolitics make it difficult to design stable long-term plans. Operationally, Korea is advancing its systematic monitoring, data, and coordination mechanisms. The rare earths supply chain task force and broader interagency frameworks must integrate information, track global developments, and respond quickly to external shocks – an institutionally complex task. At the same time, the country is trying to diversify and de-risk through R&D on recycling, substitution, and material reduction, expansion of public stockpiles, and increased overseas development funding for mining and refining. However, scaling recycling and substitution technologies to industrial levels takes time, and overseas resource projects carry political and commercial risk. Finally, Korea's strategy depends heavily on international cooperation, which comes with uncertainty. While export control dialogues and supply chain hotlines with China can speed up permit approvals, they cannot fully eliminate geopolitical risk. Efforts to deepen cooperation with "like-minded" partners for joint projects, information sharing, and stockpiling must compete with other countries' own security and industrial priorities. Korea's advanced systematic monitoring, data, and coordination mechanisms help to face these parallel challenges.

Türkiye's CSRM policy is driven primarily by national security and defense needs, creating several core challenges. It focuses on minerals essential for heavy industry and military applications, many of which are globally concentrated, exposed to geopolitical and price volatility, and of which Türkiye has a high import dependence. At the same time, Türkiye enjoys a notable strategic advantage as the world's leading producer of boron, giving it a strong position in a important for various applications, including agricultural nutrients, advanced alloys, and electronics. Leveraging this position strategically – through value-added processing and stable, predictable supply – can reinforce Türkiye's role in global CSRM value chains. Policy implementation through exploration, R&D incentives, and stockpiling – coordinated by the Critical Mineral Board – requires strong coordination among state entities and industry.

Canada's critical raw materials policy is shaped by its vast resource base, strong ESG expectations, and geographic and infrastructural constraints. A challenge is inadequate infrastructure in remote and northern regions where many deposits are located. Limited access to roads, rail, ports, and reliable, low-carbon power increases capital expenditure, operational costs, and project timelines. Another major challenge are high capital intensity of CSRM projects and the difficulty of attracting sufficient, patient risk capital, particularly for early-stage and midstream processing investments. Regulatory complexity is also a concern — proponents must navigate federal, provincial, territorial, and often indigenous regulatory frameworks, which can be overlapping and time-consuming to align. At the same time, Canada faces skills constraints in specialized mining, processing, and environmental disciplines, which may slow project execution. Yet these challenges coexist with significant opportunities: Canada can leverage its strong ESG reputation, including its good practices in indigenous partnerships, to become a preferred supplier, attract new FDI, and expand domestic value chains from extraction through processing and manufacturing, provided it can address infrastructure, capital, regulatory coordination, and workforce development.

In the **United States**, CSRM policy and assessment are challenged by uncertainty. On the analytical side, it is difficult to build robust models of vulnerability, resilience, and policy impact. Many economic models used in CRSM assessments rely on simplifying assumptions – for example, constant price elasticities or stable relationships between supply, demand, and trade patterns – that may not hold in periods of rapid technological change or geopolitical shocks. This can lead to under- or overestimation of risks, as well as an incomplete understanding of how measures such as tariffs, stockpiles, or incentives affect national security beyond their measurable economic consequences. At the same time, the United States has a relatively volatile policy environment. Shifts in priorities, incentives, and regulations – driven by changes in administrations, congressional dynamics, and evolving geopolitical strategies – create uncertainty for investors considering long-term CSRM projects. Such volatility can deter or delay investment in mining, processing, and refining capacity, even when underlying resource potential and demand outlooks are strong. From the perspective of project developers, policy stability and predictability thus might have themselves become critical "inputs" to CSRM investment decisions.

In **Brazil**, critical raw materials policy contends with a dual imperative: accelerating project development while strengthening governance to avoid environmental and social harm. A key challenge is reducing the licensing timespan without weakening oversight. Long, complex authorization processes slow down investment and project implementation, yet any attempt to "cut red tape" risks enabling deforestation, social conflict, and illegal mining. At the same time, Brazil must enhance auditing and enforcement capacity to curb illegal operations, particularly in sensitive environments such as the Amazon. This requires better monitoring systems, stronger institutions, and coordination among federal, state, and local authorities. However, there is a significant opportunity to attract new FDI aimed not only at extraction but at extending value chains within Brazilian territory – moving beyond mineral concentration into processing, refining, and manufacturing. If Brazil can make licensing more predictable while simultaneously improving environmental and social auditing, it can position itself as a major, responsible supplier of critical raw materials with higher domestic value addition.

The analyzed cases show that while specific vulnerabilities differ, all observed economies confront a shared timing and coordination challenge. New industrial projects in batteries, photovoltaics, hydrogen, digital infrastructure, and defense are being planned and built faster than data systems, criticality methodologies, institutional routines, and international cooperation mechanisms can mature. Regulatory reform, infrastructure build-out, advanced processing capabilities, ESG safeguards, and diversified partnerships all take years to design and implement, yet supply risks, policy priorities, and technological shifts often materialize on much shorter time scales. Long lead times for exploration, permitting, mine development, and ramp-up therefore sit uneasily alongside CSRM assessments that focus mainly on short- to mid-term horizons, creating a structural mismatch between when risks are identified and when major supply-side responses can realistically come online. As risks are increasingly framed with a focus on end-use sectors and technologies rather than on individual commodities, there is a growing need to map downstream exposure – identifying which components, sub-assemblies, and finished products are vulnerable, and how shortages would propagate through these value chains. Effective CSRM policy will therefore depend not only on improving assessment tools and sector-specific strategies, but also on extending the scope of assessment and accelerating the feedback loop between analysis and decision-making – so that governments can adjust priorities, instruments, and partnerships as global markets, technologies, and geopolitical conditions evolve.

6. Conclusions

The IRTC 2025 round table highlighted that critical and strategic raw materials have moved from a largely technical concern to a core pillar of economic, climate, industrial, and security policy. Across all participating actors, CSRMs are framed through a dual lens: they must be both hard to secure and indispensable to key sectors. In practice, this has led to a strong convergence on similar priority technological domains: EVs and batteries, renewables and grids, semiconductors and advanced electronics, defence and aerospace. This convergence occurs despite substantial differences in resource endowments, institutional capacity, and development levels.

At the same time, the round table showed that there is no single model of "best practice." Lists of materials, hierarchies, thresholds and triggers for inclusion, unique focus industries, and policy instruments differ between countries. The EU embeds SRMs directly into binding capacity and diversification benchmarks, the USGS advances highly sophisticated macroeconomic risk modelling and SPOF criteria, France centers analysis on transformed material forms, Japan and South Korea emphasise economic security alongside industrial competitiveness, Canada and Brazil tie criticality to domestic resource potential and key export/agricultural sectors, Türkiye prioritises defence and heavy industry, and India couples a broad criticality agenda with an explicit push for overseas assets and recycling. These differences are not merely technical; they reflect divergent resource endowments, industrial structures, political economies, development priorities, and security postures. They also mean that countries often use different "lenses" to examine largely overlapping sets of materials and technologies. This diversity can be a strength if it leads to complementary specialisations rather than purely zero-sum competition.

Common challenges run through all cases: high capital intensity, long lead times, infrastructure gaps, and slow or complex permitting make it difficult to translate criticality assessments into timely, bankable projects. Data gaps – especially on end uses, substitution, recycling flows, and transformed products – limit the robustness and comparability of assessments. Information on midstream processing and secondary supply (recycling and urban mining) is particularly scarce in many

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jurisdictions. Geopolitical tensions and shifting policy priorities, together with the concentration of processing and refining in a few countries, create vulnerabilities that no single actor can eliminate alone. At the same time, the push for rapid project development raises difficult questions around environmental integrity, social license to operate, and respect for indigenous and local communities. Balancing speed, security, and sustainability is now at the heart of CSRM governance.

A further conclusion is that assessment and strategy are increasingly intertwined. Criticality exercises are no longer neutral diagnostics; they directly shape which projects receive public support, which segments of the value chain are prioritised, and which international partnerships are pursued. This raises the stakes for methodological transparency, regular updating, and explicit communication of uncertainties and value judgements embedded in indicators and weightings. It also underlines the importance of discussing assessments across borders, so that cooperation is based on compatible views of risk and opportunities. Structured exchanges on methodologies, indicators, and scenario assumptions could improve mutual understanding and help align expectations among partners.

7. Ways Forward

Looking ahead, advancing CSRM governance will require not just technical refinement of assessments, but deliberate responses to intensifying geoeconomic competition and fragmentation. The rise of industrial subsidies, export controls, investment screening, sanctions, and “friend-shoring” strategies is reshaping mineral markets and supply chains. This creates opportunities for new alliances and investment flows, but also strong systemic risks. In this context, several directions emerge.

First, there is a need to tighten the link between assessment outcomes and concrete policy instruments, while guarding against purely inward-looking or protectionist reflexes. Clear “triggers” between criticality classes and policy tools – ranging from R&D support and de-risking finance to strategic stockpiles and diplomatic engagement – can make responses more predictable, proportionate, and efficient. At the same time, such triggers should be designed with an eye to their geoeconomic spillovers: poorly calibrated subsidies, local content rules, or export restrictions can displace risks onto partners, fuel retaliatory measures, and ultimately undermine collective resilience.

Second, countries will need to accelerate responsible project development in an environment where time-to-market and control over midstream segments are becoming strategic assets. Streamlined but credible permitting, coordinated infrastructure planning, and expanded use of blended finance and long-term offtake agreements can help crowd in private investment without diluting environmental, social, and governance standards. Transparent criteria for designating “strategic projects” and allocating support are essential to avoid subsidy races that distort markets and erode trust.

Third, sustained investment in technological capabilities and skills – particularly in advanced processing, refining, and recycling – will be crucial to avoid locking in asymmetric dependencies in midstream segments where a small number of countries currently dominate. Expanding domestic and allied capacity in complex hydrometallurgical and pyrometallurgical processes, solvent extraction, separation of rare earths and other specialty metals, and next-generation recycling is essential if countries are to move beyond a role as simple ore suppliers or downstream assemblers. This also implies investing in human capital – engineers, geologists, metallurgists, data scientists, ESG and permitting specialists – and in centres of excellence that can translate laboratory innovation into bankable projects.

Fourth, in today’s rapidly evolving technology landscape, time lags between analysis and decision-making must be sped up in order to react to new developments, without compromising principles of due diligence, human rights, and democratic policy-making. Here, governments could take a central role in facilitating access to high-quality data for faster-turnaround assessments, especially as attention shifts further downstream. Public authorities can help address confidentiality and coordination challenges by creating trusted data infrastructures, clear legal safeguards, and standardised reporting frameworks that reduce the burden on companies while still enabling timely, robust CRM assessments.

In addition, though still less embedded in CSRM strategies: deepening circularity and demand-side measures offers one of the most powerful non-zero-sum responses to geoeconomic tensions. By scaling collection, reuse, repair, remanufacturing, and high-quality recycling – alongside material efficiency, substitution, and better product design – countries can ease pressure on primary supply, reduce exposure to concentrated producers, and lower the risk that competition for new mines becomes a source of geopolitical friction. Positioning circularity as a core pillar of CSRM strategies – rather than a secondary add-on – could help to unlock this potential.

Finally, managing CSRM under increasing geoeconomic pressure will depend on the quality of international cooperation. While some degree of strategic competition is unavoidable, an unmanaged race for control over critical minerals risks fragmenting markets, amplifying price shocks, and undermining the very energy transition and security goals that CSRM strategies seek to protect. Plurilateral platforms such as the MSP, G7 and G20 initiatives, and emerging alliances (e.g. Canada's Production Alliance, EU strategic partnerships, India's and Brazil's new agreements) offer vehicles for coordinated investment, information sharing, joint early-warning systems, and cooperation on standards, ESG, and traceability. Countries already keep a close eye on one another's CRM and SRM lists, not only to track evolving risk perceptions but also to identify opportunities to position themselves as suppliers of materials that partners deem strategic; structured exchanges on lists and methodologies could therefore become a constructive element of international collaboration and strategic supply development. They can also help to develop "common goods" functions – such as open data, scenario exercises, and minimum transparency norms for export controls and stockpiling – that mitigate the most destabilising geoeconomic dynamics. Embedding friendshoring arrangements within such cooperative frameworks – for instance through shared transparency rules, joint monitoring, and inclusive dialogue with non-member states – can reduce the risk that supply clubs harden into rival blocs and instead position them as stabilising anchors in a more contested global minerals landscape. Ensuring that resource-rich developing countries are meaningfully involved in these arrangements will also be important for their long-term legitimacy and effectiveness.

The IRTC community is committed to supporting these ways forward by fostering methodological dialogue, enabling cross-regional exchange on emerging risks, and exploring cooperative scenarios that move beyond zero-sum logic. This includes comparative work on assessment frameworks, shared scenario exercises, and platforms for exchange between governments, industry, and researchers. CSRM strategies should not only safeguard national interests but also help build a more resilient and sustainable global raw materials system which is a key condition for climate change mitigation and global prosperity.

List of further methods

The table on the next pages compiles a selection of international approaches and methods for critical and strategic raw material assessment collected by the IRTC Junior Board. It brings together academic, governmental, industry, and international organization methodologies that address different facets of risk – ranging from supply disruption, geopolitical exposure, and price dynamics to environmental boundaries, circularity potential, and sector- and company-level vulnerabilities. For each method, the table records metadata and key features, and links to underlying publications or tools. The aim is to provide a structured overview of the evolving methodological landscape, and guide users towards methods that best match their specific policy, research, or corporate decision needs.

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Name	Authors	Short description	Distinguishing features	Last update
Assessing the relevance of the HHI indicator DOI: 10.1016/j.eneco.2025.108208	Pauline Bucciarelli, Emmanuel Hache, Valérie Mignon (Academia)	The study aims to (i) investigate the validity of the Herfindahl–Hirschman Index (HHI) in assessing the supply risk dimension of criticality, and (ii) determine an appropriate threshold for its use in the context of criticality assessments. Metal prices are used as a proxy for supply risk in the study. The main indicator is the concentration of production at the extraction stage, measured at the country level using the HHI.	A panel econometric approach is employed, utilizing a large dataset that covers 33 strategic metals over the 1995–2021 period.	01.03.25
Canadian Criticality Assessment Framework (CCAF): Integrating Supply Risk and Strategic Significance (Presented at IRTC24, paper accepted for publication) DOI: 10.1007/s13563-025-00573-z	Marianna Ottoni, Steven B. Young, Komal Habib (Academia)	The Canadian Criticality Assessment Framework (CCAF) evaluates critical raw materials using two non-compensatory dimensions: Supply Risk (SR) and Strategic Significance (SS), designed to reflect Canada's dual role as both a resource producer and a strategic consumer. SR captures global vulnerability through demand–supply imbalance, production concentration (HHI-based and adjusted for Canada's production share), geopolitical risk (WGI-based), and substitutability. SS combines relevance to Canadian strategic sectors (national security, low-carbon and digital technologies, and strategic value to allies) with the practical feasibility of domestic supply (production potential, processing capacity, and logistics). A material is classified as critical only when both SR and SS are ≥ 0.5, ensuring that strategic importance and exposure to supply risk are jointly required.	The CCAF reflects Canada's dual role in global supply chains, adjusts concentration risk by national output, links sectoral relevance to feasibility, integrates ESG criteria, and aligns with EC and US DOE methods for transparent, comparable policy use	16.10.25
Circular Assessment Framework for Recovery of Critical Raw Materials from Industrial Waste	Michal Šyc, Lina Constanza Villa Vargas, and colleagues of the Waste Management and Sustainable Technologies Group (ICPF-CAS) (Academia)	This study focuses on the Czech Republic. CAF aims to integrate waste management and criticality assessment by quantifying recovery potential from industrial waste. The approach combines material flow analysis (MFA), life cycle thinking, and potential waste streams as secondary sources of CRMs. The methodology focuses on identifying potential secondary sources of critical raw materials (CRMs) within industrial waste streams. It addresses the risk of supply dependency on primary sources and geopolitical factors by evaluating technological feasibility, economic recovery potential and environmental impacts of waste-derived CRMs.	CFA expands traditional criticality assessments by integrating waste valorization and recovery potential, linking industrial process data with policy indicators to align circular economy strategies with criticality methodologies.	24.10.25

		Indicators: - Availability of secondary sources - Technological capability for recovery - Economic feasibility and market relevance - Environmental benefit of substitution - Policy alignment with EU CRM strategy and circular economy goals.		
Criticality Assessment at the Corporate Level for the European Automotive DOI: 10.1016/j.jenvman.2026.128555	Daniele Perossa, Paolo Rosa, Sergio Terzi (Academia)	The study focuses on the European automotive sector and the raw materials used in the electronic components. The resulting tool measures supply risk and estimates competition among sectors for access to material supply, the increasing or decreasing worldwide scarcity of the material within the Technosphere, its substitutability, and the company's absorptive capacity, based on material stocks. The validation results are representative of the situation of an average large European automotive firm.	The study employs a structured scientific methodology to ensure the usefulness of the designed criticality assessment tool for the designated users, i.e., decision-makers inside company. The tool uses the supply chain of the company as a unit of analysis, ensuring the usefulness of the results to its users. Several innovative indices have been designed to meet the identified requirements of the designated users of the tool (i.e., European automotive practitioners).	06.01.26
Criticality factors (and actions) based on competition analysis	Yulia Lapko (Academia)	The study developed the competition analysis framework and used it to map experienced constraints and actions taken by three EU companies across two industrial sectors (wind turbines and EV) during the REE crisis (2009-2016). The results obtained provide implications for new criticality indicators across three areas of the competition framework: factor market (where a company sources its materials and components), internal environment, and product market (where a company sells its products).	This study: 1) takes a company perspective, 2) considers both internal and external environments of a company, and 3) builds on organisational theories linking resources and competition and the discourse on competitive dynamics.	28.07.25
Criticality of mines DOI: 10.1021/acs.est.9b02808	Éléonore Lèbre, John R. Owen, Glen D. Corder, Deanna Kemp, Martin Stringer, Rick K. Valenta (Academia)	The study constructs a multi-indicator evaluation system to measure the criticality of mines from two dimensions: importance and supply risk. It also uses the system to evaluate the criticality of copper mines as a case study.	Unique focus on mine site.	28.07.25
CRITICS DOI: 10.1007/s11367-025-02439-6	Isadora C. Hackenhaar, Gustavo Moraga, Gwenny Thomassen, Sue Ellen Taelman,	Several sets of criticality characterization factors (CFs) are proposed for use in product LCA, based on the values for supply risk and economic importance from the EC study on CRMs, which are combined in different ways, along with guidelines for users.	Implementable in LCA and in line with EU policy/criticality	05.02.25

	Till M. Bachmann , Jo Dewulf (Academia)	Indicators used in this study are supply risk and economic importance from the EU methodology, prices, natural reserves, and others.		
Data-centric CRM assessment platform (Password provided on request via email to alexandra.pehlken@dfki.de or ole.meyer@offis.de)	Ole Meyer, Alexandra Pehlken (Academia)	The platform is a tool capable of performing and updating various assessment methodologies, as well as communicating their results. So far, the inclusion of the European Commission's methodology has been carried out; other methods will follow.	The basis of the platform is a database of data from primary sources, which can be updated with each data release. This enables easy tracking and visualization of data as well as updating the included assessments as soon as new data is available.	30.09.25
Dutch Observer for Materials Intelligence and Operations (DOMINO)	Irina Patrahau, Jesse Kommandeur, Nidas Brandsma, Maria-Antigone Rumpf (Think tank)	DOMINO organizes large volumes of near-real-time critical raw materials news data from a wide range of international outlets using an AI-automated pipeline that applies a tailored taxonomy. The results are visualized in an interactive dashboard. In this dashboard, you can explore trends, search for content, or generate reports on 50+ materials, 40+ event types, more than 200 countries and administrative units, 3 actor categories (public, private, and non-governmental), and 20+ supply chains.	Extracting and structuring up-to-date data from global news articles.	19.12.25
Empirical risk assessment DOI: 10.1016/j.resourpol.2025.105718	Hiroki Hatayama, Shinsuke Murakami, Yurie Anzai (Academia)	The perceived risks covered by this study include natural disasters, industrial accidents, and labour strikes.	The method introduces ovel risk types.	06.08.25
Entropic approach to criticality assessment DOI: 10.48550/arXiv.2601.09827	Alan J. Hurd (Government)	This study focuses on the United States Using a geologic entropy measure for chemical element abundances and incorporating an economic constraint on total expenditure, the utility function is optimized using Lagrange multipliers. Perceived risks covered by this study are price and scarcity. The indicators used in this study are crustal abundance and the prices of mineral elements.	Yakovenko used an entropy function for price in econophysics in 2021, but did not apply it to criticality assessment.	01.09.25

ESSENZ Method DOI: 10.1016/j.jclepro.2016.07.077	Vanessa Bach, Markus Berger, Martin Henßler, Martin Kirchner, Stefan Leiser, Lisa Mohr, Elmar Rother, Klaus Ruhland, Laura Schneider, Ladji Tikana, Wolfgang Volkhausen, Frank Walachowicz, Matthias Finkbeiner (Academia)	Overall, 21 categories are established to measure impacts on the environment, physical and socio-economic availability of the used resources, as well as their societal acceptance.	The ESSENZ Method focuses on the Restricted availability of resources due to physical as well as socio-economic factors and societal acceptance, providing a comprehensive perspective. Its purpose is to identify hotspots to inform product design, material selection, and supply chain management.	27.09.24
Food-Water-Energy Nexus Criticality Assessment	Ghadi Sabra, Hari Tulsidas (International body)	The proposed FWE-Nexus methodology evaluates minerals across two interlinked dimensions: i) System Exposure; ii) Supply Risk. Perceived risks covered by this study are geological knowledge, project maturity, substitute availability, recycling rates, import dependence, environmental footprint, economic viability, and social impact. Indicators used in this study are utilized in food (agriculture), water (treatment), energy (renewable), substitute availability, recycling rates, import dependence, UNFC classifications, and inventories.	This method emphasizes systemic resilience, supply risk based on UNFC as a direct indication of the potential and time-to-market, rather than purely economic metrics, as a simplified screening matrix for policymakers	12.01.26
GeoPolRisk method DOI: 10.1016/j.resconrec.2024.107801. (latest paper)	Eskinder D. Gemechu, Guido Sonnemann, Steven B. Young, Christoph Helbig, Alexander Cimprich, Jair Santillán-Saldivar, Anish Koyamparambath (Academia)	This study employs the GeoPolRisk method to quantify the geopolitical supply risk of raw materials in clean hydrogen production from the perspective of different countries. The indicators used in the study are domestic production, production concentration, import trade flows, and the political instability of the importing country.	Including political instability, country's perspective, update with years, including trade flows.	01.06.24
Integrated conceptual framework for resilience and criticality assessments for raw material supply chains	Lars Wietschel, Christoph Helbig, Martin Hillenbrand, Andreas Thorenz (Academia)	This study reviews the literature on criticality, resilience, and raw material resilience and identifies conceptual overlaps and gaps between criticality and resilience assessments. It develops a time-dynamic, indicator-based framework that integrates disruption likelihood, disruption impacts, and recovery capacity. The framework is demonstrated through a case study of Gallium for the EU under a hypothetical export ban, providing a	Conceptual integration of criticality and resilience, time-dynamic perspective, explicit separation of dimensions between (i) probability of disruption, (ii) system performance loss, and (iii) recovery capacity, risk-to-mitigation linkage	31.05.25

DOI: 10.1016/j.resconrec.2025.108249		basis for quantitatively integrating criticality and resilience in raw material supply risk analysis.		
IRTC Decision Tool	Dieuwertje Schrijvers, Patrice Christmann, Magnus Ericsson, Komal Habib, Jan Kosmol, Anthony Ku, Min-Ha Lee, Guido Sonnemann, Luis Tercero, Patrick Wäger, Peng Wang, Alessa Hool (various author affiliations; author list is subject to changes with the development of the paper)	Linking of indicators to company-focused risks. Raw materials are scored on a 0-100 ranking per indicator. Perceived risks covered by this study include access, price, and reputation. It encompasses a broad range of indicators identified in the literature.	Following a cause-and-effect relationship between indicators and company risks.	11.01.23
Large language model-driven supply disruption probability assessment	Xin Sun, Lanxin Zhang (Academia)	A large language model (LLM)-driven method to better understand disruption risks. The indicators used in this study are based on the frequency of various supply disruption events in different countries across the supply chain.	Taxonomy of supply risk categories and applied LLMs with prompt engineering to extract and categorize disruption events from thousands of news articles spanning nearly two decades.	01.09.25
Least-effort principle for evaluating prices of elements as indicators for sustainability DOI 10.1557/s43581-020-00001-5	R. Perumal Ramasamy (Academia) Alan J. Hurd (Government)	This study focuses on the United States. A least-effort principle is proposed for predicting prices of elements by drawing on analogy to information entropy. Perceived risks covered are societal importance as reflected by price and supply risk as reflected by scarcity. Indicators used in this study are (mined) mass/volume, market price, and crustal abundance.	Zipf's Law expresses power-law regularity between frequency of occurrence and rank order, first used for word frequency and ties to information entropy. Since mineral price and mined mass reflect collective decisions by markets, this study tests the applicability of entropy to market variables.	01.09.25
Midstream Readiness and Value Addition Assessment Tool	Ghadi Sabra, Hari Tulsidas (International body)	Understanding that midstream activities are not constrained by geology nor consumer markets, the Midstream Readiness and Value Addition Assessment Tool is designed to identify, screen, and assess the potential for such activities in a given national or regional context, mainly through technology repurposing from industries that do not	The Midstream Readiness and Value Addition Assessment Tool emphasizes the repurposing or upgrading of existing and underutilized industrial assets as potential entry points for midstream value addition.	12.01.26

		directly support the Food-Water-Energy Nexus. The tool is intended to support evidence-based policymaking on midstream development within critical mineral value chains, based on UNRMS principles. The tool is sector-agnostic by design; its application focuses on Food-Water-Energy Nexus critical minerals value chains.	Based on these inputs, the tool produces an indicative Midstream Deployment Readiness Score, which is not intended to be definitive or prescriptive; rather, to serve as a screening and sense-making index to highlight strengths, gaps, and trade-offs that warrant deeper analysis. Indices and components of the tool can be refined, weighed differently, or expanded to reflect national priorities, data availability, or specific policy questions.	
Multi-objective energy system optimization of material and energy supply risks DOI: 10.1016/j.apenergy.2025.125647	Gianvito Colucci, Jonas Finke, Valentin Bertsch, Valeria Di Cosmo, Laura Savoldi (Academia)	This study focuses on Italy. It proposes a framework to minimize the energy transition supply risks by means of energy system models and multi-objective optimization of consistent material and energy supply risk functions. Perceived risks covered by this study are the supply mix and the impacts on energy transition. The supply risk (SR) function was defined based on the most used methods, thereby considering the following indicators: supply concentration, geopolitical, and import reliance indicators. In particular, the latest SR definition of the European Commission methodology was used.	To the authors' knowledge, this is a novel approach, as existing methodologies lack prospective approaches and integration with energy system planning processes.	15.06.25
PtX Lab Criticality Method	Angee Fehling, Johanna Gassenheimer, Dinh Du Tran, Dr Rita Schulze, Dr Ramona Simon, Dr Philip Ruff, Anja Paumen, Lorenzo Cremonese (Think tank)	This study focuses on Germany and aims at investigating resource-saving and sustainable technologies for the production of synthetic kerosene from renewable energy sources, with scenarios until 2050. Risk dimensions covered in this study are economic importance and supply risk (from the EU), combined with resource indicator such as TMR and RMC.	Supply risk (SR) and economic importance (EI) for all elements are normalized to show similar room of variation, namely from 0 to 1. Moreover, they are combined into a single parameter to define the relative criticality.	01.10.24
SARA_4_UNFC	Soraya Heuss-Assbichler, Iman Dorri, Bhagya Jayasinghe, Alireza Sobouti (Academia)	This study focuses on Germany. SARA_4_UNFC is a digital tool for classifying projects by waste type using the UNFC framework. The structured assessment integrates aspects of the circular economy and sustainability. The reports ensure transparency, comparability, and consistency.	SARA_4_UNFC differs from conventional tools by integrating all sustainability aspects into one framework, transforming complex project data into transparent, reproducible, and comparable insights for resource recovery	31.05.25

		Our procedure considers multiple factors, referred to as Controlling Factors (CFs). Each CF captures specific aspects of economic, environmental, technical, and social performance, ensuring that project evaluation reflects a holistic view of sustainability and resource criticality. The multidimensional approach considers the following key drivers of criticality. - Economic and market dynamics – CFs capturing market price trends, investment costs, and revenue potential of recovered materials. - Environmental sustainability – CFs evaluating emissions, waste generation, land use, and overall environmental footprint. - Social and legal acceptance – CFs related to stakeholder participation, regulatory compliance, and alignment with policy frameworks. - Technological maturity – CFs assessing technology readiness levels (TRLs), process adaptability, and operational feasibility. - Data confidence and systemic uncertainty – CFs assessing the reliability, completeness, and representativeness of available data for project evaluation. Three modules, each with a defined set of factors (control factors) and indicators, are used to record technical, economic, environmental, social, and regulatory aspects related to permits, circular economy, and sustainability.	classification and management.	
Strategic raw materials for defence. Mapping European industry needs ISBN/EAN: 9789083254180	Benedetta Girardi Irina Patrahau, Giovanni Cisco , Michel Rademaker (Think tank)	HCSS researches geopolitical, defence & security issues. This study focuses on material risks in the defence sector and on complex systems like fighter aircraft. The goal is to inform public and private strategic decision-making and contribute to international and national security. It is a data-driven approach, defining risk as probability times impact, where the probability is material dependent and the impact is sector dependent. The HCSS's assessment of critical raw materials for defense has been adopted by NATO as a list of defense-critical raw materials. HCSS is currently developing a methodology for identifying 'red flags' and sending early warning signals.	Assessment of strategic raw material specifically for European defence needs	15.01.25

		The approach was further developed and applied in the context of the naval sector in '[Raw material and supply chain vulnerabilities in the Dutch defence sector: An analysis of the Air Defence & Command Frigate'] in January 2025.		
[Supply risk considerations for photoelectrochemical water splitting materials] DOI: 10.1039/D3EE04369J	Martin Hillenbrand, Christoph Helbig, Roland Marschall (Academia)	The study semi-quantitatively assesses the short-term and long-term supply risks due to potential supply reduction, demand increase, concentration risks, and political risks for nine promising absorber materials for photoelectrochemical water splitting. The perceived risk is the supply risk. The indicators used in this study are depletion time, End-of-life recycling input rate; Future technology demand; By-product ratio; Sector competition index; Substitution; HHI; WGI; PPI; HDI.	Split between present and future-focused supply risk assessment	23.05.24
[Thermodynamic rarity] DOI: 10.1007/978-3-030-78533-8	Alicia Valero, Guiomar Calvo, Sonia Ascaso, Antonio Valero (Academia)	The thermodynamic rarity approach is not geographically limited and has been applied in several different contexts. The thermodynamic rarity of minerals is defined as the actual amount of exergy resources required to obtain a mineral commodity from bare rock to market conditions using the current best available technologies. Perceived risks covered by this study are criticality, mine ore decrease, and environmental impacts. Indicators used include the thermodynamic rarity which considers production costs and geological scarcity. Is the sum of two costs: the actual number of resources needed to convert a mineral into a commodity, and the free natural bonus for having minerals concentrated.	The study considers not only the amount of resources needed to convert a mineral into a commodity but also the free natural bonus for having mineral concentrated using a thermodynamic property that will remain practically unchanged over time.	01.07.25

Abbreviations

ADEME – French Agency for Ecological Transition

BRICS – Brazil, Russia, India, China, South Africa

BGS – British Geological Survey

CAPEX – Capital Expenditure

CEA – French Alternative Energies and Atomic Energy Commission

CFs – Controlling Factors

CMIC – Critical Raw Materials Intelligence Center

CRMs – Critical Raw Materials

CSRMs - Critical and Strategic Raw Materials

DFC – U.S. International Development Finance Corporation

DOE – U.S. Department of Defense

DOE – U.S. Department of Energy

DOI – US. Department of the Interior

DRI – Direct Reduced Iron

DX – Digital Transformation

ESG – Environmental, Social, and Governance

EU – European Union

EXIM Bank – Export-Import Bank of the United States

FDI – Foreign Direct Investment

FTA – Free Trade Agreement

G7 – Group of Seven

G20 – Group of Twenty

GX – Green Transformation

HCSS – The Hague Center for Strategic Studies

HHI – Herfindahl-Hirschman Index

HPAL – High Pressure Acid Leaching

IEA – International Energy Agency

IFP – IFP Energies nouvelles; French public research, innovation and training organisation

IFRI – French Institute of International Relations

IPEF – Indo–Pacific Economic Framework

IRTC – International Round Table on Materials Criticality

JOGMEC – Japan Oil, Gas and Metals National Corporation

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KABIL – Khanij Bidesh India Limited

KIRAM – Korea Institute for Rare Metals (name until 2023)

KORAM – Korea Institute for Rare Metals (name since 2023)

METI – Ministry of Economy, Trade and Industry (Japan)

MOTIE – Ministry of Trade and Energy (South Korea)

MMDR Act – Mines and Minerals Development and Regulation Act (India)

MPO – Major Projects Office (Canada)

MSP – Minerals Security Partnership

NCMM – National Critical Minerals Mission (India)

OFREMI – French Observatory of Mineral Resources for Industrial Sectors

OPEX – Operating Expenditure

PGMs – Platinum Group Metals

R&D – Research and Development

REEs – Rare Earth Elements

SPOF – Single Point of Failure

SRMs – Strategic Raw Materials

UNFC – United Nations Framework Classification for Resources

USGS – United States Geological Survey

WGIs – Worldwide Governance Indicators

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