Doctoral Dissertation.
Doctoral Program in Civil and Environmental Engineering (38th Cycle)

Applying the United Nations Framework Classification for Resources to Critical Raw Materials

A case study of Italy in the context of the European Critical Raw Materials Act

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2026

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Ghadi Sabra Turin, May 2026

Abstract

The accelerating global transition towards environmentally sound energy systems, digitalization, and advanced manufacturing has fundamentally reshaped the importance of raw materials. Once considered abundant or peripheral in a fossil-fuels driven world, raw materials are now central to economic and industrial competitiveness, energy security, and geopolitical stability. This transformation has placed the governance of raw materials at an imperative juncture in the global sustainability agenda. In simple terms, attaining sustainable development demands a surge in raw materials supply. Along these lines, this global shift therefore requires new approaches capable of balancing supply security with environmental protection, social responsibility, and long-term intergenerational equity. In other words, leaving a world without a compromised environment, and exacerbated resources, including raw materials, for the future generations.

With the global sustainability agenda in mind, it is therefore necessary to manage the growing challenge between the rising demand for raw materials and the environmental and social impacts associated with their extraction and processing. As such, the question remains on how to get raw materials from beginning to end, while remaining bounded to the principles of sustainable development. As a solution, sustainable resource management emerges as a foundational practice to ensure that raw materials production, use, and reuse do not undermine sustainability principles. A pillar of sustainable resource management is the ability to identify, quantify, and communicate information on raw materials under conditions of uncertainty. Resource classification renders complex information into its simplest form for utility. In the context of raw materials, classification systems provide the conceptual and operational framework through which confidence in product estimates, technical feasibility, economic viability, and more recently increasing environmental and social considerations are conveyed to stakeholders.

In Europe, resource management has historically been handled at national levels, particularly mining codes being under state's responsibility, which caused a fragmented array of reporting and classification systems across the continent. At the same time, the lack of a harmonized resource classification framework at European Union level lowers the chances for cross-country comparability, and in return strategic planning. Harmonized classification, a common language per se, is increasingly seen as essential for understanding raw materials potential and

accessibility at European level, in return supporting strategic autonomy, industrial competitiveness, and sustainability goals.

The United Nations Framework Classification for Resources (UNFC) provides a practical solution. It is a principles-based classification tool that enables consistent, coherent, and robust communication on energy and resource projects across all stakeholders. UNFC is built on a three-dimensional framework that classify projects according to environmental-socio-economic viability (E axis), technical feasibility (F axis), and the degree of confidence in product estimates (G axis). This structure allows complex project information to be presented in a clear, comparable, and transparent way, and in return, support informed decision-making. UNFC is applicable to both primary raw materials and secondary raw materials. Moreover, UNFC allows the transposition of information from one classification system to UNFC. This is carried through a bridging mechanism to align UNFC with other reporting systems, ultimately paving the way for a common language across different projects, jurisdictions, and purposes, for interoperability of data. Although well established, UNFC has to date been limited in use, mainly in private and public reporting. Moreover, only a handful of countries have formally adopted UNFC at national levels, particularly for minerals inventories, used in support of existing national codes. However, the extensive potential of UNFC is yet to be explored beyond mere inventorying. This dissertation explores how this potential supports sustainable resource management, through full alignment with the objectives, measures, and monitoring requirements of the European Critical Raw Materials Act (CRMA).

CRMA represents a paradigm shift in the European Union's raw materials policy, moving beyond criticality assessments toward a structured system aimed at securing a resilient, sustainable, and diversified supply of critical and strategic raw materials. CRMA positions UNFC as the classification tool, mandated for use on results from National Exploration Programmes, extractive wastes from closed facility, and for risk monitoring and mitigation. CRMA also requires the application of UNFC by industry, as a recognition criterion for Strategic Project application, which encompass extraction, processing, recycling, and substitution projects. On that note, recognized Strategic Projects benefit from priority status through accelerated permitting, coordinated financial support, and enhanced regulatory backing. However, these projects must be evaluated consistently across Member States, monitored over time, and assessed not only in terms of economic viability, but also with regard to environmental, social, governance, and supply chain risks. This creates a clear need for a harmonized, robust, and policy-relevant classification framework capable of supporting decision-making at multiple levels of governance, to which UNFC is suitable for. Therefore, CRMA is read as an accelerator to this research, with an established need for harmonized and quality reporting in UNFC at EU levels, and across the whole critical raw materials supply chain.

Within this broader European landscape, Italy, similar to many other EU Member States, offers a notably common case of decentralized raw materials data, without a binding national classification and reporting system. In addition, Italy has a strong manufacturing industry and therefore requires uninterrupted and secure supply of critical raw materials. Italy initiated action through regulatory reforms to tackle this matter and deliver on the CRMA objectives, notably through Decree-Law No. 84/2024. Yet, work is still in progress. With that said, UNFC and more broadly raw materials classification, are relatively new, underexplored, and unused in Italy. Hence, throughout this dissertation, Italy has been selected as the testing field for exploring how consistent, coherent, and harmonized classification of raw materials across the whole supply chain, can support the principles of sustainable resource management, and in achieving the objectives of CRMA.

The dissertation therefore covers the application of UNFC across all its provisions in CRMA. It first addresses the role of UNFC in the context of Strategic Projects, through structured methodologies designed to serve three distinct but interrelated user groups: project promoters, UNFC expert evaluators, and policymakers at European Union level. The work on Strategic Projects also includes a workable assessment model for supply potential and associated risks from designated Strategic Projects based on UNFC. The research extends the application of UNFC to National Exploration Programme. Exploration is a critical yet often weakly integrated component of raw materials policy, as early-stage projects are characterized by high uncertainty and limited data. The dissertation presents a tailored methodology for applying UNFC to exploration results. Beyond primary raw materials, the research also addresses the growing importance of secondary raw materials, particularly the application of UNFC to extractive waste, in the context of CRMA's national circularity measures. Additionally, the dissertation further proposes a UNFC-based monitoring framework aligned with the risk monitoring and mitigation provisions as per CRMA. The methodology is designed to monitor extraction, processing, and recycling critical raw materials projects over time. A national monitoring template tailored to the European context is also proposed, to illustrate how UNFC can be embedded within administrative and reporting processes to support proactive risk mitigation.

The overarching objective of the dissertation is to contribute to the practical application of UNFC in support of sustainable resource management through full alignment with the objectives, measures, and monitoring requirements of CRMA. Using Italy as a case study, the research develops scientifically robust, technically sound, and replicable approaches for integrating UNFC into national raw materials management frameworks. While grounded in the Italian context, these approaches are developed to be transferable to other EU Member States facing similar institutional, regulatory, and data challenges. The core research question driving the work examines how UNFC can support the European Union in translating raw materials data into structured knowledge and actionable policy-relevant intelligence for the sustainable management of critical raw materials projects, thereby contributing to the attainment of CRMA objectives.

A key outcome of the dissertation is the development of a first-of-its-kind Italian raw materials inventory based on UNFC. Drawing on the methodologies developed throughout the dissertation, the developed UNFC-based Italian raw materials inventory demonstrates how data from diverse sources can be harmonized within a single UNFC-based structure. Ultimately, the coverage of the whole supply chain supports the development of national raw materials inventories, based on various data sources and types. If inventories from all Member States incorporate UNFC, these could be therefore aggregated into a singular EU-level raw materials inventory, rendering the raw materials intelligence at EU scales more effective. In the case of the Italian raw materials inventory, it provided not only a snapshot of the critical raw materials potential, but also a dynamic tool for strategic planning, policy evaluation, and EU reporting. To facilitate consistent application, the research also developed UNFC decision-trees aligned with Italian mining legislation and proposed a national UNFC guidance template.

UNFC offers a robust, flexible, and policy-relevant foundation based on a common raw materials language. The dissertation therefore provides both conceptual and practical contributions, with methodologies that can be adopted by other Member States and scaled to European level. At the same time, it opens avenues for the integration of secondary raw materials and international supply chains into UNFC-based inventories. Finally, the dissertation contributes to ongoing literature around advancing applied resource classification within an active regulatory setting and to policy practice, by offering concrete pathways for embedding UNFC within evolving European raw materials landscape.

Acknowledgment

This dissertation was carried out within the framework of the GeoSciences IR project and was fully supported by the European Union under the Next GenerationEU programme, Mission 4 “Education and Research”, Component 2 “From Research to Business”, Investment 3.1 “Fund for the realization of an integrated system of research and innovation infrastructures”, Project IR0000037 – GeoSciences IR (CUP I53C22000800006). This financial and institutional support enabled the activities delivered throughout this doctoral journey.

I would like to express my sincere gratitude to my supervisors, Prof. Gian Andrea Blengini and Dr. Slavko Šolar, for their valuable and continuous guidance, support, contributions, and encouragement throughout the course of this dissertation. Their constant motivation to maintain momentum, pursue intellectual rigor, and exceed expectations has been instrumental to the completion of this work. Beyond their academic mentorship, their erudition, work ethic, and overall life philosophy have served as a profound source of inspiration, shaping not only this dissertation but also my personal and professional creeds. For their mentorship and trust, I remain forever deeply and sincerely grateful.

I would also like to sincerely thank Prof. Marilena Cardu for the continuous support, guidance, and encouragement throughout this journey. Trust, constant availability, and the opportunities provided have been invaluable to my academic and professional development.

The development of this dissertation has greatly benefited from the continuous collaboration, support, and valuable guidance provided by the United Nations Economic Commission for Europe (UNECE), particularly the Secretariat of the Expert Group on Resource Management. The UNECE has provided an exceptional platform for engagement and has strongly motivated my continued contribution to the European raw materials landscape. A significant portion of the presented work stems from this opportunity and the exposure to distinguished experts within the United Nations network. I am profoundly grateful to the UNECE colleagues for their trust, support, and intellectual generosity. In particular, I wish to extend my special appreciation to Ms. Charlotte Griffiths for believing in my capabilities, and the exceptional support and encouragement throughout this journey. Thank you for always being there.

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Chapter 1

Introduction

1.1 Raw Materials in a Changing Global Context

What does it mean to live well in an age where growth is not only desired but demanded at every level of society? Humans have entered a phase in which expectations for wellbeing, prosperity, and quality of life have reached cosmic heights, driven by this urge for growth, be it economical, technological, urban, or societal. These aspirations, while legitimate, place unprecedented pressure on natural systems, energy resources, and material supply chains. Going in this direction, the fundamental challenge of the twenty-first century lies not in curbing human development, but in anchoring it within planetary boundaries fit for this economic progress and technological evolution. It is therefore imperative to ensure that this pursuit does not conflict social equity and environmental protection, and rather advance together. This recognition has progressively led the international community to articulate shared normative frameworks capable of guiding development pathways toward long-term sustainability.

The adoption of Agenda 2030 for Sustainable Development represents the most comprehensive global response to these challenges. Endorsed unanimously by all United Nations Member States in 2015, Agenda 2030 establishes a universal plan of action for people, planet and prosperity, explicitly recognizing the interdependence between poverty eradication, environmental protection, economic development and peace (United Nations, 2015). At its core, this global initiative acknowledges that extreme poverty remains the greatest global challenge and an indispensable requirement for sustainable development, and that addressing it cannot be separated from safeguarding natural resources and ecosystems. The 17 Sustainable Development Goals (SDGs) and their 169 targets are deliberately designed as integrated and indivisible, balancing the economic, social and environmental dimensions of development. Unlike previous global development agendas, the SDGs apply universally to all countries, and call for collaborative partnerships involving governments, industry, academia and civil society. Several SDGs are directly or indirectly linked to natural resource management and extractive activities, notably SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 15 (Life on Land).

Closely aligned with Agenda 2030, the Paris Agreement constitutes a landmark in global climate governance. Adopted in December 2015 at the twenty-first Conference of the Parties (COP21) of the United Nations Framework Convention on Climate Change (UNFCCC), it is the first legally binding international agreement to bring all nations together in the fight against climate change (UNFCCC, 2015). Its overarching objective is to hold the increase in the global average temperature to well below 2°C above pre-industrial levels, while pursuing efforts to limit warming to 1.5°C. Subsequent scientific assessments by the Intergovernmental Panel on Climate Change (IPCC) have underscored the urgency of this ambition, demonstrating that exceeding the 1.5°C threshold would significantly increase the frequency and intensity of extreme weather events, biodiversity loss, and socio-economic disruptions (IPCC, 2018). Achieving this target requires global greenhouse gas emissions to peak before 2025 and decline rapidly thereafter. This has profound implications for energy systems, industrial processes, and material supply chains, including a substantial increase in demand for minerals and metals required for renewable energy technologies, electrification, and low-carbon infrastructure. The Paris Agreement therefore amplifies the strategic importance of mineral resources, particularly those deemed “critical” for the energy transition. At the same time, it reinforces the need for transparent, consistent and sustainability-oriented frameworks to assess, monitor and manage these resources throughout their life cycle, from exploration to production, recycling and closure.

At regional level, the European Union (EU) has translated these global commitments into a comprehensive policy framework through the European Green Deal. Launched in 2019, the Green Deal represents the EU’s growth strategy to transform Europe into a modern, resource-efficient and competitive economy, while ensuring a just and inclusive transition (European Commission, 2019). It commits the EU to achieving climate neutrality by 2050, a target made legally binding through the European Climate Law, and to reducing greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels (European Commission, 2021). Beyond climate mitigation, the European Green Deal explicitly addresses resource efficiency, circular economy principles, industrial resilience and strategic autonomy. It recognizes that the green and digital transitions will significantly increase Europe's demand for certain raw materials, many of which are currently sourced from outside the EU and are subject to supply risks. As a result, sustainable access to raw materials, improved resource efficiency, and enhanced recycling and recovery of secondary resources have become central policy priorities.

Taken together, the Agenda 2030, the Paris Agreement, and the European Green Deal form a coherent, multi-level sustainability architecture. Agenda 2030 provides the overarching normative vision, the Paris Agreement defines the climate boundary conditions, and the European Green Deal operationalizes these commitments within a concrete regulatory and economic framework. Their interconnection highlights a critical governance challenge formed on the necessity for the transition to a low-carbon, resource-efficient, and circular economy.

Within these frameworks, the sustainable governance of raw material resources emerges as both an enabler of the development and a potential source of environmental and social risk if not properly managed (Figure I).

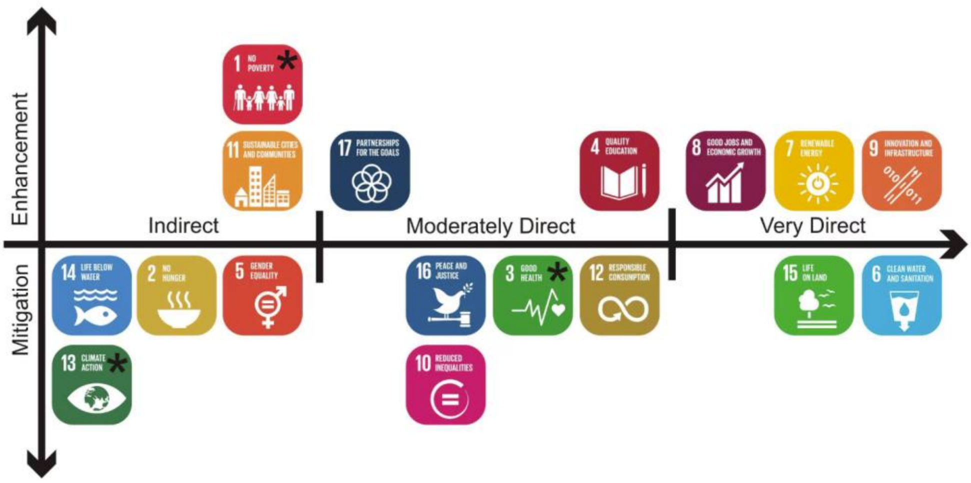

Figure I: The correlation of raw materials and the SDGs (World Economic Forum, 2015)

The global commitment to sustainable development has profoundly altered the context in which minerals are extracted, managed and utilized. As articulated in Agenda 2030 and reinforced by international climate commitments, minerals extraction is no longer assessed solely through its economic contribution, but increasingly through its environmental footprint, social acceptability and long-term contribution to societal prosperity (United Nations, 2015; UNFCCC, 2015). In this evolving frame, the mining sector is witnessing a structural transition, shaped extensively by geopolitical dynamics, trades and restrictions, and emerging supply risks. Sustainable development in mining entails the responsible management of mineral products across their entire life cycle, from exploration and extraction to closure and post-closure rehabilitation. This requires therefore the systematic integration of environmental protection, social welfare, and economic viability, to ensure that mineral extraction contributes to development without compromising the needs of future generations (OECD, 2019).

Besides lucrative, relatively low-risk minerals such as gold, the global energy transition constitutes one of the most significant drivers reshaping mineral demand patterns (S&P Global Market Intelligence, 2024). The deployment of renewable energy technologies, electrification of transport systems, and expansion of energy storage infrastructure, are inherently material- and metal-intensive processes. Scenarios aligned with limiting global temperature increase to 1.5°C indicate an unprecedented scale-up of low-carbon infrastructure, including tens of thousands of gigawatts of renewable power capacity and the electrification of the vast majority of road transport by mid-century (IRENA, 2023). While historically the bulk of mineral demand was linked to construction, manufacturing and traditional industrial uses, the energy transition is progressively altering both the composition and magnitude of demand. This shift is already manifesting in supply–demand mismatches for certain materials, driven by rapidly expanding deployment rates, long project lead times, and constrained upstream investment (IRENA, 2023). Against this, the surge in attention to minerals is very much observed with recent geopolitical developments.

In parallel, a further and increasingly prominent dimension driving raw materials demand relates to the defense sector (Girardi et al., 2023). The current geopolitical landscape has brought renewed attention to mineral use in military systems. Aerospace technologies, combat machineries, communication equipment, satellites, and navigation systems rely heavily on a wide range of minerals (Pavel and Tzimas, 2016). This reliance of defense technologies on minerals has led governments to prioritize the security and resilience of their supply chains (Girardi et al., 2023). In this context, raw materials are treated not only as economic commodities but also as strategic ones, where their availability is of utmost necessity under conditions of heightened geopolitical tension.

Nowadays, securing mineral supply is more strategic than finding the next oil and gas reservoir. To quote President von der Leyen "*Lithium and rare earths will soon be more important than oil and gas*" (European Commission, 2022). The escalating trade tensions between China and the United States have led to the use of export restrictions on minerals and related technologies as policy instruments. In 2025, China imposed tighter export controls on several minerals and processing technologies, including rare earth elements (REEs) and associated metals, widely interpreted as a response to U.S. tariffs and technology restrictions (AP News, 2025). At the same time, mineral resources have become embedded in broader geopolitical negotiations and post-conflict strategies. In 2025, the United States and Ukraine advanced a framework agreement on cooperation in mineral development, linking access to mineral resources with reconstruction financing and long-term economic partnership (Reuters, 2025). On the same note, mineral supply chains are strongly influenced by geographical concentration at different stages, including extraction, processing and refining. A limited number of countries dominate the production and export of several minerals, while downstream manufacturing and consumption are often located elsewhere (USGS, 2023; JRC, 2020). The location of upstream activities is purely dictated by geology, whereas downstream by the market. This reaffirms that the spatial distribution of minerals does increase geopolitical tensions, trade restrictions and regulatory divergence, rendering their supply at high risks even in the absence of physical scarcity. Recent studies highlight that concerns surrounding mineral supply are not primarily driven by geological limitations, as global reserves of most energy transition minerals are considered sufficient at the aggregate level (IRENA, 2023). Instead, constraints arise from limited mining and refining capacity, long permitting timelines, environmental and social opposition, and underinvestment in upstream activities. In the short to medium term, these factors may lead to market tightness and price volatility, with cascading effects across industrial value chains (BloombergNEF, 2023).

On the other hand, and unlike fossil fuels, whose continuous supply is essential for uninterrupted energy provision, minerals used in low-carbon technologies exhibit fundamentally different risk profiles. Once installed, renewable energy systems can operate for decades without requiring continuous material inputs. Consequently, disruptions in mineral supply pose a greater risk to the pace of the energy transition rather than to immediate energy security (IRENA, 2023). This distinction is crucial for policy design, as it shifts attention from short-term supply shocks to long-term planning, diversification and resilience (Figure II). Moreover, equating future mineral dependencies with historical fossil fuel dependencies risks oversimplification. Mineral supply chains differ significantly in terms of trade patterns, stockpiling potential, recyclability and substitution opportunities. These characteristics suggest that dependency risks must be assessed through a nuanced, context-specific lens rather than through direct analogy with energy commodities (IRENA, 2023).

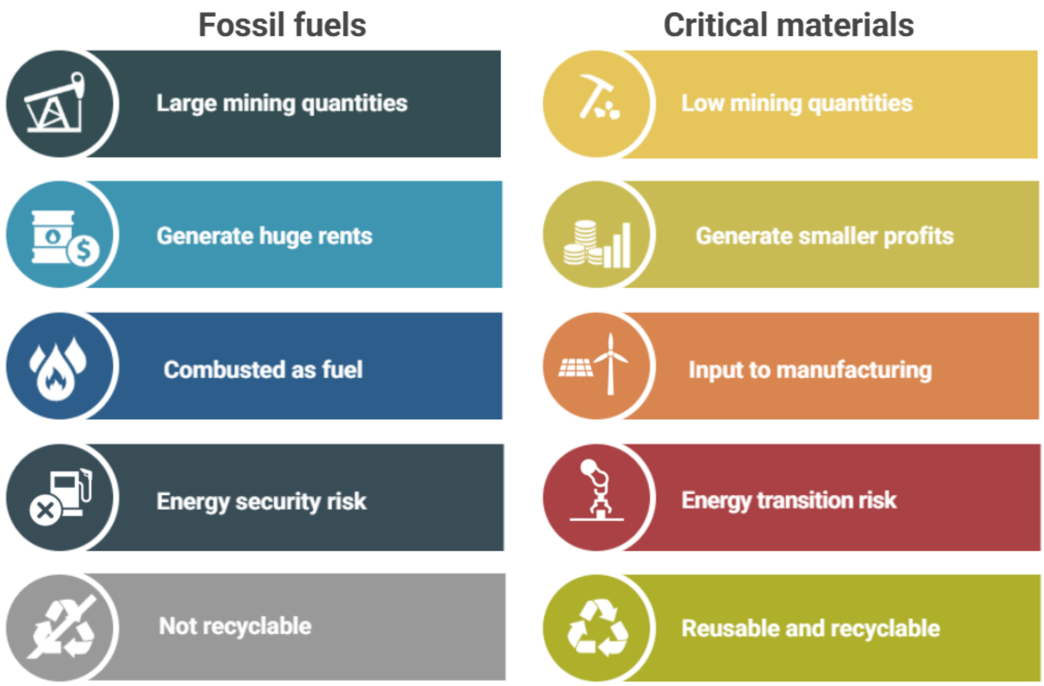

Figure II: Fundamental differences between fossil fuels and critical minerals (IRENA, 2023)

The evolving geopolitical landscape has also revealed limitations in existing approaches to assessing supply risks. Comparative analyses of national and regional raw material lists demonstrate that assessment criteria are often shaped by local industrial structures, policy priorities and geopolitical perspectives, resulting in heterogeneous and sometimes inconsistent outcomes (Runganga et al., 2025). This fragmentation complicates international coordination and undermines the comparability of assessments across jurisdictions. Recent literature further emphasizes that emerging markets and producing countries remain underrepresented in global assessment frameworks, despite their central role in mineral supply chains (Runganga et al., 2025). Addressing this imbalance requires governance tools that are transparent, adaptable and applicable across different raw materials development contexts, ones that take into account consistent evaluation of geological knowledge, technical feasibility and environmental-socio-economic conditions.

1.2 Research Scope and Objectives

The growing demand for critical raw materials (CRMs) has fundamentally altered their role in economic security, industrial competitiveness, and sustainability governance. At the European level, the European Critical Raw Materials Act (CRMA) represents a paradigm shift, moving beyond conventional market monitoring towards active coordination across exploration, extraction, processing, recycling, and waste and strategic stock management. However, raw materials data in Europe remain fragmented, heterogeneous, and incomparable across Member States. Without a common classification tool to harmonize EU-wide raw materials information, this challenge risks hindering the effectiveness of CRMA, and ultimately the EU's strategic autonomy objectives. Within this broader European landscape, Italy, similar to many other EU Member States, offers a notably common case of decentralized raw materials data, without a binding national classification and reporting system in place. Italy has a strong manufacturing industry and therefore requires uninterrupted supply of CRMs. To this matter, safeguarding CRMs becomes imperative to maintain industrial competitiveness. To this end, Italy initiated action through regulatory reforms to tackle this matter and deliver on the CRMA objectives, notably through Decree-Law No. 84/2024. Yet, work is still in progress. Therefore, throughout this dissertation, Italy has been selected as the testing field for exploring how consistent, coherent, and robust classification of raw materials across the whole supply chain can support the principles of sustainable resource management, secure supply of CRMs, and achieve the objectives of CRMA. In this dissertation, the gap between the policy mandate for harmonized raw materials classification and the practical absence of operational frameworks for implementing that mandate at national and EU levels, is addressed. This dissertation is concerned with how UNFC can convert data into knowledge, and how that knowledge can be structured to support decision-making. The work targets mainly primary raw materials, though secondary raw materials are considered as in the context of extractive waste and other provisions related to recycling projects.

The central premise of this dissertation revolves around the notion that sustainable resource management begins with mapping and classifying raw materials in a consistent and robust manner, while factoring in environmental, social, and governance considerations associated with their development. The United Nations Framework Classification for Resources (UNFC) is a classification tool that incorporates these aspects, within the broader frame of sustainable resource management. UNFC is a globally applicable, principles-based classification tool that enables consistent, coherent, and robust communication on energy and resource projects across all stakeholders (UNECE, 2020). This framework allows complex project information to be presented in a clear, comparable, and transparent way, and in return, support informed decision-making regarding energy or resource projects. Furthermore, UNFC is applicable to all sorts of raw materials projects, from exploration to extraction, processing, and recycling, while remaining compatible with international and national classification codes through bridging mechanisms. These features allow cross-resource and cross-country data comparison. As such, interoperability of data across various jurisdictions, and at any segment of the supply chain, becomes possible with UNFC, without replacing existing standards (UNECE, 2020). Pinned against this premise, this dissertation positions UNFC as the structural bridge between geological knowledge and raw materials intelligence, project development, sustainability constraints, and policy objectives.

With its entry to force, CRMA is considered as the catalyst for this research, one that established the need for harmonized and quality reporting in UNFC at EU levels, and across the whole CRMs supply chain. Therefore, the research covers the application of UNFC across all its provisions in CRMA. It first addresses the role of UNFC in the context of Strategic Projects, through structured methodologies designed to serve three distinct but interrelated user groups: project promoters, UNFC expert evaluators, and policymakers at European Union level. The research extends the application of UNFC to National Exploration Programmes, particularly with a tailored methodology for applying UNFC to their results, as early-stage projects characterized by high uncertainty and limited data. Beyond primary raw materials, the research also addresses the growing importance of secondary raw materials, particularly the application of UNFC to extractive waste, in the context of CRMA's national circularity measures. It is to be noted that the application of UNFC to end-of-life waste is explored through the proposed methodologies for recycling projects, under Strategic Projects and for monitoring purposes. Additionally, the dissertation further proposes a UNFC-based monitoring framework aligned with the risk monitoring and mitigation provisions as per

CRMA. A national monitoring template tailored to the European context is also proposed, to illustrate how UNFC can be embedded within administrative and reporting processes to support proactive risk mitigation. Accordingly, the overarching objective of this research is to contribute to the application of UNFC in support of sustainable resource management, through full alignment with the objectives and requirements of CRMA. The scope of the work takes Italy as a case study to test and illustrate the developed methodologies. The approaches for integrating UNFC into national raw materials management, are developed to be transferable and relevant to other EU Member States facing similar institutional and data challenges.

The core research question that fueled this dissertation is: ***How can UNFC support the EU in transforming CRMs data into structured knowledge and actionable intelligence for the classification, monitoring, and the overarching sustainable management of CRMs projects, while remaining in compliance with CRMA?*** To address this question, the dissertation is structured around the following interrelated research questions:

1. **How can European raw materials projects be classified using UNFC across the whole supply chain, in a manner consistent with the provisions of CRMA?**

2. **How can a UNFC-based national inventory of raw materials be developed for Italy?**

3. **How can UNFC be used as a dynamic monitoring tool for critical raw materials nationally and regionally?**

This dissertation aims to position UNFC not merely as a technical reporting tool, but as a strategic policy instrument, linking classification with decision-making. The research contributes to ongoing literature around advancing applied resource classification principles within a real-world regulatory context, and to policy practice with concrete pathways for integrating UNFC into current evolving raw materials governance system. Ultimately, this work assists in demonstrating that effective implementation of CRMA depends not only on regulatory acceleration and investment mobilization, but on the availability of consistent, harmonized, transparent, and sustainability-aware knowledge systems.

1.2.1 Methodological Overview

This dissertation adopts a mixture of qualitative and analytical research, combining conceptual analysis, framework development, and applied testing within a real-world example. The methodological frameworks are grounded in resource classification principles and sustainable resource management, with UNFC serving as the central analytical backbone. The research proceeds through three interlinked methodological components.

First, a structured review and synthesis of scientific literature, international frameworks, and policy instruments is undertaken to clarify the conceptual foundations of sustainable resource management, CRMs, and resource classification and estimation (Chapter 2). Particular attention is given to how different strands of literature, ranging from mineral economics and exploration geology to sustainability governance and resource policy, intersect, and to the role that classification tools play in mediating between these domains. This chapter established the theoretical and conceptual basis for positioning UNFC as the integrative framework.

Second, the research developed methodological frameworks for applying UNFC to CRMs projects in a manner consistent with CRMA. The projects cover exploration, extraction, processing, extractive waste, and recycling. More specifically, the research covers Strategic Projects (Chapter 3), National Exploration Programmes and extractive waste (Chapter 4), and risk monitoring and mitigation for extraction, processing, and recycling projects (Chapter 5). This involved translating the principles of UNFC into operational criteria and workflows that can accommodate heterogeneous data availability, varying levels of project maturity and geological confidence, and diverse environmental-socio-economic contexts. Rather than treating UNFC as a static reporting tool, the research explored its application as a dynamic classification and monitoring system, capable of evolving as projects progress along the value chain and as external conditions change.

Third, the developed methodologies are tested on Italian raw materials projects to explore the challenges of fragmented data, decentralized governance, and evolving regulatory frameworks (Chapter 6). Available geological, administrative, and project-level data were analyzed and interpreted through the UNFC lens to assess the feasibility of developing a national-level inventory and monitoring system aligned with CRMA objectives (Chapter 7). This applied component allowed the research to evaluate the strengths, limitations, and practical implications of the proposed approach, while maintaining a focus on methodological transferability to other jurisdictions.

Qualitative validation is used throughout. The classification methodologies are validated through expert review within the UNECE network, cross-referencing with established national UNFC guidance documents, and application to real Strategic Projects data from CRMA's first call. The Italian national inventory is validated against publicly available data and records.

1.2.2 Original Contribution

This doctoral dissertation was conducted partly within an active collaborative research environment involving several organizations. In this context of academic and ethical obligation, Table 1 defines explicitly what constitutes original scholarly contribution versus collaborative, co-produced, or institutionally-derived output. Together, the contributions advance the operationalization of UNFC as a policy-relevant governance tool within an active regulatory setting, extending the framework beyond its established use. The collaborative dimensions of this research are not a limitation but a characteristic of applied research in active policy environments. The original contribution lies in translating, contextualizing, extending, and critically evaluating UNFC within a rigorous academic and empirical framework.

Table 1: Research sections and nature of contribution

Chapter / Section	***Nature of Contribution***	***Credits***
Ch. 3, Sec. 3.2.1 — UNFC Methodology for Project Promoters	Original methodological contribution includes the structured top-down classification workflow, the Key Terms framework, and the linkage to the CRMA Strategic Project Form (published on the UNECE Knowledge Hub).	Developed under the coordination of UNECE colleagues (Slavko Šolar contributed to conceptual and methodological framing and review)
Ch. 3, Sec. 3.2.2 — UNFC Verification Methodology for Expert Evaluators	Original methodological contribution includes the Evaluation Grid, the Key Terms checklist, the decision rules (Balanced Judgment vs. Lowest-Rank Prevails), and the consensus-building protocol (published on the UNECE Knowledge Hub).	Developed under the coordination of UNECE colleagues (Slavko Šolar contributed to conceptual and methodological framing and review)
Ch. 3, Sec. 3.4 — Supply Risk Analysis based on UNFC	Original methodological contribution includes the framework linking UNFC class to supply risk factor and the aggregated risk table.	-
Ch. 3, Sec. 3.5 — Monitoring Model for Strategic Projects	Original methodological contribution includes the three-module Excel-based monitoring template (Project Information, Operational Monitoring, Financial Viability) and the controlling-factor framework for each UNFC axis.	Developed alongside UNECE colleagues, in particular Erika Ingvald
Ch. 4, Sec. 4.3 — Methodology for NEP Classification in UNFC	Contribution to the development of the ICE-SRM EU guidance document "UNFC NEP-R".	Primary authors of the document: Hendrik Falck, Snježana Miletić, and Slavko Šolar
Ch. 4, Sec. 4.5 — UNFC Application to Extractive Waste	The application framework presented is an adaptation of existing GTK (Hokka et al., 2026) and FutuRaM project guidelines to the Italian context. Original contribution involves the contextualization of the methodology for Italy and its alignment with CRMA.	GTK methodology and FutuRaM project outputs adapted; no co-authorship of this chapter section
Ch. 5 — UNFC for Risk Monitoring and Mitigation	Contribution to the development of the UNECE monitoring manual, specific original contributions involves UNFC tables for extraction, processing, and recycling projects, the proposed national template, and the application narratives for each project type.	Co-authored with Erika Ingvald, Victoria Oliver Tenconi, and Minwoo Ki (UNECE), under the supervision of Erika Ingvald
Ch. 6 — Applying UNFC to Italian Raw Materials	Original contribution includes the UNFC template for Italian projects, the Italian decision-trees, and the UNFC National Guidance Template.	The National Guidance Template reviewed under the coordination of UNECE
Ch. 7 — UNFC-based Italian Raw Materials Inventory	Original contribution includes the first application of UNFC to national-scale Italian raw materials, the inventory structure, classification methodology, and analysis.	Published as peer-reviewed paper; co-authors Dr. Solar and Prof. Blengini

Chapter 2

Concepts and Foundations for Raw Materials Management

2.1 Sustainable Resource Management

The accelerating demand for minerals driven by the current environmental-socio-economic development, technological change, and the energy transition, combined with rising geopolitical tensions and supply uncertainties, begs the question on how resources should be managed. In this context, sustainable resource management emerges as the primary governance response to the challenge of meeting growing demand for raw materials without compromising long-term environmental integrity, social equity, or the resource access for future generations. Sustainable resource management is commonly defined as the coordinated management of natural resources in a manner that balances economic viability with environmental protection and social responsibility over time (Ali S. et al., 2017). Recent research further emphasizes that unsustainable human actions such as inefficient extraction, inadequate governance, and delayed rehabilitation, can directly compromise the long-term accessibility of resources, even where geological availability remains abundant (Dewulf J. et al., 2021). In the face of this backdrop, robust information systems and transparent decision-support tools prevail as indispensable for guiding policy and investment toward sustainable outcomes.

2.1.1 Resource Classification and Estimation

A pillar of sustainable resource management is the ability to systematically identify, quantify, and communicate resources information under conditions of uncertainty. Historic frauds and fake cases involving miscommunication, misreporting, and manipulation of resource data, especially in the mining sector, have resulted in drastic financial loss, and reputational consequences e.g., the Bre-X scandal (Ruffell et al., 2012). Resource classification systems play a critical role in this process. Classification can be broadly understood as the structured ordering of objects or phenomena into categories based on defined relationships, enabling consistent inventorying, mapping, and analysis (Kleckner, 1981). Resource classification renders complex information into its simplest form to serve a purpose, policy formulation for instance. In the context of natural resources, classification systems provide the conceptual and operational framework through which geological information, technical feasibility, economic viability, and more recently increasing environmental and social considerations are conveyed to stakeholders. Effective classification systems must therefore adhere to logical principles while remaining flexible, scalable, and usable across different institutional contexts, often combining bottom-up aggregation of site-specific data with top-down subdivision according to policy or planning needs (Kleckner, 1981).

Fundamental to resource classification is the distinction between different types of mineral concentrations and their potential for economic extraction. According to the most common standard definition used globally, a mineral occurrence refers to a concentration of a mineral or a commodity valuable for a stakeholder, or generates scientific or technical interest (Cox and Singer, 1986). A mineral deposit represents a subset of occurrences that exhibit sufficient size and grade such that they may, under favorable conditions, possess economic potential (Cox and Singer, 1986). Within this hierarchy, an ore deposit (or simply ore) is a mineral deposit that has been sufficiently studied and tested to be economically extracted (Cox and Singer, 1986). A mineral resource is generally understood as a concentration of material of economic interest in or on the Earth's crust, for which there are reasonable prospects for eventual economic extraction (USGS, 1980). In contrast, a mineral reserve constitutes the economically extractable part of a mineral resource, derived from specified minimum criteria related to current extraction practices. Reserves include resources that are economic, marginally economic, and sub-economic (USGS, 1980). Categories and sub-categories for both, resources and reserves, have been further subdivided with time by new classification standards (next sub-sections). The conceptual foundation of modern resource classification is often traced to the McKelvey framework, which formalized the relationship between geological certainty and economic feasibility. The McKelvey diagram (Figure III) features mineral occurrences along two principal axes: the degree of geological assurance and the degree of economic feasibility. This dual-axis representation illustrates that mineral resources are not static quantities but evolve dynamically as new geological information becomes available and as economic or technological conditions change. As such, the boundary between resources and reserves is not fixed but contingent upon both knowledge and context (McKelvey, 1972).

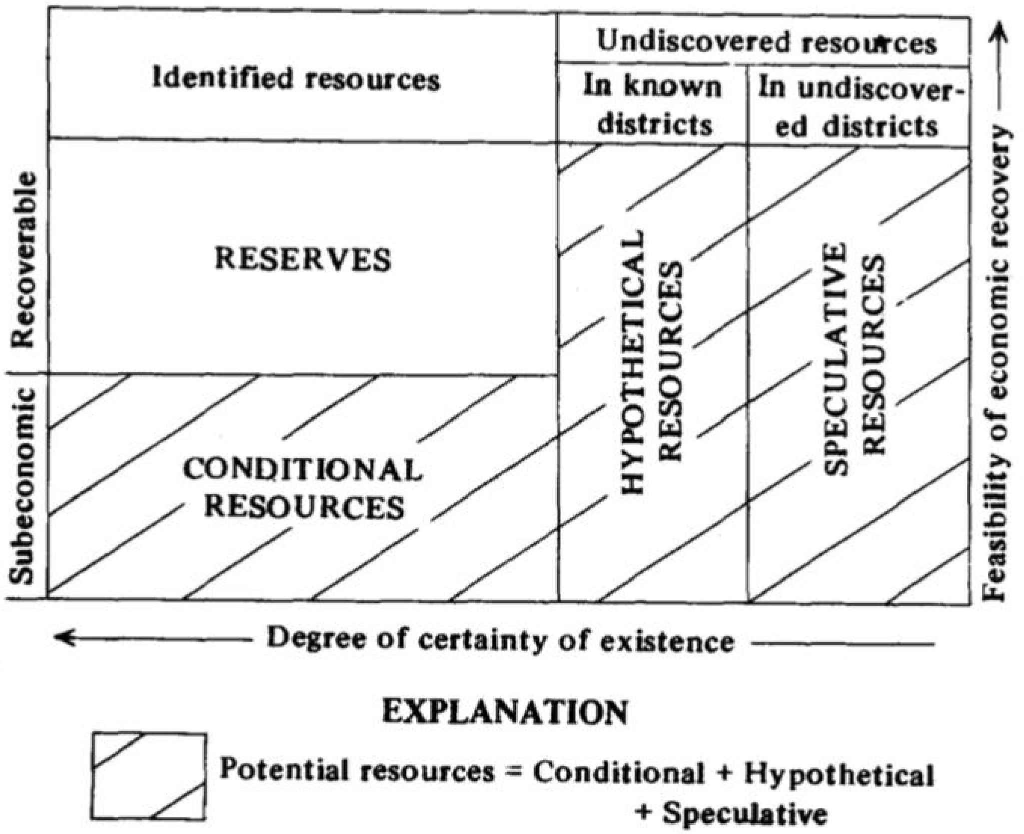

Figure III: The McKelvey Diagram: Classification of mineral resources according to geological certainty and economic feasibility (McKelvey, 1972)

These definitions constitute the fundamentals for resource estimation, an intrinsic and broader field linked to resource classification. Resource estimation reflects and progressively redefines the different stages of geological knowledge, technical feasibility, and economic assessment (USGS, 1980). Resource estimation involves the quantitative evaluation of mineralization in terms of tonnage, grade, and spatial distribution (Glacken and Snowden, 2001). At its core, it is a model-based process that integrates geological interpretation with statistical and geostatistical techniques to generate a three-dimensional representation of a mineralized body (Dominy, 2002). This process relies on the systematic acquisition and integration of multiple data, including from drilling, sampling, assaying, bulk density measurements, and geological mapping, followed by interpolation and estimation procedures to derive grade–tonnage relationships (Glacken and Snowden, 2001). A critical characteristic of mineral resource estimation is the inherent presence of uncertainty, arising from incomplete sampling, geological complexity, and limitations in modelling approaches (Dominy, 2002). Unlike most industrial sectors, mining decisions are based on knowledge of the orebody, and therefore estimation must explicitly account for both systematic and random errors (Dominy, 2002). These uncertainties propagate through subsequent stages of project evaluation, directly influencing mine planning, economic feasibility, and ultimately the conversion of resources into reserves (Lindi et al., 2024). As such, estimation is not a static exercise but an iterative process, continuously refined as new data become available and as geological understanding improves (Dominy, 2002). From a methodological perspective, a robust mineral resource estimate requires the integration of several key components: (i) data acquisition and quality assurance/quality control (QA/QC); (ii) geological and structural interpretation; (iii) construction of a geological and block model; (iv) application of estimation techniques, ranging from classical methods to advanced geostatistical approaches such as kriging; and (v) validation against independent datasets or production data (Coombes, 2016). The selection of estimation technique is particularly critical, as different methods may yield significantly different results depending on the spatial continuity and distribution of grades, thereby influencing the confidence classification of the resource (Coombes, 2016). Importantly, mineral resource estimation provides the quantitative foundation upon which mineral estimation is built. The transition from resources to reserves requires the application of modifying factors, including mining, metallurgical, economic, environmental, legal, and social considerations, which transform a geological estimate into an economically extractable prospect (Lindi et al., 2024).

Within mineral resource management, classification has evolved from a purely geological exercise toward a multidimensional decision-support function. Resource classification is now widely understood as a structured process that assigns potentially recoverable resources to categories reflecting varying degrees of geological confidence, technical maturity, and socio-economic feasibility (McKelvey, 1972; Speirs et al., 2015). This process typically follows a sequence of information collection, quality assurance, evaluation, classification, and reporting, each step explicitly addressing uncertainty and data limitations. It is necessary to note that, while no classification system can eliminate uncertainty owing to geological complexity and uneven data availability, classification remains an indispensable tool for risk-informed decision-making (Speirs et al., 2015; UNECE, 2019).

2.1.2 Committee for Mineral Reserves International Reporting Standards

Progress in mineral resource classification has been accompanied by the development of standardized reporting frameworks aimed at ameliorating mineral information and combatting geologic frauds and fakes through transparency, accountability, and reliability in the reporting. In this regard, the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) has established an international association to develop and promote best practices for exploration results, mineral resources, and mineral reserves. Through an International Reporting Template, CRIRSCO provides a globally recognized reference that serves as the basis for a family of aligned national and regional reporting codes (CRIRSCO, 2024). The primary purpose of CRIRSCO is to provide instructions on the various factors that should be considered when evaluating and reporting mineral estimates, including the size of deposit and mineral content (Sides and Allington, 2024). The set of guidelines serve to prepare public reporting, defined as the disclosure of information and requirements intended for investors, and their professional advisers (CRIRSCO, 2024). The CRIRSCO Template is underpinned by three principles: transparency, materiality, and competence. Transparency requires that information is presented clearly and unambiguously, materiality ensures that all relevant information necessary for informed decision-making is disclosed, and competence requires that reports are prepared and endorsed by suitably qualified professionals, commonly referred to as Competent Persons (CRIRSCO, 2024). A Competent Person is referred to as a minerals industry professional who is a member of a recognized professional organization, possesses a minimum level of relevant experience (typically at least five years), and is subject to enforceable professional codes of ethics and disciplinary procedures (CRIRSCO, 2024). In other words, the Competent Person bears personal responsibility for the accuracy and integrity of the reported estimates.

At the core of the CRIRSCO Template lies a standardized set of terminologies that formalize the classification of mineral resources and mineral reserves, as well as their corresponding sub-categories. A Mineral Resource is defined as "*a concentration or occurrence of material of economic interest in or on the Earth's crust in such form, grade, or quality that there are reasonable prospects for eventual economic extraction*" (CRIRSCO, 2024). Mineral Resources are subdivided into three categories, reflecting increasing levels of geological confidence: Inferred, Indicated, and Measured (CRIRSCO, 2024). An Inferred Mineral Resource is based on limited geological evidence and sampling, and while it implies the presence of mineralization, it carries a low level of confidence in terms of geological continuity. As such, it cannot be used as the basis for detailed mine planning or for conversion into mineral reserves (CRIRSCO, 2024). An Indicated Mineral Resource is supported by more detailed and reliable data, allowing for preliminary mine planning and the application of modifying factors (CRIRSCO, 2024). A Measured Mineral Resource represents the highest level of geological confidence, with sufficient detail to support robust technical and economic evaluations (CRIRSCO, 2024).

The transition from resources to economically extractable quantities is captured through the concept of Mineral Reserves, defined as "*the economically mineable part of a Measured and/or Indicated Mineral Resource*" (CRIRSCO, 2024). This transition requires the application of a comprehensive set of modifying factors, which include mining, metallurgical, economic, marketing, legal, environmental, social, and governmental considerations. Mineral Reserves are subdivided into Probable and Proved categories. A Probable Mineral Reserve is derived primarily from Indicated Mineral Resources, and in some cases from Measured Resources, where there is sufficient confidence to support mine development decisions, albeit with some remaining uncertainties. A Proved Mineral Reserve, on the other hand, is derived from Measured Mineral Resources and represents the highest level of confidence, indicating that the deposit has been comprehensively evaluated and is economically viable under defined conditions (CRIRSCO, 2024). Figure IV shows the hierarchical and progressive relationship between exploration data, mineral resources, and mineral reserves as defined by CRIRSCO standard (CRIRSCO, 2024).

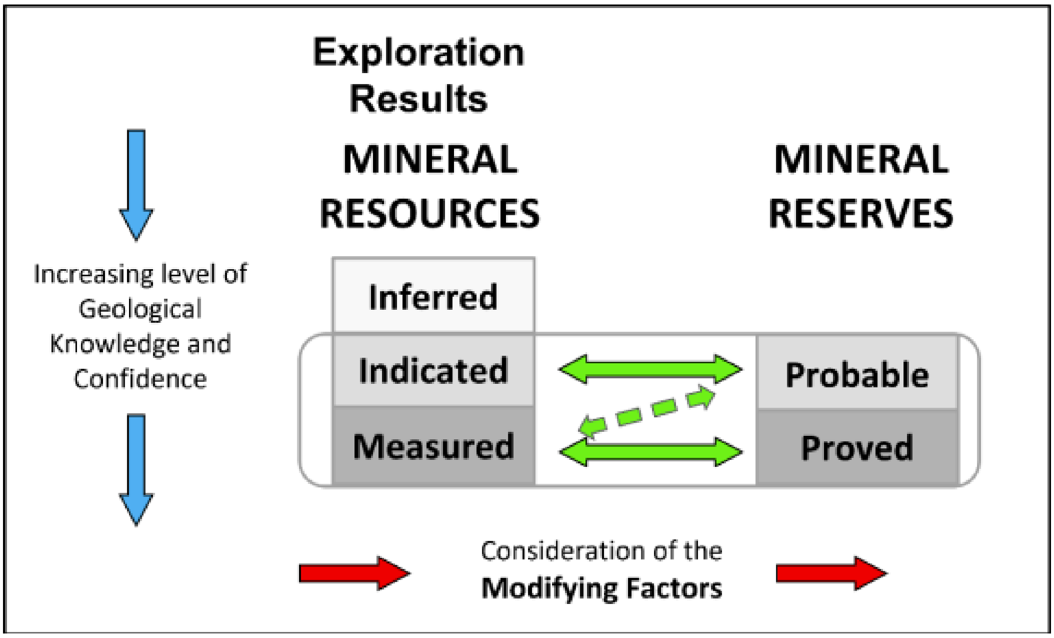

Figure IV: General relationship between Exploration Results, Mineral Resources and Mineral Reserves (CRIRSCO, 2024)

Exploration Results represent preliminary information that is insufficient for resource classification, while Mineral Resources require reasonable prospects for eventual economic extraction, and Mineral Reserves require demonstrated economic viability through at least pre-feasibility or feasibility studies (CRIRSCO, 2024). Importantly, not all Mineral Resources are converted into Mineral Reserves.

The global applicability of the CRIRSCO Template is ensured through a network of National Reporting Organizations, each responsible for implementing CRIRSCO-aligned standards within their respective jurisdictions (Figure V) (Sides and Allington, 2024). Within the European context, the CRIRSCO principles are operationalized through the Pan-European Reserves and Resources Reporting Committee (PERC) standard. The PERC Reporting Standard provides instructions and guidance for the public reporting of exploration results, mineral resources, and mineral reserves across Europe, while remaining consistent with CRIRSCO and accounting for European regulatory, geological, and institutional specificities (PERC, 2021). Importantly, PERC extends the CRIRSCO principles beyond traditional financial reporting to encompass a broader range of disclosures relevant to European stakeholders, including technical documentation, environmental and social considerations, and viability.

Figure V: Equal area map of the world showing CRIRSCO member organizations as at November 2023 (Sides and Allington, 2024)

2.1.3 European Resource Classification and Reporting

In Europe, resource management has historically been governed at national level. This has produced a highly heterogeneous landscape of reporting and classification systems across regulatory frameworks. In many European countries, national mining legislation mandates the reporting of mining-related activities, including small deposits and occurrences, often in parallel with statistical reporting and national mineral yearbooks. These systems are particularly well developed in countries with long mining traditions or those influenced by former centrally planned systems, where assessment and classification were prescribed in detail and reporting to central authorities was mandatory (Figure VI) (Kumelj S. et al., 2019; Bide T. et al., 2019). It is imperative to make the point that absence of national systems for classification and reporting does not implicate that industry does not report at all. Several European projects, in Member States with no legally binding classification codes, report publicly on stock exchange programmes in CRIRSCO-compliant codes, such as the PERC standard, for investment purposes (S&P Global Market Intelligence, 2024). Important to note that a significant influence on national classification systems in Europe, particularly in Central and Eastern European countries such as Croatia and Slovenia, comes from the State Commission for Mineral Reserves system (or GKZ), originally developed in the former Soviet Union. The GKZ system was designed within a centrally planned technical-economic characterization, where mineral resources were considered state assets and their assessment formed the state reserve balance (Rendu and Miskelly, 2001). Essentially, in the GKZ system, mineral concentrations are classified into seven categories based on the degree of geological exploration performed, with explored resource or reserve (A, B, C1), evaluated resource or reserve (C2), and prognostic resource (P1, P2, P3) (Henley, 2004). However, the terminologies and categories vary from one GKZ-based national system to another.

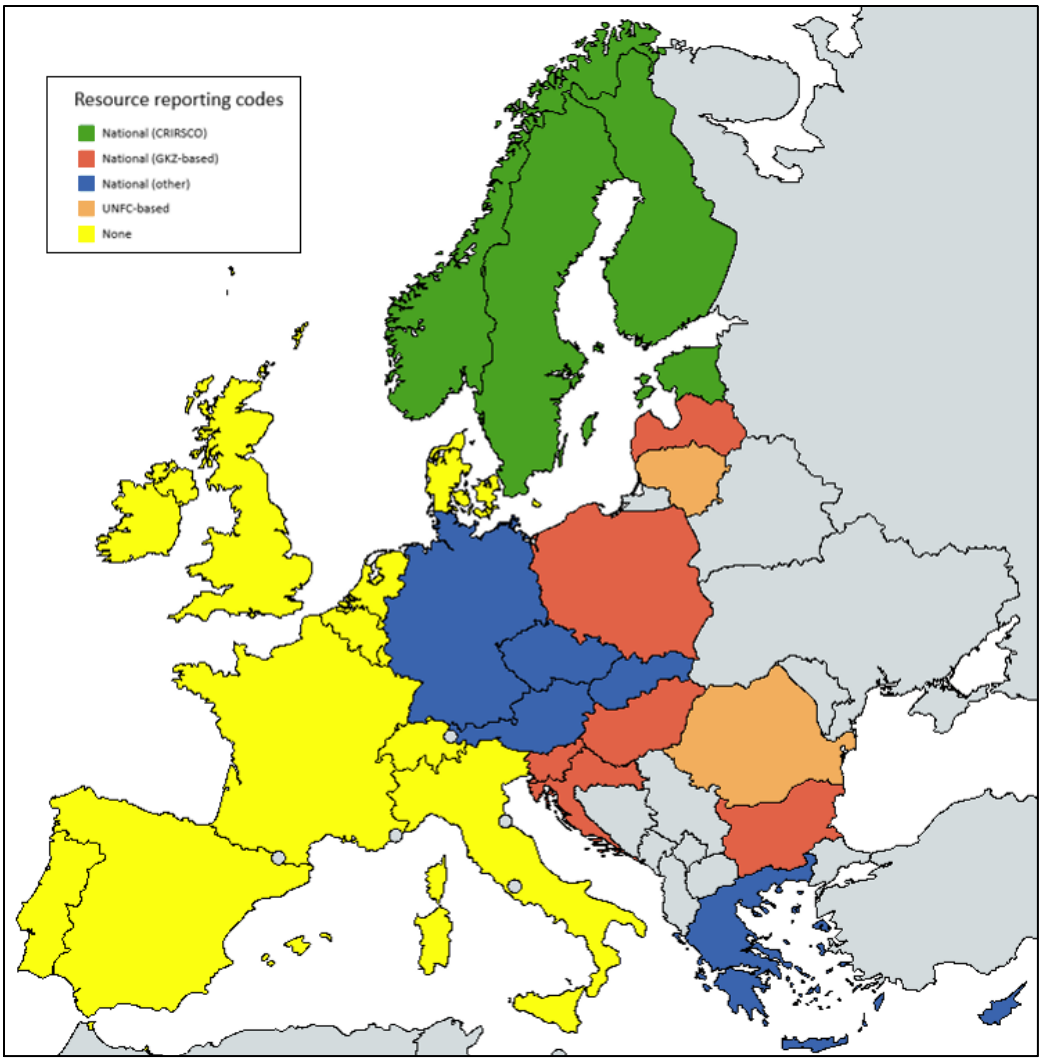

Figure VI: National resource reporting codes in EU countries, according to ORAMA, in 2019 (Modified from Bide T., et al., 2019)

Frequent revisions of national mining laws and reporting standards over recent decades have led to increasing divergence among national classification systems, reducing comparability across borders. Moreover, the growing policy emphasis on sustainability, land-use planning, and environmental protection has further expanded the range of stakeholders requiring access to mineral resource information. Resource classifiers are no longer concerned solely with recovery potential, but also with environmental impacts, social acceptance, remediation liabilities, and land uses. This shift has exposed the limitations of single-purpose or commodity-specific classification systems and reinforced the need for integrated, environmentally sound approaches capable of supporting multiple-use mandates (UNECE, 2019).

At EU level, the absence of harmonized, aggregated resource figures classified under a common system remains a significant challenge. Studies conducted under the EU-funded “Minventory” and “ORAMA” projects demonstrated that no unified classification framework exists in national minerals inventories across EU Member States, limiting comparability, transparency, and strategic planning (Kumelj S. et al., 2019; Bide T. et al., 2019). However, with acknowledgement to recent EU-wide regulations, this landscape is modifying towards a unified system across all Member States. As the situation currently stands, EU countries can be broadly grouped according to whether they rely on international reporting standards, legacy national systems, or incoherent and fragmented data collection practices. It is noteworthy to mention that these differences affect data availability, scale, update frequency, and the extent to which national datasets can be harmonized at European scale. Thus, the lack of uniform resource classification has implications that extend beyond commercial reporting. Harmonized classification would not only support investment decisions, but also provide indicative estimates of short- and long-term resource accessibility, informing EU-level initiatives on strategic autonomy, industrial policy, and sustainability transitions (European Commission, 2022). Recognizing this, European policymakers have increasingly called for coordinated action to improve the consistency and quality of raw material data across Member States, while preserving national competencies (Breton, 2022). In this evolving governance landscape, internationally recognized classification systems capable of integrating geological, technical, economic, environmental, and social dimensions are needed to offer a pathway toward more coherent and sustainable resource management across Europe. As a result, the growing complexity of mineral supply chains coupled with accelerating demand driven by technological change and the energy transition, the question on what minerals are predominantly of economic concern to a strategic policy remains an issue.

2.2 Critical Raw Materials

As discussed in the previous section, sustainable resource management requires not only robust classification systems but also an understanding of which raw materials warrant particular policy attention due to their economic relevance and vulnerability to supply disruption. It is within this context that the concept of *critical raw materials* has emerged as a central screening exercise, linking availability, industrial dependency, and geopolitical risk within an integrated framework fit for policy making. It is imperative to make one thing clear for the sake of this thesis, that in the terminology for critical elements can be labeled as minerals or raw materials, depending on geographic settings. In global policy and scientific discourse, *critical minerals* are typically defined as non-fuel mineral resources that are essential to the economy and whose supply chains are vulnerable to disruption. Over the recent decades, this concept has evolved to reflect the increasing geopolitical, technological, and environmental (as well as social in some cases) factors. Definitions vary slightly across geographies and jurisdictions. For instance, the European Union defines CRMs as those "*of high economic importance and high supply risk*", especially those vital for the green and digital transitions (European Commission, 2023), whereas the United States of America considers critical minerals as "*essential to the economic or national security of the U.S. and which have a supply chain vulnerable to disruption*" (USGS, 2025). To put it plainly, critical minerals or raw materials should be viewed not as commodities, rather as special material products that are tailored to tight consumer specifications (Pickles S., 2023). Throughout this thesis, the selected term to describe these materials is "critical raw materials" or CRMs, as to remain aligned with the EU terminology. Despite differing lists, global frameworks tend to prioritize minerals needed for clean energy technologies (e.g. lithium, cobalt, REEs), high-tech industries (e.g. gallium, germanium), and national defense.

Though, what makes raw materials "critical"? In an increasingly raw material-constrained world, criticality assessments have become essential instruments for addressing challenges related to supply security, industrial resilience, and the energy transition. Raw materials considered "critical" are typically those that combine high economic importance with a high risk of supply disruption, making them indispensable to key industrial value chains while simultaneously vulnerable to external shocks (Helbig et al., 2021). These materials constitute fundamental inputs for a wide range of low-carbon, digital, and advanced manufacturing technologies, positioning them as enabling factors for sustainable development trajectories. Criticality assessments are designed to identify and prioritize such materials by evaluating multiple dimensions of risk and importance. However, these assessments are not standardized globally. Differences in geographical scope, policy objectives, industrial structure, and data availability have led to a diversity of methodologies and outcomes across regions (Schrijvers et al., 2019; Helbig et al., 2021). As a result, what is considered "critical" in one jurisdiction may not be classified as such in another, reflecting the inherently contextual nature of criticality. Despite this variability, criticality assessments play a pivotal role in informing policy and investment decisions. They enable governments and industry stakeholders to better understand supply chain vulnerabilities, anticipate potential disruptions, and design targeted measures to enhance resilience. In this sense, criticality assessments serve as an entry point for broader strategies encompassing exploration, extraction, trade, recycling, substitution, and international cooperation (Grohol and Veeh, 2023). At their core, criticality assessments function as screening tools that support strategic resource governance. By identifying materials that exceed predefined thresholds of economic importance and supply risk, these assessments guide policy prioritization and resource allocation. They underpin the formulation of mineral strategies, inform research and innovation agendas, and support industrial planning aligned with sustainability objectives (Schrijvers et al., 2019). While indicators vary across methodologies, several dimensions recur across most criticality frameworks. Economic importance is widely used to capture the role of a material in value creation, employment, and industrial activity, often assessed through sectoral dependence and market value. Supply risk evaluates the likelihood of disruption, considering factors such as production concentration, import dependency, governance conditions in producing countries, and substitutability (Grohol and Veeh, 2023). Environmental considerations are increasingly incorporated to account for impacts related to extraction, processing, and waste generation, thereby linking criticality with sustainable resource management (Schrijvers et al., 2019). In some assessments, technological importance is also considered, reflecting the role of specific materials in enabling key technologies.

Globally, criticality assessments have been adopted by major economies, each reflecting distinct policy priorities. In the United States, the National Research Council and the U.S. Geological Survey have developed frameworks focusing on economic importance, supply risk, and national security considerations (Nassar and Fortier, 2021). Japan’s assessments emphasize supply–demand risks, recycling constraints, and substitution potential to support strategic industrial planning (Hatayama and Tahara, 2015). Canada, Australia, China, and the United Kingdom have similarly tailored methodologies aligned with their economic structures, resource endowment, and geopolitical positioning (Schrijvers et al., 2019; Hackenhaar et al., 2022; Geoscience Australia, 2023; Natural Resources Canada, 2022). Despite methodological differences, these assessments consistently identify a group of materials that recur across jurisdictions, including rare earth elements, lithium, cobalt, platinum group metals, and tungsten. Their repeated appearance reflects shared technological dependencies and reinforces the global nature of resource challenges.

Within the EU, criticality assessments have been conducted regularly by the European Commission since 2010, reflecting growing concern over the Union’s high dependency on imported raw materials and the concentration of supply in a limited number of countries. The EU methodology evaluates raw materials based on two main dimensions: economic importance and supply risk, while also accounting for factors such as substitution potential, recycling rates, governance performance of supplier countries, and trade restrictions (Figure VII) (Schrijvers et al., 2019; European Commission, 2023). The most recent *Study on the Critical Raw Materials for the EU* (European Commission, 2023) highlights a continued increase in the number of raw materials considered critical, reflecting both evolving industrial needs and heightened geopolitical uncertainty. In addition to CRMs, the 2023 assessment has introduced Strategic Raw Materials (SRMs), which constitute a subset of CRMs selected for their strategic importance to the EU's long-term supply chain resilience and security (Figure VIII). Introduced formally through CRMA, SRMs are defined not only by their high supply risk and economic importance, but also by their role in enabling key value chains, including the green and digital transitions, defense, and space (European Commission, 2023). Accordingly, SRMs are evaluated based on demand forecasts and their significance for key strategic sectors such as renewable energy, digital technologies, aerospace, and defense (Carrara, S., et al., 2023). This assessment also considers expected demand growth compared to current supply levels, as well as the challenges involved in expanding production. As a result, the forward-looking assessment of SRMs was carried out to identify bottlenecks, pinpoint the segments of supply chains that require strengthening, and determine how improvements can be made (Carrara, S., et al., 2023). The first list of SRMs includes 17 raw materials (Figure VIII) (European Commission, 2023).

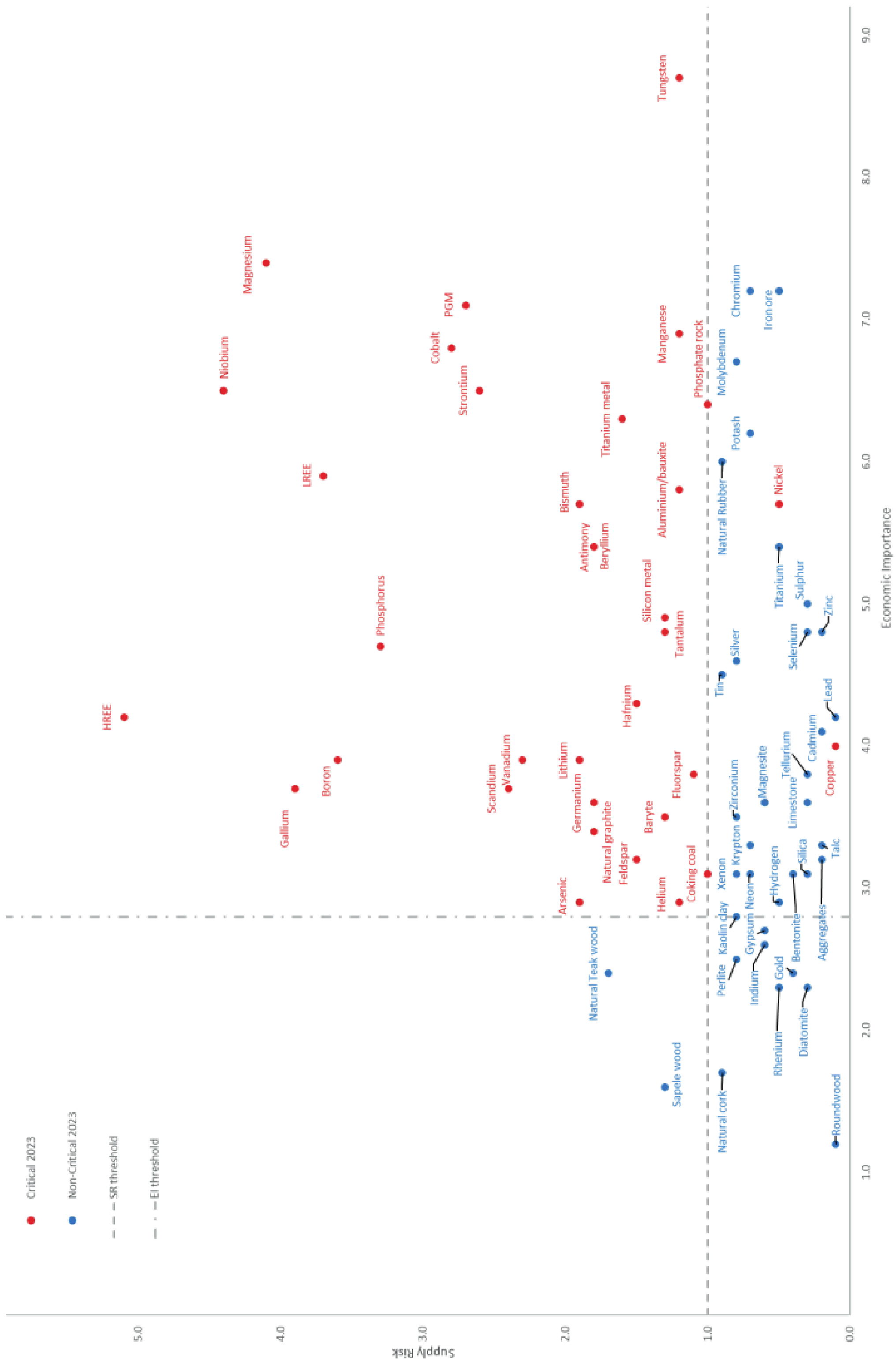

Figure VII: 2023 EU criticality assessment results (European Commission, 2023)

2023 Critical Raw Materials (*new CRMs in italics)*			
aluminium/bauxite	coking coal	lithium	phosphorus
antimony	*feldspar*	LREE	scandium
arsenic	fluorspar	magnesium	silicon metal
baryte	gallium	*manganese*	strontium
beryllium	germanium	natural graphite	tantalum
bismuth	hafnium	niobium	titanium metal
boron/borate	*helium*	PGM	tungsten
cobalt	HREE	phosphate rock	vanadium
		*copper**	*nickel**

2023 Critical Raw Materials (*Strategic Raw Materials in italics)*			
aluminium/bauxite	coking coal	*lithium*	phosphorus
antimony	feldspar	*LREE*	scandium
arsenic	fluorspar	*magnesium*	*silicon metal*
baryte	*gallium*	*manganese*	strontium
beryllium	*germanium*	*natural graphite*	tantalum
bismuth	hafnium	niobium	*titanium metal*
boron/borate	helium	*PGM*	*tungsten*
cobalt	*HREE*	phosphate rock	vanadium
		*copper**	*nickel**

* Copper and nickel do not meet the CRM thresholds, but are included as Strategic Raw Materials.

Figure VIII: List of the 2023 EU CRMs (European Commission, 2023)

The EU's criticality assessment underscores that the EU remains heavily dependent on imports for many of these materials, often sourcing them from highly concentrated global supply chains (Figure IX). This dependency amplifies exposure to external risks, trade disruptions, and policy decisions in producing countries, reinforcing the strategic relevance of domestic resource knowledge and supply diversification.

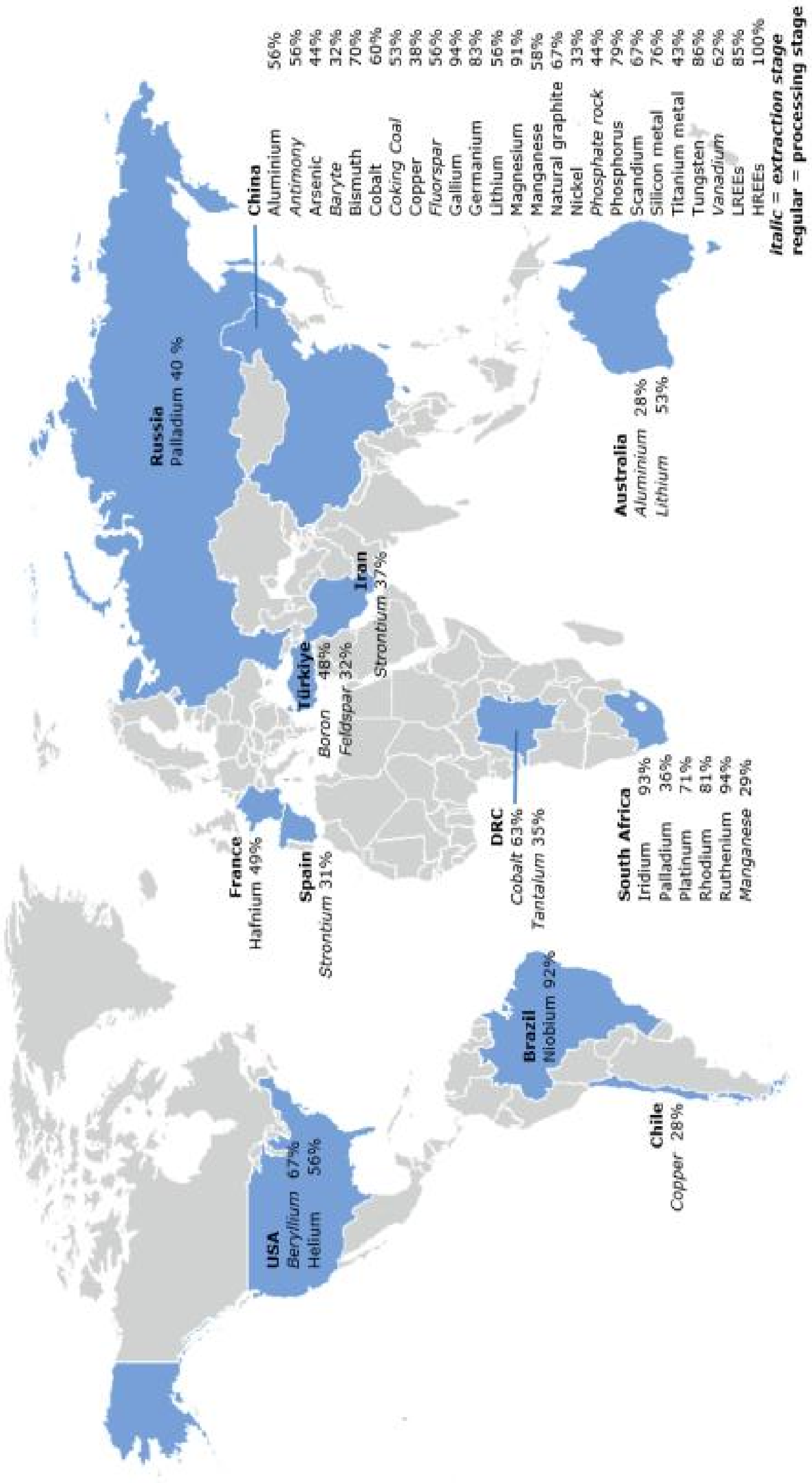

Figure IX: Global share of CRMs supply (European Commission, 2023)

Importantly, the EU's criticality framework shows structural challenges in raw materials governance, notably the lack of harmonized and comparable data across Member States. While criticality assessments operate at EU scale, their effectiveness ultimately depends on the quality and consistency of national-level data on raw materials, projects, and production. This reinforces the need for standardized classification systems capable of feeding reliable information into EU-wide assessments and monitoring mechanisms.

While criticality assessments are valuable for identifying vulnerabilities, their effectiveness is constrained by data gaps, methodological opacity, and limited integration with resource classification and monitoring systems (Table 2). Greater transparency and consistency in criticality methodologies are necessary to support interpretation and policy action (Helbig et al., 2021). Moreover, criticality is inherently dynamic, evolving with technological change, market conditions, and geopolitical developments. This underscores the need for governance frameworks that move beyond static lists toward adaptive systems capable of tracking resource availability, project maturity, and supply chain risks over time. In this context, linking criticality assessments with harmonized resource classification systems offers a pathway toward more robust and actionable resource governance. Such integration is particularly relevant for the EU, where strategic objectives increasingly depend on the alignment of national resource management practices with EU-wide policy goals.

Table 2: Common CRMs identified across most Criticality Assessments

Mineral / Mineral Group	***Key Applications***
Rare Earth Elements (REEs)	Electronics, wind turbines, electric vehicles, defense technologies
Lithium	Rechargeable batteries, electric vehicles, energy storage
Cobalt	Lithium-ion batteries, electronics
Platinum Group Metals (PGMs)	Catalytic converters, hydrogen technologies
Tungsten	Defense, industrial tools, machinery, high-temperature applications

2.3 United Nations Framework Classification for Resources

The accelerating pursuit of achieving sustainable development, defined by global agendas such as the 2030 Agenda for Sustainable Development, has fundamentally reshaped expectations of how natural resources should be produced, managed, and utilized. As demand for minerals intensifies, driven by population growth, rising living standards, and most specifically the rapid deployment of green and digital technologies, the mining and extractive sectors are increasingly positioned not merely as suppliers of raw materials, but as enablers of global sustainability objectives (United Nations, 2015). This shift is particularly evident for CRMs, which remain indispensable for renewable energy systems, electrification, digital infrastructure, and strategic industries, yet often associated with environmental degradation, social conflict, and geopolitical vulnerability. In this context, sustainable resource management becomes the solution for reconciling the growing demand of CRMs to support the green and digital transition, while remaining aligned with environmental protection, social prosperity, and long-term economic resilience. However, and crucially, sustainable resource management cannot occur in the absence of consistent, transparent, and decision-useful information on resource viability, availability, project maturity, and associated risks. Before resources can be managed, financed, or regulated, they must first be systematically classified. It is at this foundational stage, where knowledge, uncertainty, feasibility, and sustainability intersect. Policy makers, project managers, and all relevant stakeholders require complex information made and classified in a simple, understandable, and robust form for decision making. In that, UNFC serves a central role. In simple words, UNFC transforms information into knowledge.

UNFC is an internationally recognized, principles-based system for the classification, management, and reporting of energy and resource projects. Developed and maintained by the Expert Group on Resource Management (EGRM) of the United Nations Economic Commission for Europe (UNECE) and endorsed for global use by the United Nations Economic and Social Council (ECOSOC), UNFC provides a common language through which governments, industry, investors, and international organizations can communicate about resource projects in a consistent and comparable manner (UNECE, 2019; ECOSOC, 2021). Unlike traditional reporting tools that focus primarily on geological confidence or economic aspects, UNFC adopts a holistic perspective, integrating technical, economic, environmental, and social dimensions of resource development. It applies across a wide spectrum of energy and resource projects, including minerals, petroleum, renewable energy, and anthropogenic resources, making it uniquely suited to address the complex and interconnected challenges of modern resource management.

UNFC is used to classify projects, including all energy and resource projects, based on principles that act as a baseline for a correct and standardized application of UNFC. This classification scheme is built on three fundamental criteria of the *environmental-socio-economic viability (E axis)* and *technical feasibility (F axis)* of projects, as well as the *degree of confidence* in the estimates *(G axis)*. The criteria put forth by UNFC, allow stakeholders to receive a full set of information regarding the project's "*How is it done or will it be done*", "*What is done or can be done*", and "*What is it after and how much does it have*". The classification of projects in UNFC is therefore the combination of these three criteria, plotted on a three-dimensional scheme using a numerical coding system, that are factored in and interconnected to determine a Class defined by a level of viability. The entire system is thus further defined with the Categories and Sub-Categories for each of the axes for a granular and comprehensive framework. The combined group of Categories and Sub-Categories lead to determining the particular Class (e.g., Viable, Potentially viable, Non-viable, Prospective) and Sub-Class (e.g., On Production) of the project (Figure X).

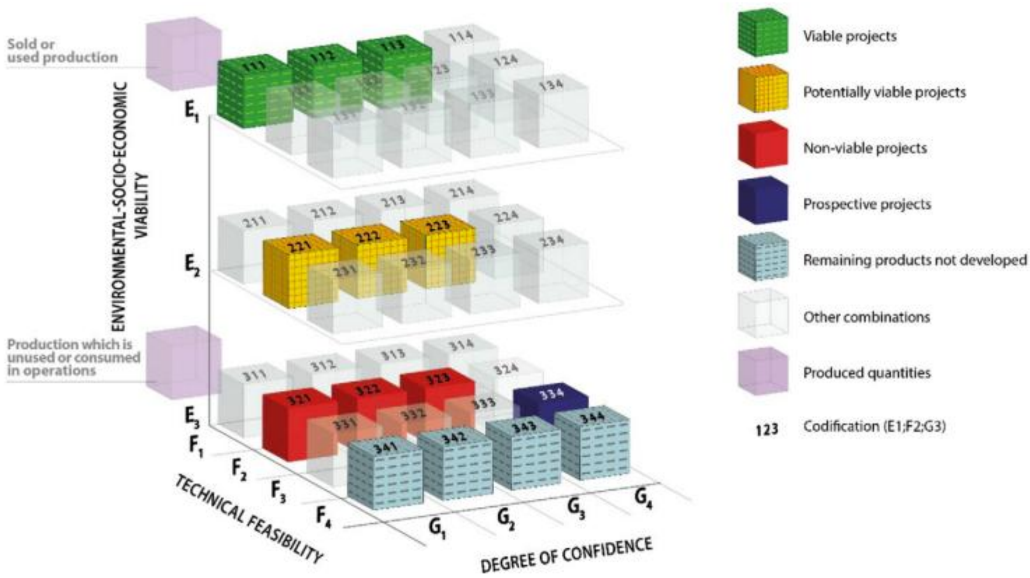

Figure X: 3D representation of UNFC (2019) Classes (UNECE, 2020)

At the core of UNFC lies a three-dimensional classification system, structured around the E, F, and G axes, which together capture the full maturity and sustainability profile of a resource project.

- **E axis:** The environmental-socio-economic viability. "Viability" in this context is defined as the possibilities of and practices followed by the project to operate sustainably. This axis reflects the project's condition in terms of economic factors, social considerations, and environmental measures such as permitting status, regulatory and legal commitments, contractual conditions, social acceptance, environmental impact assessment, etc. Put plainly, the E axis addresses the question pertaining to how the project is producing or will be developed for production from the environmental, social, and economic perspectives.

- **F axis:** The technical feasibility. "Feasibility" in this context is defined as the likelihood of a project to operate technically. This set of categories are indicative of the technical maturity of the project in terms of technical readiness to produce. Aspects factored into this axis include feasibility studies, operational plans, method and technology, and development and infrastructure. In simple terms, the F axis looks into what can be done or what is being done to produce, market the resource with what exists in technical terms. This also goes within the lines of the willingness to investment, posing the question of "Is it worthwhile investing in the project's technical solution?".

- **G axis:** The degree of confidence. "Degree of Confidence" in this context is synonym to "How sure is the project of the resource quantity and quality before it is turned into a product?". This axis is designated to the level of knowledge in product estimates, reflecting the confidence in the range of quantities for current or future production, depending on the project status. The estimation can be determined with high, moderate, or low levels of confidence, depending on the extent of studies and investigation done. The G axis relates to what resource the project has or is after i.e., the degree of confidence in quantity and quality estimates of the targeted resource, answering the inquiry on what does the project have and the level of knowledge on the resource to estimate the quantity and quality. This axis is fundamental as it underpins the requisite resource for any operational endeavor.

Together, these axes are combined into "Classes" and "Sub-Classes", using a standardized numerical coding system that allows projects to be consistently positioned within a three-dimensional "UNFC cube" (UNECE, 2020). The "Categories" and "Sub-categories" are the building blocks of the system, and are combined in the form of "Classes". A "Class" is uniquely defined by selecting from each of the three criteria a particular combination of a "Category" or a "Sub-category" (or groups of Categories/Sub-categories). Since the codes are always quoted in the same sequence (i.e. E; F; G), the letters may be dropped and just the numbers retained. Further elaboration on the UNFC definitions for "Classes, Sub-Classes, and the Categories and Sub-categories" for each axis is discussed in various chapters of this dissertation (Figure XI).

<table>
<tr><th colspan="7">UNFC Classes Defined by Categories and Sub-categories</th></tr>
<tr><td rowspan="14">Total Products</td><td rowspan="2">Produced</td><td colspan="5">Sold or used production</td></tr>
<tr><td colspan="5">Production which is unused or consumed in operations</td></tr>
<tr><td colspan="2" rowspan="2">Class</td><td rowspan="2">Sub-class</td><td colspan="3">Categories</td></tr>
<tr><td>E</td><td>F</td><td>G</td></tr>
<tr><td rowspan="8">Known Sources</td><td rowspan="3">Viable Projects</td><td>On Production</td><td>1</td><td>1.1</td><td>1, 2, 3</td></tr>
<tr><td>Approved for Development</td><td>1</td><td>1.2</td><td>1, 2, 3</td></tr>
<tr><td>Justified for Development</td><td>1</td><td>1.3</td><td>1, 2, 3</td></tr>
<tr><td rowspan="2">Potentially Viable Projects</td><td>Development Pending</td><td>2</td><td>2.1</td><td>1, 2, 3</td></tr>
<tr><td>Development On Hold</td><td>2</td><td>2.2</td><td>1, 2, 3</td></tr>
<tr><td rowspan="2">Non-Viable Projects</td><td>Development Unclarified</td><td>3.2</td><td>2.2</td><td>1, 2, 3</td></tr>
<tr><td>Development Not Viable</td><td>3.3</td><td>2.3</td><td>1, 2, 3</td></tr>
<tr><td colspan="2">Remaining products not developed from identified projects</td><td>3.3</td><td>4</td><td>1, 2, 3</td></tr>
<tr><td rowspan="2">Potential Sources</td><td>Prospective Projects</td><td>[No sub-classes defined]</td><td>3.2</td><td>3</td><td>4</td></tr>
<tr><td colspan="2">Remaining products not developed from prospective projects</td><td>3.3</td><td>4</td><td>4</td></tr>
</table>

Figure XI: UNFC Classes and Sub-classes defined by Sub-categories (UNECE, 2020)

In accordance with UNFC (2019), a project is defined as a development or operation with a base for evaluation on the E, F, and G axes, to instigate decision-making, even if only at conceptual levels (UNECE, 2020). In terms of resource projects, UNFC is applicable to primary and secondary raw materials. Primary raw materials pertain to minerals projects (e.g., mining project) and Secondary raw materials to anthropogenic resources projects (e.g., recycling project). Supplementary specifications further tailor the framework to minerals and anthropogenic resources.

UNFC Specifications for Minerals and Anthropogenic Resources provide detailed guidance on applying UNFC to mineral projects and anthropogenic projects (secondary raw materials). While UNFC was originally designed as a generic classification framework for all resource types, its sector-specific adaptations ensure a more precise application in different industries. For mineral projects, the Supplementary Specifications for the Application of UNFC to Minerals, published in 2021, refine the framework's application to metal ores, coal, technical minerals, and aggregates (UNECE, 2021). These specifications tailor the descriptions of the E-, F-, and G-axis categories to mining projects, incorporating essential factors such as prospection and exploration work, laboratory sample analysis, deposit type, resource modeling, geological uncertainties, feasibility studies, market conditions, technical operation plans, mining licenses, environmental impacts, stakeholder engagement, beneficiation techniques, and mining waste management. These refinements ensure that the evaluation, classification, and reporting of mineral projects align with industry-specific challenges and requirements (UNECE, 2021). UNFC Supplementary Specifications for Anthropogenic Resources provide a structured approach to classifying and managing secondary raw materials, including mining residues, post-consumer waste, and industrial by-products (UNECE, 2025). A key aspect of the specifications is their emphasis on resource recovery projects, which include the entire lifecycle of secondary materials, from initiation and production to residue treatment, recycling, and final disposal. The framework evaluates these projects based on their technical feasibility, environmental-socio-economic viability, and degree of confidence in resource estimates. UNFC's role in anthropogenic resource management extends beyond classification; it facilitates the integration of circular economy principles, ensuring that waste materials are efficiently recovered, reused, and reintegrated into production cycles. The specifications highlight best practices in stakeholder engagement, transparency, and quality assurance, enabling industries and policymakers to assess secondary resource projects with greater accuracy and comparability (UNECE, 2025).

Additionally, UNFC documentation is supported by Bridging Documents. These play a crucial role in enhancing interoperability between UNFC and other resource classification or reporting systems. Their primary purpose is to clarify the relationship between UNFC and another system, and to provide practical guidance on how estimates generated under that system can be translated into UNFC numerical codes, ensuring consistency and comparability of resource information (UNECE, 2020). In the CRMs sector, a prominent example is the Bridging Document between CRIRSCO and UNFC, which explains how mineral resource and reserve estimates reported under CRIRSCO codes can be mapped onto UNFC categories (Figure XII). This alignment highlights the complementary nature of the two systems: while CRIRSCO-based codes are primarily designed to support investment and public reporting, UNFC provides a broader, policy-oriented classification framework that integrates environmental, social, technical, and economic considerations. The use of either system, or both in parallel, depends on the purpose of the project evaluation and the specific reporting or governance requirements being addressed (UNECE, 2025).

CRIRSCO Template			*Corresponding UNFC Category*[c]			*UNFC Class*
Public Report and Study Types[a]	*Standard Definitions*					
Feasibility Study or Life of Mine Plan[b] (for an operating mine)	Mineral Reserves	Proved	E1	F1	G1	Viable Projects
		Probable			G2	
Pre-feasibility Study[d]	Mineral Reserves	Proved	E2	F2	G1	Potentially Viable Projects
		Probable			G2	
Feasibility Study, Life of Mine Plan[b] (for an operating mine) or Pre-feasibility Study[e]	Mineral Resources (exclusive of Mineral Reserves)	Measured	E2	F2	G1	
		Indicated			G2	
		Inferred			G3	
Scoping Study report or other Public Report on a Mineral Resource estimate[f]	Mineral Resources	Measured	E2	F2	G1	
		Indicated			G2	
		Inferred			G3	
Public Report on exploration stage projects	Exploration Target		E3	F3	G4	Prospective Projects
	Exploration Results		Estimates not published			
Not applicable[g]	Estimates obtained from historical reports[h]					Non-viable Projects

[a] The use of a Life of Mine Plan on operating mines, as indicated below, only applies in cases where no material changes to the current operation are envisaged.
[b] In cases where a Life of Mine Plan includes a proportion of Inferred Mineral Resources, and such material has been reported separately, then such material should be coded as E2F2G3.
[c] These are the Categories which would normally be used for a study when the mapping is based on a current (or recently published) study. Where there have been material changes since the effective date of a report, or the study is otherwise no longer considered current, the assumptions used in the study should be reviewed in order to determine whether the results obtained are still valid and whether the E and F axis values need to be altered. For instance, where an operating mine has ceased operation, where mining licences have expired or been revoked, or where there have been material changes in costs of prices the mapping of Mineral Reserves from a feasibility study or Life of Mine Plan would be downrated from E1 to E2 and from F1 to F2.
[d] Estimates included in a Life of Mine Plan which is potentially viable under current conditions.
[e] Estimates of material not included in the Life of Mine Plan which could be economically extracted using reasonably assumed future conditions.
[f] Estimates which are considered to have 'reasonable prospects for eventual economic extraction' under reasonably assumed future conditions.
[g] CRIRSCO Template aligned reporting does not allow the Public Reporting of estimates on non-economic mineralisation.
[h] Historical estimates will generally be downrated to E3 and F3, with the original G Categories being retained.

Figure XII: Mapping of CRIRSCO Template estimates to UNFC Categories (UNECE, 2025)

UNFC functions as a bridging mechanism across stakeholder groups (Figure XIII). For governments, it supports national resource inventories, strategic planning, and evidence-based policymaking, enabling alignment between domestic resource endowments and broader objectives such as climate neutrality, industrial competitiveness, and supply security (UNECE, 2021). For industry, UNFC offers a practical and scalable classification system, based on a numerical coding structure, that enhances consistency across projects and jurisdictions. For investors and financial institutions, UNFC improves access to comparable, ESG-aligned, and decision-useful information, thereby reducing uncertainty and supporting responsible capital allocation. In an era where financing for critical minerals is increasingly contingent on sustainability performance and risk transparency, UNFC strengthens the informational foundation upon which investment decisions are made.

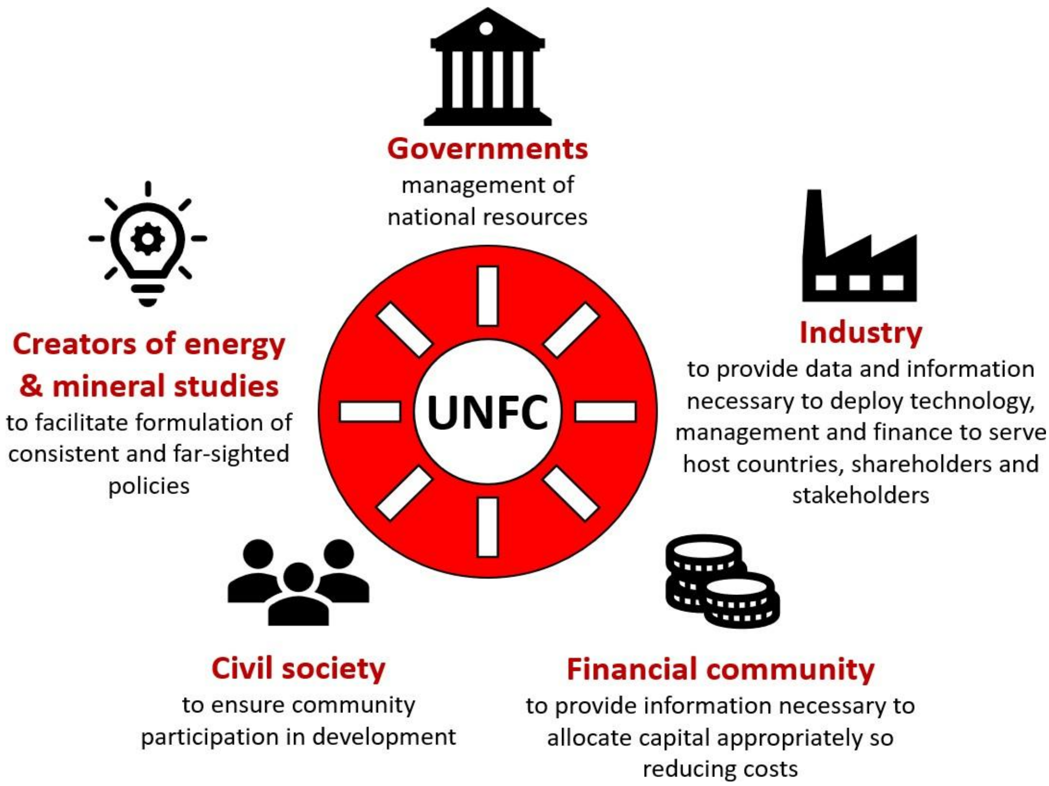

Figure XIII: UNFC use by the different stakeholder groups (UNECE, 2024)

Global raw material supply chains are characterized by increasing complexity, fragmentation, and opacity. Data on mineral resources remain uneven in quality, non-interoperable across jurisdictions, and often incomprehensible to policymakers and the public. This lack of harmonization undermines effective decision-making, exacerbates supply risks, and weakens trust among stakeholders (Schrijvers et al., 2019). UNFC responds directly to these challenges by consolidating best practices from established national and regional classification systems, drawing from frameworks used in Europe, North America, and elsewhere, into a neutral, globally applicable structure. In doing so, it facilitates policy alignment, supports cross-border cooperation, and enhances transparency across the entire resource value chain. For CRMs in particular, where supply disruptions, capital intensity, and ESG scrutiny are pronounced, UNFC provides the structured, sustainability-referenced information required to mobilize investment and guide public policy. For governments seeking to secure CRMs, UNFC can support a foundation for project identification, informed capital allocation, and long-term resource planning. The framework enables consistent, real-time, and transparent representation of project maturity and sustainability performance, conditions that are essential for prioritizing projects aligned with national and regional interests. In this sense, UNFC transforms classification from a descriptive exercise into a governance tool, directly supporting policy objectives related to supply security, sustainability, and resilience (Figure XIV).

Figure XIV: UNFC-based Roadmap to securing mineral supply (UNECE, 2024)

As an extension of the UNFC, the United Nations Resource Management System (UNRMS) builds upon it by embedding project-level classification within a broader, systems-based approach to sustainable resource management. UNRMS aligns resource governance with the principles of the 2030 Agenda, integrating environmental stewardship, social responsibility, and economic efficiency (UNECE, 2020). The application of UNRMS is corroborated in a case study on CRM projects in Cornwall, United Kingdom (UNECE, 2024). The case study evaluated how well existing systems correspond to UNRMS requirements, which involved selecting specific principles and criteria from UNRMS and examining their implementation within Cornwall's mining sector (UNECE, 2024). While UNFC provides a snapshot of project maturity, UNRMS focuses on improving that maturity over time, guiding stakeholders toward best practices across the resource life cycle. The two frameworks are thus mutually reinforcing: UNFC informs decision-making, while UNRMS shapes long-term outcomes (Figure XV).

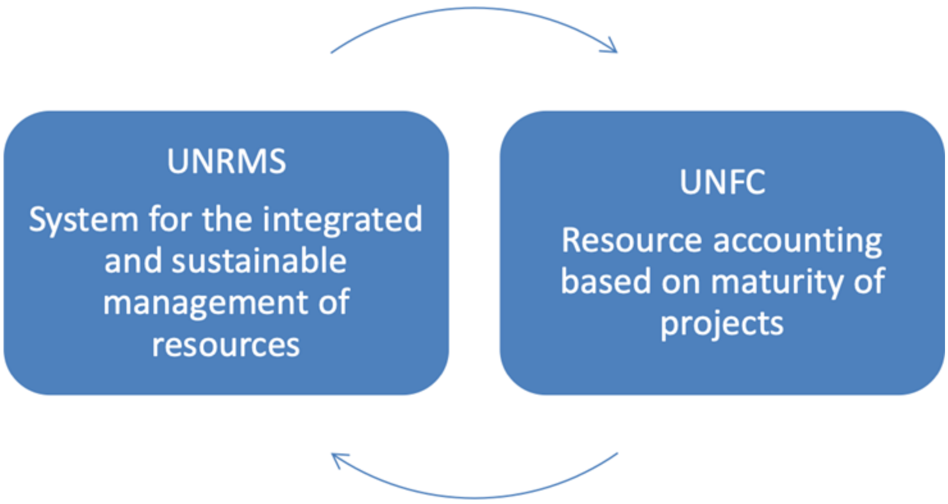

Figure XV: UNRMS and UNFC connection for project implementation (UNECE, 2024)

2.3.1 Limitations and Critical Perspectives on UNFC

UNFC's architecture and its alignment with sustainable resource management establishes the conceptual and institutional case for the its adoption within CRMA. However, several limitations of UNFC have been identified from implementation experience across national geological surveys, comparative analyses with alternative reporting standards, and the growing body of research on environmental, social, and governance dimensions of resource management. It is important to note that the identified limitations do not undermine the case for UNFC adoption in the CRMA context. Rather, they define the conditions under which UNFC performs reliably, the areas where supplementary methodological development is required, and the scope of generalization that is justified on the basis of the Italian case study. One major observation underpins that data gaps, consistency of approach, and the harmonization of datasets from diverse sources must be understood and managed, not concealed, if UNFC-based inventories are to serve as credible foundations for policy (Bide et al., 2022).

Despite ECOSOC's endorsement and the formal designation as the classification tool for CRMA, UNFC's adoption at national levels remains uneven. Within the EU alone, Member States do not apply UNFC similarly, and that data quality and methodological inconsistencies across national systems make meaningful aggregation at EU level extremely difficult (Hokka et al., 2021). Additionally, the pan-European MINTELL4EU project, which tested UNFC across 19 case studies from nine countries, identified that harmonization at EU level remains a challenge to be addressed for UNFC implementation (Mark S., et al., 2021; GSEU, 2025). In this regard, the body of evidence on how UNFC performs in practice across diverse regulatory, geological, and data-quality contexts is still accumulating. Significant efforts have improved the practical use of UNFC, but the framework itself acknowledges that it is principles-based rather than prescriptive (UNECE, 2020). This means that different practitioners can arrive at substantially different classifications for the same project. At the same time, UNFC's principles-based flexibility design generates a reproducibility limitation that is particularly consequential for cross-jurisdictional comparability. Because UNFC does not prescribe quantitative thresholds for axis assignment i.e., no defined quantitative criteria that mechanically trigger a given E, F, or G category, the classification outcomes depend largely on the judgement of the practitioner. Comparative work on national UNFC implementations within the Geological Service for Europe (GSEU) project found that historical estimates and the handling of data gaps generate classification variability that cannot be resolved solely through methodological guidance (GSEU, 2025). The sharing of experiences across national surveys, as recommended GSEU, helps narrow this variability, but does not eliminate it. As the CRIRSCO-UNFC Bridging Document explicitly states, UNFC is not designed for market reporting on mineral resources and reserves, where Competent Person standards and requirements enforce greater reproducibility (UNECE, 2025). In the absence of equivalent accountability mechanisms, UNFC is inherently softer and more contextual.

On another note, the Environmental-Socio-Economic (E) axis remains operationally immature. At a time where social dimensions are a major risk for the global mining and metals industry, how to assess the 'social' component of this axis in a consistent and measurable way remains ambiguous (Rouget, V., 2022). The E axis nominally integrates permitting, economic viability, environmental performance, and social acceptability as co-equal considerations. In practice, however, permitting status and economic modelling are tractable and documentable; social acceptability is not. By nature, the social aspect is non-binary, temporally unstable, and community-specific. It cannot be reduced to a permitting checklist without losing most of its analytical content (Dare, 2014). UNFC's E axis provides a qualitative category for 'social constraints,' but offers no standardized methodology for measuring, weighting, or tracking it. This creates the risk that E axis classifications are effectively determined by regulatory permitting and economic proxies, with social risk assessed only when it has already materialized into formal legal challenge or project suspension.

Another limitation involves the confusion often associated with UNFC being a forecasting model. A recurrent challenge in practice is the tendency to assign E and F axis categories based on expectations about future conditions rather than evidence of current project status, as in effectively confusing classification with assumption (Hokka et al., 2021). In optimistic project environments, this can produce E1 or F1 classifications for projects that have not yet secured viability or feasibility (Hokka et al., 2021). The results of such confusion are a systematic upward bias that may create mislead decisions and impressions.

A structural limitation in UNFC for national inventories is the asymmetry of information between private operators and public geological surveys or regulatory authorities. In jurisdictions where operators are not required by law to disclose resource and reserve estimates beyond the minimum necessary, competent authorities must classify projects on the basis of publicly available information, without access to the proprietary resource estimation work that would enable higher-confidence G axis classifications. This constraint systematically misrepresents national inventories, with possibly lower-confidence G axis classifications not because the geological potential is genuinely low, but because the information necessary to substantiate higher-confidence classifications is withheld within industry (GSEU, 2025).

2.4 European Critical Raw Materials Act

CRMA represents a cornerstone of the EU's response to growing vulnerabilities in CRMs supply chains that underpin its economic resilience, industrial competitiveness, and strategic autonomy. It is the leading raw materials-related regulation currently in the EU. As mentioned earlier, CRMs are the building blocks for a wide range of technologies central to the green and digital transitions, including renewable energy systems, electric vehicles, batteries, hydrogen technologies, electronics, and advanced manufacturing. However, their supply is often characterized by high geographical concentration, exposure to geopolitical risks, trade distortions, and market volatility. CRMA was therefore conceived to address these structural challenges by strengthening the EU's capacity to secure reliable, sustainable, and diversified access to CRMs (European Commission, 2024). Adopted as a Regulation and entering into force in May 2024, CRMA responds directly to recent global disruptions that have highlighted the EU's heavy reliance on imports, frequently from a single third country, for many strategically important materials. Without coordinated and timely action, such dependencies threaten the functioning of the Single Market, the competitiveness of European industries, and the EU's ability to meet its climate neutrality and digitalization objectives. Building on the strengths of the Single Market, the CRMA seeks to establish strong, resilient, and sustainable value chains for CRMs by acting across the entire lifecycle, from exploration and extraction to processing, recycling, and waste recovery (European Commission, 2024).

Strategic Projects constitute one of the most operational and transformative instruments introduced under CRMA, translating policy objectives into concrete, bankable actions along the CRMs value chain. These projects are designated because of their strategic importance to the EU's security of supply, their contribution to the green and digital transitions, and their alignment with high environmental, social and governance (ESG) standards. Strategic Projects cover extraction, processing, recycling, and substitution projects, and may be located both within the EU and in third countries, provided they demonstrably strengthen the resilience and diversification of EU supply chains (European Commission, 2024). The rationale for Strategic Projects lies in the recognition that market forces alone are insufficient to overcome structural barriers in SRM value chains, such as high capital intensity, long development timelines, regulatory complexity, and geopolitical risk. The list of criteria for recognition are listed in CRMA, however the most important ones are that these projects should target SRMs and make a meaningful contribution towards the benchmarks. The formal recognition of projects of strategic relevance enables the EU to prioritize those initiatives that can deliver the greatest systemic benefits in terms of supply security, sustainability and technological leadership. In return, project promoters gain access to a package of coordinated support measures designed to accelerate project development and de-risk investment decisions (Figure XVI) (European Commission, 2024). As mentioned in CRMA, a benefit of Strategic Project recognition is enhanced support to finance access. Projects may receive coordinated support from the European Commission, Member States and EU-level and national financial institutions, including assistance in mobilizing public and private capital, blending instruments, and facilitating connections with relevant industrial off-takers. This is particularly important for CRM projects, where long payback periods and price volatility often deter private investment. Another cornerstone incentive is fast-tracked permitting. Under the CRMA, Strategic Projects benefit from significantly shortened and more predictable permitting timelines, capped at a maximum of 27 months for extraction projects and 15 months for processing, recycling and substitution activities, compared to current permitting processes that can take five to ten years. This acceleration is achieved through coordinated administrative procedures, designated single points of contact at national level, and clearer timelines, without lowering environmental or social standards. Faster permitting reduces uncertainty, lowers development costs, and enhances the global competitiveness of EU-based CRM projects (European Commission, 2024).

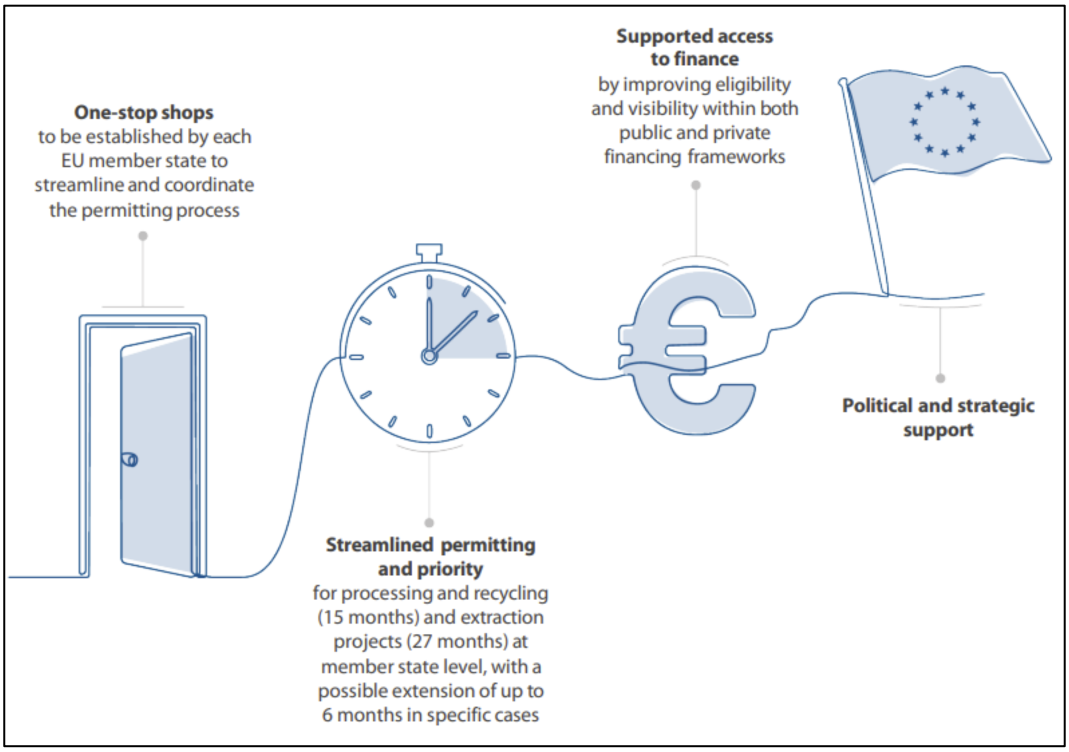

Figure XVI: Expected support for recognized Strategic Projects in the EU (ECA, 2026)

Beyond financial and administrative advantages, Strategic Projects are also embedded in the EU's broader strategic partnerships and diversification agenda. Projects located in third countries are expected to operate within mutually beneficial partnerships, supporting local value creation, sustainability objectives and long-term cooperation, while securing reliable supplies for the EU. In this way, Strategic Projects act as anchor points for resilient, transparent and responsible CRM value chains, directly supporting the CRMA's benchmarks for extraction, processing, recycling and supply diversification (European Commission, 2024). One policy measure taken by the EU to diversify CRMs supply involves “Strategic Partnerships”. Strategic partnerships with resource-rich third countries are a central policy lever for diversifying EU supplies of CRMs and SRMs, aimed to reduce dependency on a small number of suppliers and strengthening resilience across value chains (Figure XVII). With this long-term cooperation, the EU can secure supply for batteries, wind turbines, high-performance magnets and other green/digital technologies while promoting sustainable value-chain development in partner countries (European Commission, 2024). Well-designed partnerships can deliver mutual economic benefits (jobs, technology transfer, domestic added value), lower supply risk through portfolio diversification, and help channel capital toward socially and environmentally responsible extraction, processing and recycling projects that align with CRMA benchmarks and Strategic Projects framework. These partnerships also sit within broader EU external investment initiatives, such as the Global Gateway, which are intended to mobilize sustainable infrastructure finance and deepen reliable, rules-based cooperation with third countries (European Commission, 2025).

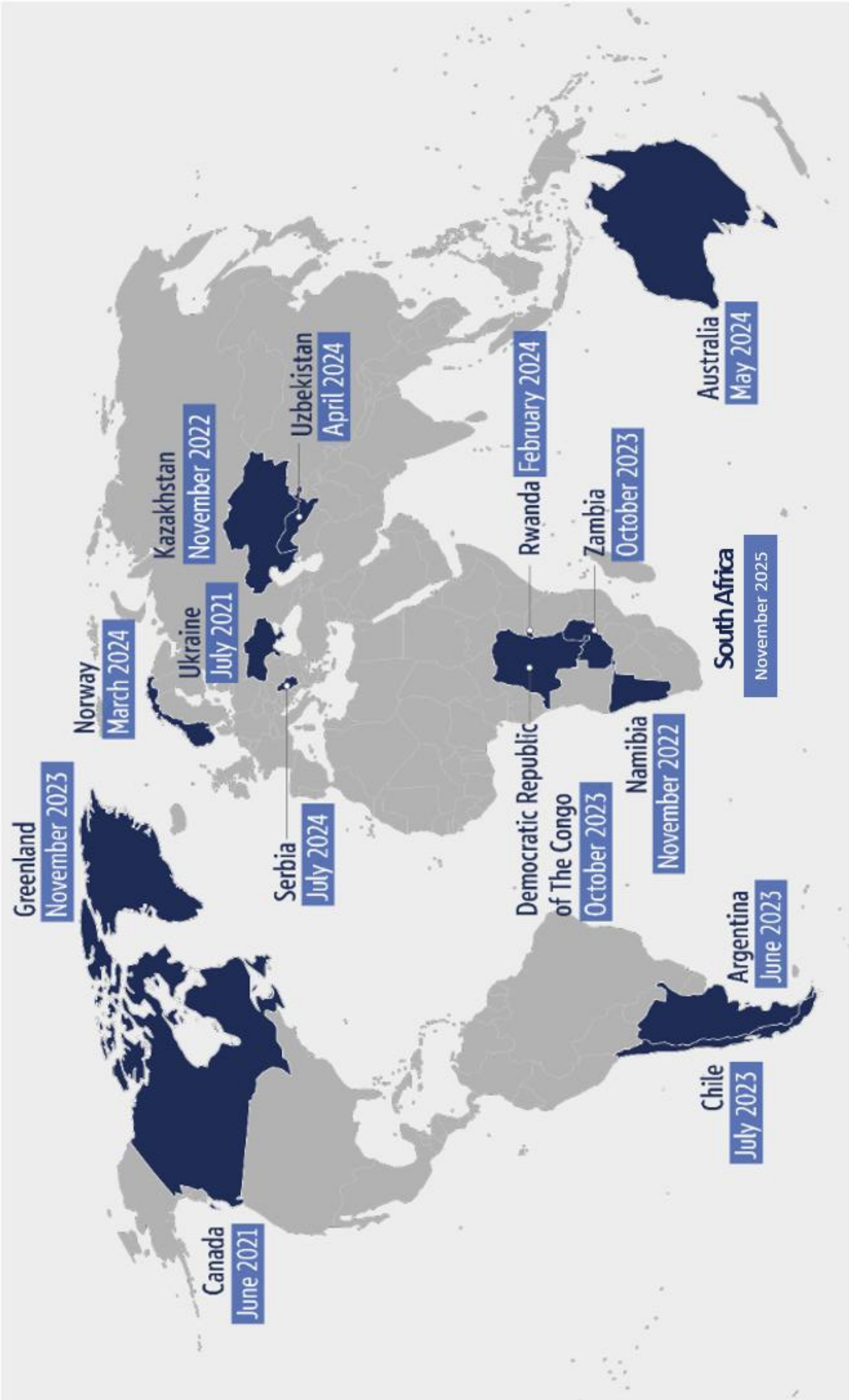

Figure XVII: EU Raw Materials Strategic Partnerships (European Commission, 2024)

A central objective of CRMA is to strengthen all stages of the EU CRMs value chain. This includes increasing domestic capacities for extraction, processing, and recycling; diversifying sources of supply through strategic partnerships with reliable third countries; improving monitoring and mitigation of supply disruption risks; and enhancing circularity and sustainability. In parallel, a dedicated communication accompanying the Regulation outlines how the EU intends to reinforce its global engagement through mutually beneficial partnerships that support sustainable development in partner countries while ensuring secure, affordable, and diversified supply chains for the EU (European Commission, 2024). In this sense, CRMA aligns closely with the European Green Deal Industrial Plan and is designed to operate in tandem with the Net Zero Industry Act, which focuses on scaling up the manufacturing of key net-zero technologies within Europe. Within CRMA, particular attention is given to SRMs, a subset of CRMs identified on the basis of their high strategic importance for the EU economy, the green and digital transitions, and defense and space applications. For these materials, CRMA establishes clear and forward-looking benchmarks to reduce strategic dependencies and guide investment and policy action along the value chain. By 2030, the EU aims (European Commission, 2024):

- at least 10% of the EU's annual consumption for extraction
- at least 40% of the EU's annual consumption for processing
- at least 25% of the EU's annual consumption for recycling
- no more than 65% of the EU's annual consumption from a single third country

These benchmarks reflect a shift from reactive supply management toward a more anticipatory and resilience-oriented resource policy.

Despite its strategic ambition, CRMA and, in particular the Strategic Projects mechanism have attracted increasing scrutiny from institutional, legal, and civil society perspectives. Concerns have been raised regarding the governance robustness, transparency, and accountability of the recognized Strategic Projects and their designation process. Firstly, fast-tracked permitting procedures may in practice constrain the depth of environmental assessment, stakeholder consultation, and administrative review, particularly in complex or contested projects (ECA, 2026). Civil society organizations have argued that the priority status risks creating procedural pressure on competent authorities, and in return limiting meaningful public participation and access to environmental information during project evaluation and authorization phases (ClientEarth, 2025). Second, questions have been raised regarding the transparency and oversight of the Strategic Project selection process itself (ECA, 2026). The criteria for recognition involve a degree of technical and political discretion in interpretation. Limited public disclosure regarding the detailed evaluation of projects may undermine trust in the objectivity and consistency of the designation process, especially where projects are recognized despite substantial environmental or social controversy (Clean Energy Frontier, 2025). Third, and most importantly, without financial support, the benefits do not in themselves guarantee project advancement (ECA, 2026). Mineral development projects remain highly capital intensive, technically complex, and exposed to considerable market and price volatility. Consequently, it is noted that that the European Union has not yet established a fully coherent financing architecture capable of systematically supporting Strategic projects across the value chain, and that access to capital remains a major bottleneck for project promoters despite CRMA's emphasis on investment facilitation (ECA, 2026). Taken together, the success of CRMA's implementation will depend not only on accelerating projects, but also on ensuring financial access, and that governance mechanisms remain transparent, evidence-based, socially and environmentally robust (ECA, 2026).

In scope of this dissertation, a distinctive feature of CRMA is the explicit integration of UNFC, as the reference tool for resource classification and reporting (Figure XVIII). UNFC and its benefits have been recognized by regulatory bodies, in particular by the European Commission. UNFC is incorporated under four key provisions of the Regulation, underscoring its role as an enabling tool for harmonized, transparent, and sustainability-oriented resource governance. The provisions are aimed at both, EU Member States and Industry. First, Member States are required to report the results of their National Exploration Programmes (NEPs) using UNFC (CRMA, Article 19), ensuring comparability and consistency of exploration data across the EU. Second, UNFC is mandated for risk monitoring and stress testing of producing CRM projects (CRMA, Article 21), supporting the EU's capacity to anticipate and manage supply disruptions. Third, UNFC is applied to the classification of extractive waste from closed facilities (CRMA, Article 27), where relevant, thereby supporting circular economy objectives and the recovery of valuable materials. Finally, project promoters seeking Strategic Project recognition under CRMA must classify their projects using UNFC as part of the application process (CRMA, Article 7) (European Commission, 2024).

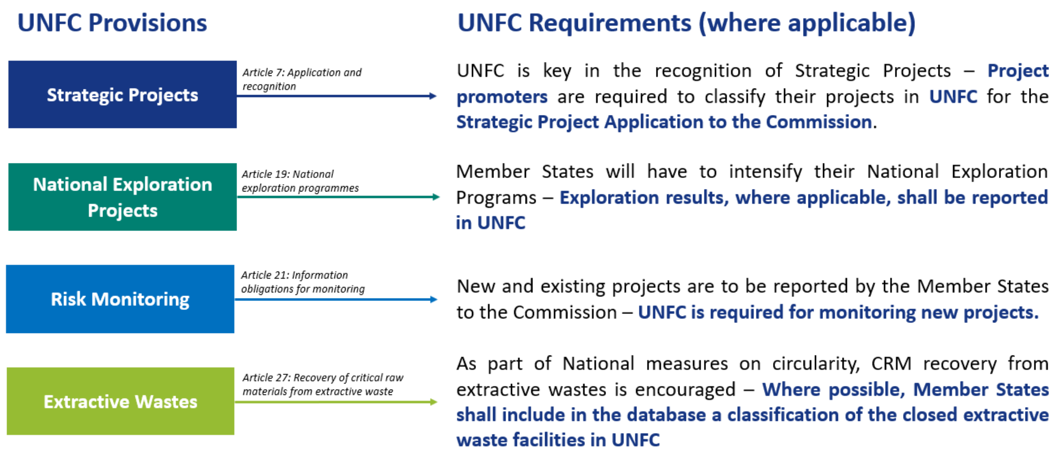

Figure XVIII: CRMA provisions for UNFC and their requirements

The first call for Strategic Projects under the CRMA illustrates the operational relevance of UNFC in practice. A total of 170 projects, located both within the EU and in third countries, were submitted and classified using UNFC. This classification supported the technical assessment of project proposals by enabling a structured evaluation of economic viability, technical feasibility, environmental and social performance, and overall project maturity and readiness (European Commission, 2025). Beyond project selection, UNFC also provides a robust basis for monitoring the evolution of Strategic Projects over time, allowing regulators to track progress, risks, and changes in sustainability and feasibility in a consistent manner. Out of the 170 projects, 60 were designated as Strategic, out of which 47 are in the EU and 13 in third countries (Figure XIX). This number constitutes the largest dataset of UNFC classified projects in the EU, spanning on both primary and secondary raw materials. UNFC's application to Strategic projects supports on three main branches: i) to project promoters to ensure that all project applications are reflect their project's viability and technical maturity in a similar manner; ii) to UNFC expert validators to ensure that all projects are communicating in one common language; and iii) to the European Commission to monitor the progress of the recognized projects towards the benchmark year.

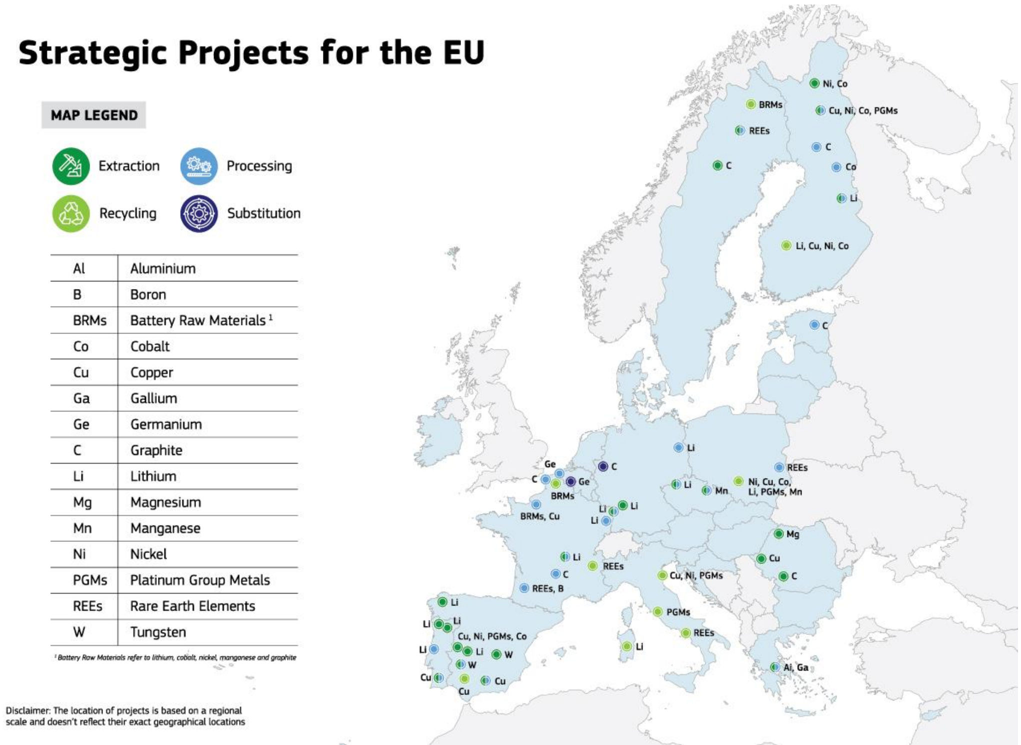

Figure XIX: Selected Strategic Projects in the EU, from the first call for application (European Commission, 2025)

The choice of UNFC within CRMA reflects its suitability for the EU's policy objectives. UNFC is simple to apply, yet comprehensive in scope, allowing for the comparison of diverse resource projects, including primary minerals, secondary raw materials from recycling and end-of-life streams, and other resource types, across different stages of the value chain, from exploration to processing and recycling. Crucially, it integrates environmental and social considerations alongside technical and economic factors, and enables the translation of information from a wide range of existing reporting systems into a common format without imposing additional reporting burdens on users (Grohol, 2024). As such, UNFC functions as a key enabler of evidence-based policymaking under CRMA, supporting sustainable sourcing, informed investment, and long-term resilience of the EU's raw materials supply chains.

2.5 Italian Raw Materials Landscape

Italy's mining tradition extends back to when the Italian peninsula played a central role in supplying metals such as copper and iron to the Roman Empire. Although the scale of mining activity has declined significantly since its historical peak, the sector continues to hold strategic economic relevance. Today, Italy remains a major European producer of industrial minerals, including marble, gypsum, and clay, and maintains active extraction of strategically important minerals such as lead, zinc, and barite. These resources support key downstream industries, particularly construction, manufacturing, and materials processing. Since 2008, the industry in Italy has witnessed a major decrease for non-energy minerals (Lucarini M., et al., 2024). Despite this decrease, a number of occurrences, including CRMs, are documented and show potential (Figure XX).

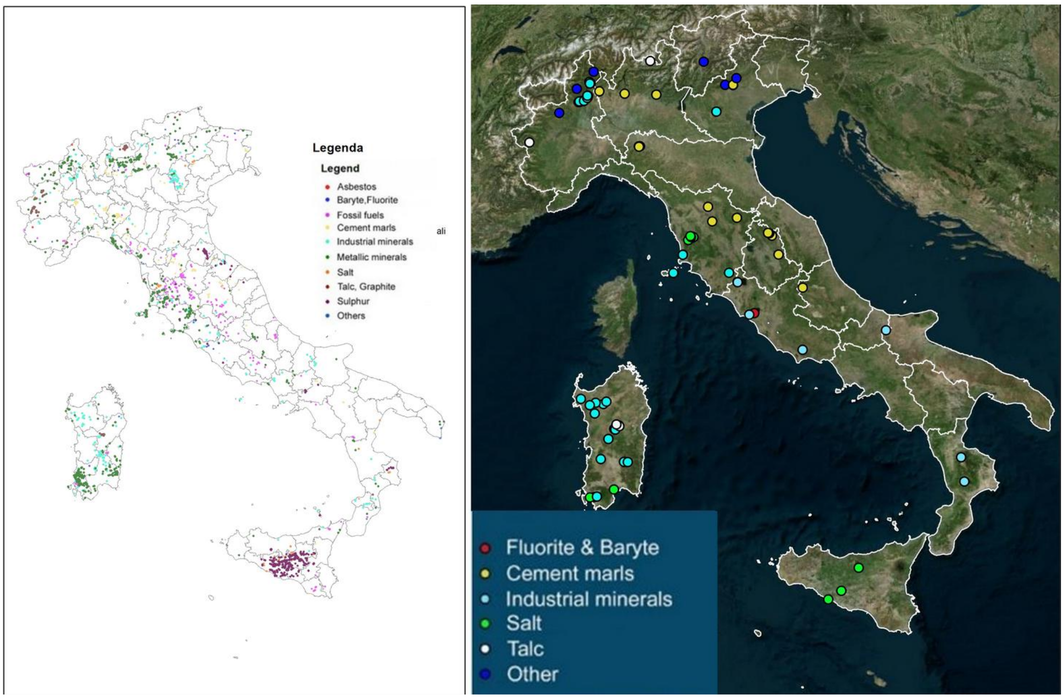

Figure XX: Raw materials occurrences in Italy (Lucarini M., et al., 2024)

Despite the geological endowment, the advancement of mineral projects in Italy is frequently constrained not by subsurface potential, but by non-geological factors. Social acceptance, environmental sensitivities, regulatory complexity, land-use competition, and biodiversity protection increasingly determine project viability. As showcased earlier, these constraints are explicitly captured within the E axis of UNFC. Across the EU, limitations associated with the E axis have become particularly pronounced, greatly influencing the pace and feasibility of raw materials development. On the other hand, meeting the growing demand for CRMs therefore requires a forward-looking policy response. Evidence indicates that private-sector exploration investment in Europe remains insufficient relative to projected demand growth (McKeith et al., 2010; European Commission, 2020). As demand accelerates, conventional market mechanisms alone may not enable timely supply responses. This situation may justify interim policy measures, including public or public–private development of less economically attractive deposits, to safeguard security of supply during transitional periods. In this context, the establishment of a comprehensive raw materials inventory, supported by reliable and decision-relevant data, becomes essential. Such inventories allow authorities to evaluate strategic priorities, direct public funding more effectively, and assess long-term supply options (UNECE, 2022). Consequently, Italy's raw material potential must be approached through a long-term strategy that integrates geological knowledge with governance capacity and sustainability considerations (Figure XVII).

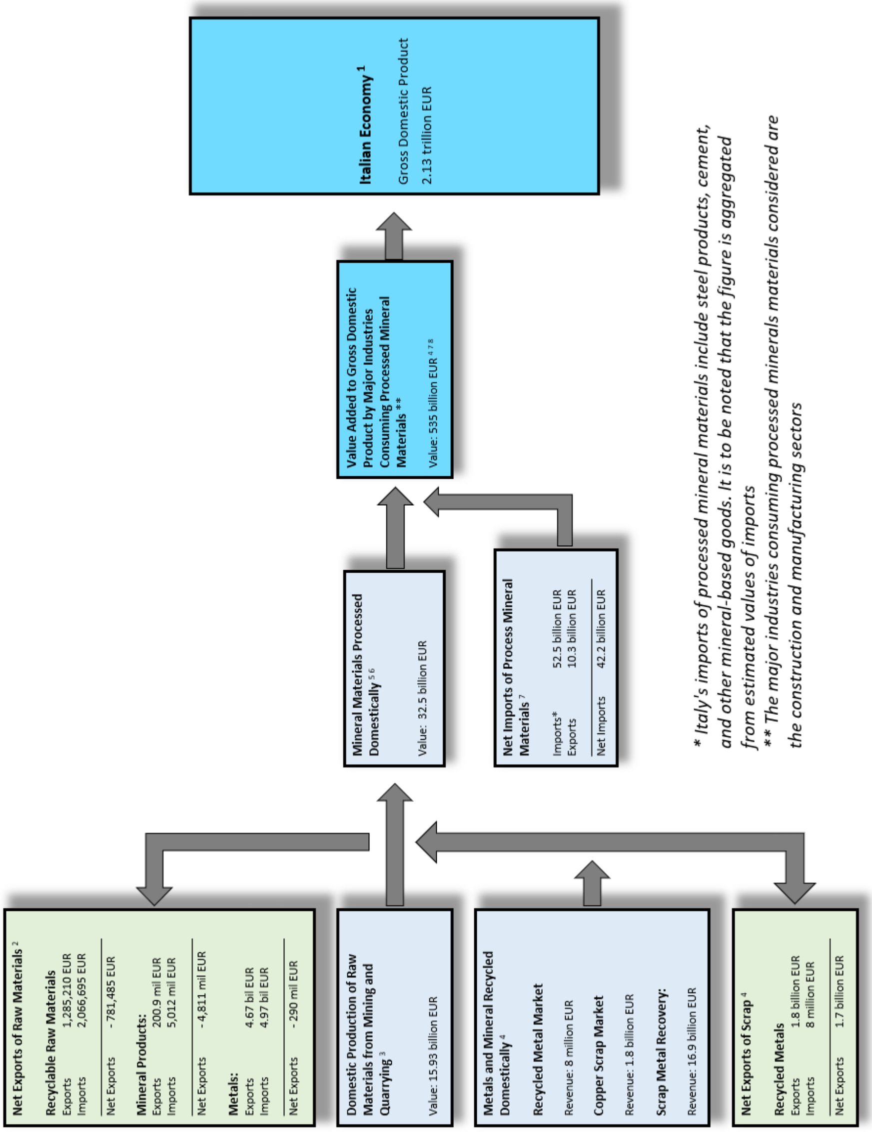

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Figure XXI: The contribution of nonfuel minerals to the Italian economy, estimated values in 2023

Italy’s mining sector operates within a comprehensive legal and institutional framework designed to balance economic development with environmental protection and public safety. The cornerstone of this framework is the Royal Decree No. 1443/1927, the national mining code which defines the legal regime governing mineral ownership, exploration rights, and extraction activities. Although enacted nearly a century ago, the Royal Decree No. 1443/1927 has been repeatedly amended to reflect evolving environmental, safety, and sustainability standards, particularly those arising from EU legislation. This national framework is complemented by regional laws and regulations, which play a decisive role in operational governance. Regions adapt permitting and management procedures to local geological, environmental, and socio-economic conditions, ensuring that site-specific constraints and community concerns are adequately addressed. Together, national and regional instruments form a multi-layered governance structure that regulates all stages of the mining lifecycle. Italy’s legislative framework for mineral exploration and extraction is shaped by the interaction of national legislation and binding EU directives. At the European level, instruments such as the Water Framework Directive (2000/60/EC) and the Environmental Impact Assessment Directive (2014/52/EU) impose strict requirements for environmental protection, water resource management, and impact mitigation. These directives directly influence how mining projects are planned, assessed, and authorized. At the national level, environmental safeguards are consolidated within the environmental code (Legislative Decree No. 152/2006). This legislation establishes mandatory environmental impact assessments (EIA) for mining projects, ensuring that environmental risks are identified, evaluated, and mitigated before authorization is granted. The environmental code thus serves as a key mechanism for integrating sustainability considerations into mineral development decisions. Responsibility for mineral exploration and extraction in Italy is distributed across several public authorities. The Ministero delle Imprese e del Made in Italy (MIMIT), formerly the Ministry of Economic Development, acts as the principal authority for issuing exploration permits and mining concessions, supervising compliance with mining regulations, and promoting sustainable resource development. Environmental oversight is provided by the Ministry of Environment and Energy Security (MASE), which is responsible for reviewing EIAs and ensuring adherence to environmental legislation. In parallel, regional authorities play a central operational role, particularly through regional mining plans and permitting procedures, reflecting Italy’s decentralized governance model for natural resources (MINLEX Project, 2019). In terms of raw materials projects, MIMIT oversees all processing activities, whereas MASE all mining and recycling activities.

Obtaining an exploration license in Italy involves a structured, multi-stage process. Applications are submitted to the competent regional offices and must include detailed descriptions of the proposed exploration programme, the geographical area concerned, targeted mineral substances, and the planned duration of activities. Applicants must also demonstrate adequate technical expertise, financial capacity, and professional qualifications. Once submitted, applications are reviewed by regional authorities in coordination with environmental bodies, including MASE and regional environmental agencies. This review assesses the potential environmental impacts of the proposed activities and the adequacy of proposed mitigation measures. Depending on the scale and nature of the exploration, a full EIA may be required, particularly where significant environmental effects are anticipated. Where exploration confirms a commercially viable deposit, operators may apply for an extraction license (mining concession). This application undergoes a more rigorous evaluation process, encompassing technical feasibility, economic viability, and environmental performance. A comprehensive EIA is mandatory and must demonstrate how environmental risks will be managed throughout the operational life of the mine. Following approval, concession holders are subject to stringent obligations, including continuous environmental monitoring, periodic reporting, and compliance with mine rehabilitation and closure requirements. These conditions ensure that extraction activities remain aligned with environmental protection objectives and public safety standards throughout the project lifecycle (MINLEX Project, 2019).

Similar to everywhere else, mining activities in Italy have significant environmental and social implications, ranging from land disturbance and water pollution to impacts on local communities. To address these challenges, Italy has progressively strengthened its environmental regulations and aligned its mining policies with circular economy principles. These measures aim to reduce waste generation, encourage material recycling and reuse, and minimize the environmental footprint of extractive activities. As a note, the integration of UNFC into Italy's resource management framework represents a critical step toward enhancing transparency and sustainability. Standardizing how mineral resources are classified and reported could support more informed decision-making and facilitates alignment with EU-level initiatives through UNFC, including CRMA. This integration enables Italy to manage its mineral endowment responsibly while contributing coherently to broader European strategic objectives.

The process for obtaining mining permits in Italy is decentralized and largely managed at the regional level, reflecting the constitutional delegation of competences for solid minerals and mineral waters to the Regions. With the exception of marine minerals, each Italian Region applies its own permitting procedures, defined through regional legislation and administrative practice. As a result, permitting requirements, authorities involved, and timelines may vary across the country. A key feature of the Italian system is the distinction between first category materials and second category materials, which determines the applicable permitting pathway.

As per the Italian Royal Decree No. 1443 of 1927, Italy's mineral resources are legally classified into two groups: first-category and second-category minerals. First-category minerals are owned by the State and include energy minerals (with the exception of peat), metallic ores, and non-metallic minerals of major industrial relevance such as salt and potash, barite and fluorspar, gemstones, garnet, corundum, leucite, fluorite, barium and strontium minerals, talc, asbestos, cement marls, and lithographic stones. Rights to marine sand and gravel also fall under national State ownership. Second-category minerals are typically extracted through quarrying activities and comprise peat, construction materials used for building, road and hydraulic works (excluding cement marls), quartz and silica sands, millstones, sandstone, igneous rocks, limestone, chalk, dolomite, sand and gravel, common clays, and other industrial minerals not classified as first-category. These resources are legally owned by the landowner. Through Legislative Decree No. 616/1977 (for second-category minerals), Legislative Decree No. 112/1998, and Constitutional Law No. 3/2001 (for first-category minerals), responsibilities for planning, management, and permitting were progressively transferred from the national level to the Regions, establishing the current decentralized governance framework for mineral resources in Italy.

For first category materials, permitting follows a two-stage process consisting of: 1) an exploration permit; and 2) an extraction permit (mining concession) (Figure XXII). The competent authority for both stages is the Region, although in some Regions, such as Emilia-Romagna, certain responsibilities are further delegated to provinces or municipalities. The exploration phase begins with an application to the Region, accompanied by a research programme and documentation demonstrating the applicant's technical competence, financial capacity, and professional qualifications. Exploration permits are typically granted for two years, with the possibility of extension. In Emilia-Romagna, for example, the competent regional authority issues exploration permits within 45 days of application submission. Exploration permits confer exclusive rights over the licensed area and establish a preferential link to future exploitation. Holders of exploration permits benefit from priority consideration when applying for an extraction concession. Investors are required to pay an exploration fee calculated at €15.64 per hectare. If exploration identifies a commercially viable deposit, the permit holder may apply for an extraction concession, also granted by the Region. Extraction projects may be subject to EIA procedures, typically conducted by regional environmental offices. Once granted, extraction permits impose binding obligations related to environmental monitoring, safety standards, rehabilitation, and mine closure (MINLEX Project, 2019).

For second category materials, the permitting regime differs substantially. These materials are generally land-owned, and no exploration permit is required. Areas suitable for extraction are predefined within Regional Mining Plans, meaning that geological exploration has already been undertaken as part of regional planning processes. In this case, investors must acquire ownership of the land or obtain permission from the landowner before proceeding. The absence of an exploration permitting phase simplifies administrative procedures, but extraction activities remain subject to regional authorization and environmental controls, depending on the characteristics of the deposit and the applicable regional legislation.

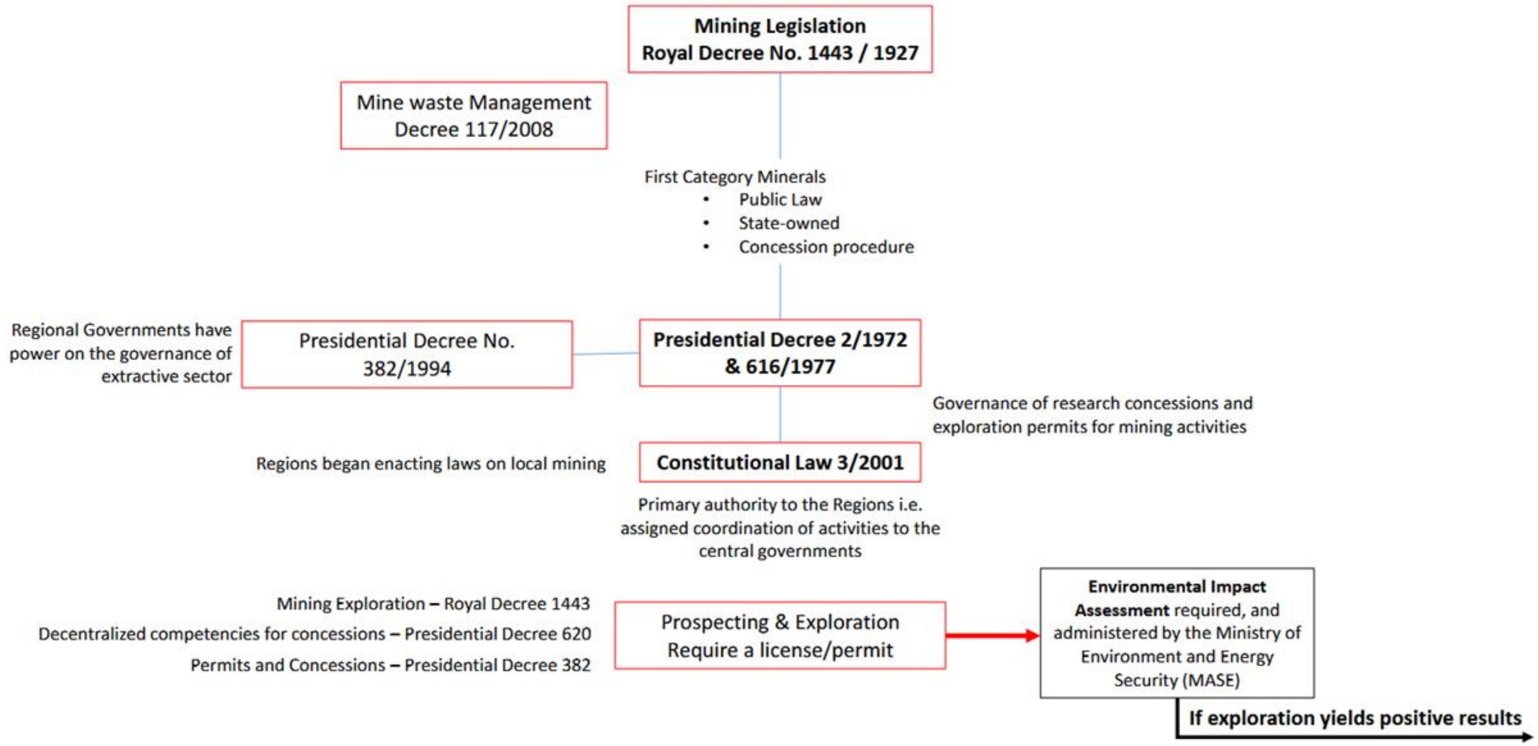
Public entities involved in the permitting process are determined by regional legislation, resulting in institutional variation across Italy. While Regions hold primary competence, additional authorities may include: provincial and municipal administrations (where delegated), regional environmental agencies, and/or national ministries involved in oversight and policy coordination. For first category materials, Regions evaluate exploration applications and issue permits, while also managing extraction concessions. For second category materials, regional planning instruments, particularly Mining Plans, define suitable areas for exploitation, reducing the need for case-by-case exploration authorization.

The average timeframe for obtaining an exploration permit for first category materials is approximately 90 days, although shorter timelines are observed in some Regions. No equivalent exploration permitting timeframe applies to second category materials, as exploration authorization is generally not required. Exploration permits do not impose predefined limits on geographic coverage; the licensed area depends on the specific procedure and regional rules. The legal nature of exploration rights is exclusive, and exploration permits are formally linked to future extraction rights, providing regulatory continuity and investment certainty.

The Italian permitting process is designed as a multi-stage system that integrates environmental protection and public interest considerations at each phase:

- **Exploration permit application** enables geological surveys and exploratory drilling.
- **Permit review** assesses environmental impacts and mitigation measures; a full EIA may be required depending on project characteristics.
- **Permit approval** authorizes exploration for a defined period, subject to compliance with permit conditions.
- **Extraction permit application** follows successful exploration and includes detailed technical, economic, and environmental documentation.
- **Extraction permit review** involves technical evaluation, environmental assessment, and, where applicable, public consultation.
- **Extraction permit approval** grants the right to mine, subject to strict environmental, safety, reporting, and rehabilitation obligations.

Italian Minerals Law – Summary (1)



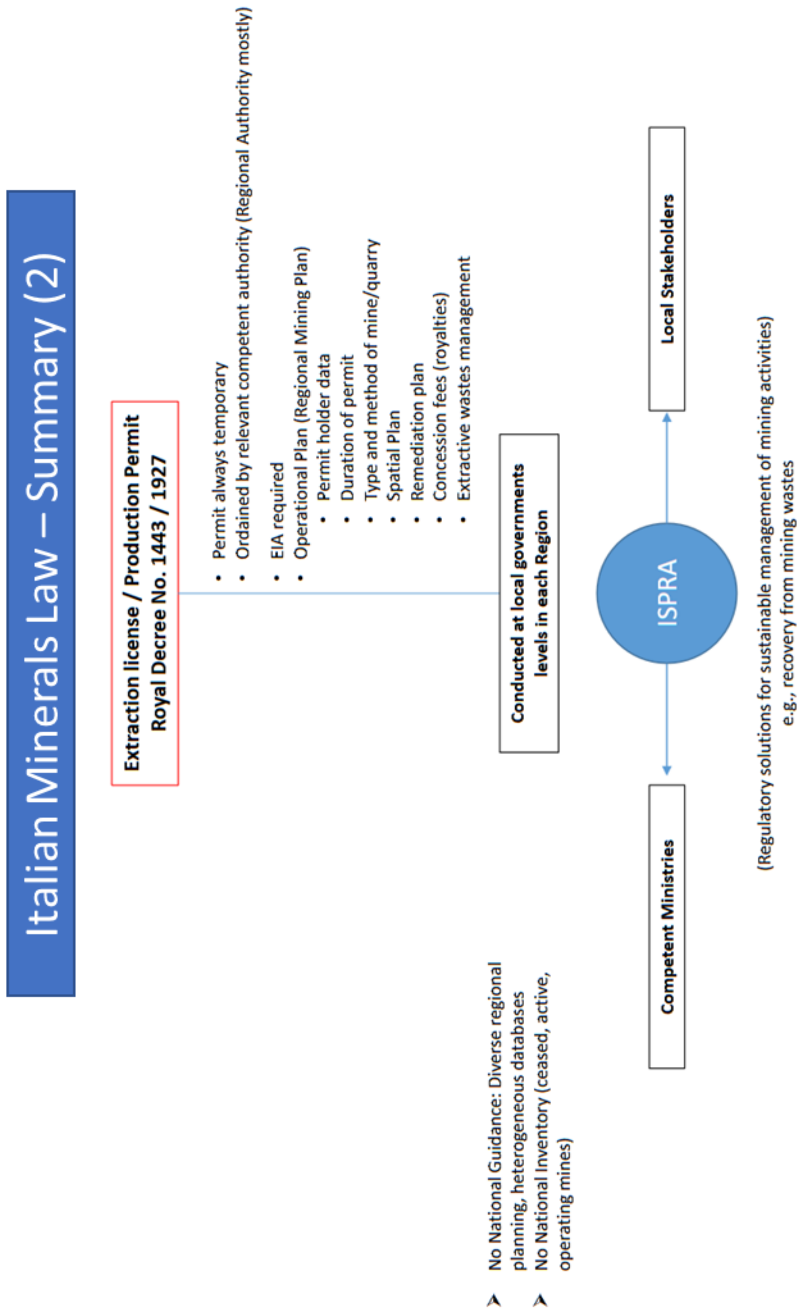


Figure XXII: Summary of the Italian mining permitting procedures

Italy's raw materials sector remains a cornerstone of the national industrial system. The country is a leading European producer of industrial minerals, particularly marble, most notably Carrara marble, gypsum, clay, feldspar, bentonite, limestone, and kaolin, all of which underpin construction, ceramics, glass, and cement industries. Although metallic mineral production has declined, Italy continues to extract lead, zinc, and barite, primarily in Sardinia, Tuscany, and the Apuan Alps, alongside smaller-scale gold and silver operations in northern regions. In the energy domain, domestic production is limited, with modest natural gas extraction in the Po Valley and Adriatic offshore, complemented by an expanding geothermal sector, especially in Tuscany.

Across Europe, the collection of mineral raw materials data is constrained by persistent challenges related to data confidentiality, limited accessibility, and inconsistent reporting practices. Statutory reporting obligations are a key instrument for governments to ensure transparency and continuity in mineral data flows, helping to prevent information losses during corporate bankruptcies, mergers, or license holding without development activities. While publicly listed companies are required to disclose exploration and production information to investors, the growing emphasis on environmental, social, and governance criteria has further increased expectations for transparency, social accountability, and environmental disclosure. This shift has had a direct impact on access to capital, as investors increasingly prioritize sustainable and traceable mining projects, influencing funding availability for exploration and mine development. These challenges are opted in the formulation of CRMA, and the answer to data harmonization will flourish through the classification of CRMs projects, from early exploration to producing projects, in UNFC. This will result in an EU-wide CRMs repository based on UNFC, hence strengthening the transformation and the development of an EU CRMs knowledge base.

At present, Italy does not enforce a legally binding national or internationally recognized classification system for the reporting of mineral resources and reserves. As a result, raw materials information remains fragmented across regions, characterized by heterogeneous terminology, non-harmonized data formats, and irregular reporting intervals (MINLEX Project, 2019). Although exploration companies are legally required to submit resource and reserve data to the competent regional authorities, the decentralized governance structure has led to significant variability in data quality, consistency, and accessibility. On that note, the absence of reporting obligation does not refrain industry from reporting in international codes for investment purposes, such as on stock exchange programs.

Most Italian regions have established Regional Plans for Extractive Activities (PRAE), which are designed to regulate the full lifecycle of extractive operations, from site identification and exploration to extraction, closure, and post-mining remediation. These plans aim to balance mineral resource utilization with environmental protection and land-use planning. However, the legislative basis, scope, and implementation of PRAEs vary considerably between regions, reflecting differences in regional laws and administrative practices. Consequently, the level of detail and consistency of reported data differs significantly across the national territory. Primary raw materials data in Italy are collected predominantly at the regional level. Regional authorities are responsible for the administration and supervision of mineral and thermal waters, as established by Presidential Decree No. 616 of 24 July 1977 (Articles 61 and 62), as well as for quarries and peat bogs. Competences related to solid mineral extraction and mining activities—both for mines and quarries—were formally transferred from the national government to regions and local authorities by Legislative Decree No. 112 of 31 March 1998 (Articles 33–35). In some cases, provinces and municipalities are designated by regional governments to carry out specific functions related to exploration, evaluation, development, and production. Data collection procedures are therefore defined by regional legislation and implemented through region-specific administrative systems (Figure XXIII). For each extraction site, most regional databases include information on production volumes and remaining reserves, with data typically collected on an annual basis. However, offshore and marine raw materials are generally excluded from regional datasets. At the national level, responsibilities are more limited and focus mainly on industrial and metallic minerals, mining exploration (including activities abroad), mining industry data gathering, and the formulation of national mining policies. The Raw Materials Laboratory of the Ministry of Industry and Made in Italy (MIMIT) supports regional authorities in raw materials governance and contributes to the identification of strategic minerals at the national level, in alignment with European raw materials policy. The Geological Survey of Italy, operating within ISPRA, collects statistical data on quarrying activities through the Environmental Data Yearbook and maintains a historical database covering industrial and metallic mineral extraction from 1860 to 2007. In addition, the Italian National Institute of Statistics (ISTAT) gathers economic, financial, and statistical data related to mining and quarrying activities. Together, these datasets provide nationwide coverage of primary raw materials, although they remain aggregated from heterogeneous regional sources.

ISRPA / ISTAT	Arranging Harmonized mining census across Italy based on international standard codes, in collaboration with MIMIT
Ministry of Industry and Made in Italy (MIMIT)	Supports regional policies for raw materials exploitation; collaboration on defining minerals in line with EU policies
Exploration Companies	Reports resource and reserve data for regional territories, required by statutory obligation
ISTAT	Gathers economic, financial, and statistical mining data; collaborates with ISPRA for national harmonized mining activity census
Geological Survey of Italy (ISPRA)	Collects statistical data on mining and quarrying activities; maintains data on industrial and metallic mineral extraction; collaborates with ISTAT for mining census using international codes
National Government	Jurisdiction on mining exploration, industrial and metallic minerals, national mining policy, and strategic minerals identification
Local Authorities	Occasionally involved in exploration, evaluation, development, production of raw materials by designation from regions
Regional Authorities	Collects raw material data; administers minerals, thermal waters, quarries, and peat bogs. Manages solid minerals extraction. Implements regional plan for extractive activities

Figure XXIII: Summary of the roles and responsibilities in Italian primary raw materials data collection

Italy benefits from extensive geological mapping coverage, including national geological maps at a scale of 1:100,000 and more detailed 1:50,000 coverage for approximately half of the national territory. The Mining Map of Italy (1:1,000,000) was produced in 1973, while some regions, such as Tuscany and Sardinia, have developed more recent and detailed regional mining maps. Regional authorities also monitor ongoing mineral exploration activities, with exploration companies under statutory obligation to report resource and reserve data for all raw materials within regional jurisdictions. However, it is noteworthy to mention that plans to intensify geologic coverage through mapping are expected as part of the activities listed in the NEP.

Raw materials data are owned and managed by regional or provincial departments responsible for extractive activities. Data storage systems vary widely and include centralized databases, GIS platforms, and online inventories. While datasets are generally spatially referenced, they are not compliant with INSPIRE standards and are usually accessible only through formal requests, often mediated by ISPRA. Furthermore, data are typically available only in Italian, limiting their usability at the European and international levels. A key structural challenge for Italy is the harmonization of a large volume of heterogeneous data, particularly for industrial and metallic minerals, where national aggregation is constrained by inconsistencies in regional databases. The absence of a national reporting code and the lack of systematic application of internationally recognized classification systems further exacerbate these issues. To address these limitations, ISPRA, in collaboration with ISTAT and under the guidance of MIMIT, is developing a national harmonized census of mining and quarrying activities. The objective is to standardize data collection and reporting using international frameworks such as the UNFC or CRIRSCO-aligned systems (ISPRA, 2018; MINLEX Project, 2019). This initiative explicitly recognizes the need to integrate Italian raw materials data into broader European and international classification and reporting systems, particularly in the context of CRMA (European Commission, 2024). However, until such a system is fully implemented and formally adopted, raw materials data collection in Italy remains characterized by incoherent practices, decentralized governance, and the absence of a common system specification. Even where consistent data collection exists at the regional level, differences in legal frameworks and reporting standards continue to pose significant barriers to national and EU-level harmonization.

Therefore, CRMA reinforces the need for Italy to develop a comprehensive and standardized inventory of its raw material resources. Aligning national data collection and reporting practices with frameworks such as the UNFC is essential for ensuring consistency, transparency, and comparability across the EU. Integrating UNFC into Italy's resource management system would not only support compliance with the CRMA but also enhance national capacity for sustainable resource governance, facilitating informed decision-making and long-term strategic planning.

2.5.1 Decree-Law No. 84/2024: Urgent Provisions on Critical Raw Materials of Strategic Interest in Italy

In response to growing geopolitical risks, accelerating demand for CRMs, and increasing supply chain vulnerabilities, Italy has adopted Decree-Law No. 84 of 25 June 2024. This represents a decisive step in aligning national legislation with CRMA. The decree was approved by the Council of Ministers on the proposal of the President of the Council, Giorgia Meloni, together with the Minister of Business and Made in Italy and the Minister of the Environment and Energy Security. Its overarching objective is to strengthen Italy's contribution to EU strategic autonomy by improving governance, accelerating project development, mobilizing investment, and promoting circular approaches to raw materials supply, while safeguarding environmental and social standards (Senato della Repubblica, 2024).

A central pillar of Decree-Law 84/2024 is the establishment of a reinforced governance architecture for strategic raw materials. The decree designates the Inter-ministerial Committee for Ecological Transition (CITE), expanded to include the Minister of Defense and the Minister for Civil Protection and Marine Policies, as the authority responsible for assessing whether there are overriding public interest or security-related reasons that may prevent Italy from supporting applications submitted to the European Commission for the recognition of projects as "strategic" under the CRMA framework. This provision ensures coherence between national security, environmental protection, and EU-level strategic objectives, while reinforcing Italy's role as an active gatekeeper in the identification of strategic projects involving research, extraction, processing, or recycling of CRMs on national territory (Decree-Law No. 84/2024). To operationalize this framework, the decree establishes three single national contact points, located within the competent ministries, responsible for coordinating and issuing authorizations related to the extraction, transformation, and recycling of strategic CRMs. In line with the CRMA, maximum permitting timelines are introduced, set at 18 months for extraction projects and 10 months for recycling or transformation projects, significantly reducing administrative uncertainty and aligning national procedures with EU targets for accelerated project development (Senato della Repubblica, 2024). It is to be noted that this is an extra step towards accelerating the permitting process in Italy, as opposed to CRMA's timeline for extraction permits, as well as processing and recycling.

The decree further establishes a Technical Committee for Critical and Strategic Raw Materials within the Ministry of Business and Made in Italy. This body is tasked with monitoring economic, technical, and strategic developments across CRM supply chains; assessing companies' supply needs at an aggregate level; and coordinating and monitoring available stock levels of strategic raw materials and evaluating supply security risks. Every three years, the Technical Committee is required to prepare a National Plan for Critical Raw Materials, to be approved by the expanded CITE. This plan is intended to provide an integrated overview of national priorities, planned actions, financing instruments, and expected outcomes, thereby creating a structured and forward-looking framework for Italy's raw materials strategy. The plan also serves as a key interface between national policy and EU-level monitoring and stress-testing mechanisms foreseen under CRMA (Senato della Repubblica, 2024).

Additionally, recognizing that security of supply begins with geological knowledge, Decree-Law 84/2024 entrusts ISPRA with the development of the NEP, to be implemented through agreements with the competent ministries. This programme includes: systematic mineral mapping; geothermal exploration campaigns; geognostic investigations; and processing and integration of data derived from general exploration activities. The programme is further elaborated in later chapters of this thesis. This measure marks a significant shift toward a more proactive, state-supported approach to upstream exploration, addressing long-standing underinvestment in geological knowledge and reinforcing the evidence base required for strategic decision-making. It also provides a critical foundation for applying internationally recognized classification systems, such as the UNFC, in support of CRMA implementation. To further reduce procedural bottlenecks, the decree introduces simplified procedures for exploration activities related to strategic raw materials. Notifications of exploration permits with a duration not exceeding two years are submitted to a single contact point at the Ministry of Environment and Energy Security, which then informs the Technical Committee. Exploration activities may commence 30 days after notification, unless objections are raised. Supervision and control functions are assigned to ISPRA and the territorially competent Superintendence, which are empowered to verify compliance and, where necessary, order the suspension of exploration activities in case of irregularities. This approach balances procedural acceleration with regulatory oversight, ensuring that environmental and technical standards are not compromised (Senato della Repubblica, 2024). Moreover, Decree-Law 84/2024 introduces a production contribution mechanism for mining concessions associated with strategic projects involving the transformation of CRMs. Concession holders are required to pay annually a quota equivalent to 5–7% of the value of production, payable to the State for offshore projects, or jointly to the State and the host region for onshore projects. Funds accruing to the State are channeled into the National Made in Italy Fund and earmarked for reinvestment in strategic CRM supply chains. This mechanism reflects a policy shift toward enhanced value capture and reinvestment, ensuring that strategic raw materials development contributes directly to national industrial resilience and regional development. In line with circular economy principles and CRMA objectives, the decree introduces a Plan for the Recovery of Raw Materials from Historical Mining Waste. The recovery of mineral substances from closed or abandoned waste facilities is permitted only upon submission of a dedicated Recovery Plan, demonstrating the economic and environmental sustainability of the entire lifecycle. Where sites are contaminated or subject to remediation procedures, the Recovery Plan must be consistent with existing remediation projects and include measures to prevent the dispersion of pollutants. This provision formalizes secondary resource recovery as a strategic supply option, while ensuring coherence with environmental protection obligations (Senato della Repubblica, 2024). To reduce legal uncertainty and delays, the decree introduces simplified and accelerated administrative judicial procedures for disputes concerning the recognition or authorization of strategic CRM projects. These procedures mirror those adopted for projects under Italy's National Recovery and Resilience Plan (PNRR), reflecting the strategic importance attributed to CRM projects in the national interest (Senato della Repubblica, 2024). Another measure involves the National Register of Companies and Strategic Value Chains, established at the Ministry of Business and Made in Italy. The register serves as a monitoring and analytical tool to assess national supply needs, conduct stress tests, and support evidence-based policymaking. This instrument enhances transparency and supports coordination between industrial policy, investment planning, and supply chain resilience. Finally, Decree-Law 84/2024 expands the scope of the National Made in Italy Fund, enabling it to support the extraction, processing, and transformation of CRMs, as well as the development of enabling infrastructure. The decree allows for:

- increased funding through contributions from public administrations;
- investments in equity and risk instruments issued by Italian non-financial companies;
- investments in real estate assets, including public assets, instrumental to strategic supply chains;
- the designation of additional fund managers within defined expenditure limits.

These measures significantly enhance Italy's capacity to mobilize public and private capital in support of strategic CRM value chains, in alignment with both industrial policy and EU strategic autonomy objectives (Table 3).

Table 3: Summary of Decree-Law No. 84 of 25 June 2024, linked to UNFC

Article	Decision/Strategy	Points of Contact	Action Plan	UNFC relevant
Art. 8 – Production Royalties	Introduces a production royalty (5-7%) for strategic mining concessions. Funds go to the state (offshore projects) or state & region (onshore projects).	Ministry of Economy and Finance, Ministry of Environment and Energy Security, Ministry of Industry and Made in Italy	Implement via a decree in coordination with the Unified Conference. Allocate funds to the National Made in Italy Fund for strategic raw materials investment.	Unrelated
Art. 9 – Mineral Recovery from Waste	Extends existing mining regulations to allow extraction from closed/abandoned waste storage sites.	Ministry of Environment and Energy Security, Ministry of Industry and Made in Italy	Define eligibility criteria for waste extraction projects. Grant extraction permits under the extended mining law framework.	Yes
Art. 10 – National Exploration Program	Assigns ISPRA (Italian Geological Survey) responsibility for drafting the National Exploration Program.	ISPRA, Ministry of Industry and Made in Italy, Ministry of Environment and Energy Security	Establish a formal agreement between ISPRA and relevant ministries. Develop and implement the exploration program.	Yes
Art. 11 – Strategic Value Chains Monitoring	Requires monitoring of strategic value chains and national needs. Establishes a National Register of Strategic Companies & Value Chains.	Ministry of Industry and Made in Italy	Set up the registry and conduct stress tests to assess vulnerabilities in supply chains.	Yes
Art. 12 – Fast-Track Disputes on Strategic Projects	Applies fast-track legal procedures for disputes over strategic project approvals.	Ministry of Justice, Ministry of Industry and Made in Italy	Align procedures with those used for PNRR-funded projects to accelerate legal resolution.	Unrelated
Art. 13 – Support for Critical Raw Materials Processing & Extraction	Expands the National Made in Italy Fund to include extraction & processing projects. Allows INVIMIT S.p.A. to create investment funds for strategic companies' infrastructure.	Ministry of Industry and Made in Italy, INVIMIT S.p.A.	Amend fund regulations. Identify eligible projects and investment opportunities.	Unrelated

Art. 14 – Export Controls on Critical Raw Materials	Strengthens export notification requirements for critical raw materials, including scrap metals. Establishes a monitoring committee.	Ministry of Industry and Made in Italy, Ministry of Foreign Affairs	Update regulations to include EU tariff codes. Monitor and evaluate market impacts.	Unrelated
Art. 15 – Coordination of Sectoral Policies	Adjusts the role of the Interministerial Committee for Ecological Transition (CITE).	CITE, Ministry of Industry and Made in Italy	Align CITE's functions with new industrial policies.	Unrelated
Art. 16 – Strategic Companies Oversight	Modifies rules on transactions involving strategic companies.	Ministry of Industry and Made in Italy	Implement regulatory adjustments for foreign and domestic investments.	Unrelated
Art. 17 – Decree Implementation	Establishes decree enforcement timeline.	Government of Italy	Publish and execute the decree following parliamentary approval.	Unrelated
Motivation & Urgency	Ensures secure supply of critical raw materials and strengthens supply chains. Recognizes strategic projects as being of high public interest.	Government of Italy, Parliament	Fast-track legislative approval. Align policies with EU strategies.	Unrelated
Legislative Competence	Confirms state authority over competition and environmental protection. Notes regional role in mining sector.	Constitutional Court, Ministry of Industry and Made in Italy, Regional Authorities	Ensure compliance with national and EU laws. Address potential regional concerns.	Unrelated

Chapter 3

EU Strategic Projects and UNFC

3.1 Background and Scope of Work

The transition to a climate-neutral, digital, and industrially resilient Europe is contingent upon the availability of reliable and sustainable supplies of CRMs. These materials are indispensable for the manufacture of technologies underpinning the green and digital transitions, including batteries, wind turbines, solar panels, hydrogen systems, and advanced electronics. Recognizing the escalating global competition for access to CRMs and the EU's increasing import dependence, the European Commission proposed CRMA as part of the broader Green Deal Industrial Plan. CRMA aims to strengthen the Union's capacities across the CRM value chain, from early exploration and extraction to processing, recycling, and substitution, thereby ensuring a secure, diversified, and sustainable supply base (European Commission, 2024).

A central instrument of CRMA is the designation of Strategic Projects, which represent a key operational mechanism to deliver on the Regulation's objectives. According to CRMA, Strategic Projects are defined as raw materials recovery activities, located within or outside the Union, that make a meaningful contribution to the EU's supply of strategic raw materials and adhere to high standards of ESG performance (European Commission, 2024). These projects are designed to accelerate the development of supply chain segments and are subject to a set of streamlined procedures intended to remove administrative barriers, attract investment, and ensure timely implementation, namely through permitting procedures. CRMA necessitates that projects granted the status of "Strategic" benefit from coordinated permitting procedures, access to financial support mechanisms, and inclusion in a dedicated monitoring and foresight framework managed by the European Commission (European Commission, 2024).

The permitting and support measures associated with Strategic Projects further enhance their strategic significance. CRMA establishes time limits for permit granting, typically twenty-seven months for extraction projects and fifteen months for processing and recycling projects, and calls for Member States to appoint single national competent authorities to coordinate authorizations (European Commission, 2024). The Regulation also foresees access to financial instruments, such as guarantees, loans, and equity under EU programmes including InvestEU, the Innovation Fund, and national schemes aligned with State Aid frameworks (European Commission, 2024). The combination of regulatory facilitation with financial support and transparency through monitoring creates a comprehensive enabling environment for strategic raw materials development within Europe.

The rationale for establishing Strategic Projects is grounded in the Union's strategic autonomy and competitiveness agenda. CRMA seeks to mitigate vulnerabilities arising from concentrated global supply chains, particularly the overreliance on third countries for CRMs. Strategic Projects are thus conceived not merely as individual industrial ventures, but as pillars within a systemic approach to CRMs resilience.

Their collective purpose is to contribute to the Union's quantified benchmarks: at least 10 % of annual consumption extracted, 40 % processed, and 25 % recycled within the EU by 2030 (European Commission, 2023). These targets are complemented by the objective of ensuring that no more than 65 % of any strategic raw material at any stage of processing comes from a single third country (Figure XXIV) (European Commission, 2024).

2030 Benchmarks for Strategic Raw Materials

EU Extraction	EU Processing	EU Recycling	External Sources
At least 10% of the EU's annual consumption for extraction	At least 40% of the EU's annual consumption for processing	At least 25% of the EU's annual consumption for recycling	Not more than 65% of the EU's annual consumption of each SRM at any relevant stage of processing from a single third country

Figure XXIV: 2030 Benchmarks for Strategic Raw Materials according to CRMA

Projects are selected through calls for applications managed by the European Commission, open to project promoters. To qualify as a Strategic Project, a project must fulfil a set of eligibility criteria, including the demonstration of technical and financial feasibility, environmental and social sustainability, and potential for cross-border or Union-wide benefits (European Commission, 2024). Applications are assessed against these criteria, and successful projects are formally designated through a European Commission decision, with Member States consultations. Once recognized, Strategic Projects become subject to specific obligations, including periodic reporting, monitoring of progress, and adherence to the principles of CRMA.

A distinctive feature of the CRMA's implementation framework is the requirement that all Strategic Projects proposals be classified according to UNFC. This requirement establishes a direct linkage between project evaluation and internationally standardized classification, ensuring consistency, transparency, and comparability across Member States. The use of UNFC enables projects to be assessed in terms of their socio-economic viability (E axis), technical feasibility (F axis), and degree of geological knowledge or product confidence (G axis), thereby facilitating evidence-based decision-making and providing a harmonized baseline for monitoring over time (UNECE, 2024). In practice, project promoters are required to submit a UNFC classification as part of their application dossier, while independent UNFC expert verifiers review the classification and prepare a consensus report validating the promoter's submission.

The first call for Strategic Projects was launched in May 2024, following the entry into force of CRMA, and concluded in August 2024. This call amassed over 170 applications. In March 2025, the European Commission announced the first wave of designations, recognizing forty-seven projects across thirteen Member States, covering fourteen of the seventeen strategic raw materials listed in CRMA. The three strategic raw materials not targeted are bismuth, silicon metal, and titanium metal. The selected projects encompass various segments of the CRM value chain, including extraction, processing, and recycling. It is necessary to note that this constitutes one of the largest UNFC database of primary and secondary raw materials.

Four of these projects are located in Italy, all focused on recycling activities, underscoring the country's strategic emphasis on circular economy pathways and secondary raw materials recovery (European Commission, 2025). These Italian projects will be analyzed later in this chapter, serving as case studies to demonstrate how UNFC classification supports transparent evaluation and ongoing monitoring.

In this context, the introduction of Strategic Projects under CRMA represents not only a legal innovation but also an operational shift in how the EU manages its raw materials security and industrial resilience. It reflects the recognition that strategic autonomy in CRMs requires coordinated public–private action, supported by scientific classification, structured monitoring, and harmonized governance mechanisms. For Italy, the implementation of CRMA and participation in Strategic Projects present a unique opportunity to align national raw materials policy with European objectives, to mobilize investment in recycling and processing infrastructure, and to contribute directly to the Union's circularity and sustainability goals.

The following sections of this chapter will elaborate on the proposed methodology for applying UNFC to Strategic Projects, including for project promoters and UNFC expert verifiers, both developed during the course of this doctoral work.

3.2 Methodology for Applying UNFC to Strategic Projects

The integration of UNFC into CRMA represents a significant innovation in aligning industrial policy, sustainability governance, and data harmonization within the European Union. Under Article 7 of the CRMA, project promoters applying for the recognition of their projects as Strategic Projects are required to classify their projects according to UNFC and to provide supporting evidence for their classification (European Commission, 2024).

The presented methodological frameworks were developed under the supervision and support of Dr. Slavko Šolar, who significantly contributed to the conceptualization and the methodological development of both frameworks, for project promoters and UNFC experts. They aim to operationalize this requirement by providing detailed guidance for both project promoters and UNFC expert verifiers. The contribution of this work lies in establishing a standardized and transparent process for UNFC classification under CRMA, ensuring consistent application across Strategic Projects, reducing subjectivity in interpretation, and enabling effective monitoring of Strategic Projects over time.

3.2.1 Classification of Strategic Projects by Project Promoters in UNFC

The proposed methodology is built on a set of pre-defined guiding principles, anchored mainly on facilitating the UNFC application to Strategic Project proposals. According to Section 2 ("Strategic Projects"), Article 7 ("Application and recognition") of CRMA, each application for recognition as a Strategic Project must include a classification of the project according to the United Nations Framework Classification for Resources, supported by appropriate evidence (European Commission, 2024). The inclusion of this requirement ensures that projects are evaluated within a structured, internationally recognized framework that reflects their environmental-socio-economic viability, technical maturity, and confidence in resource estimates.

UNFC serves as a comprehensive scheme applicable to projects involving extraction, processing, recycling, and substitution of raw materials, and is designed to communicate the project's sustainability characteristics, technical progress, and level of confidence in its outputs. Within the CRMA context, UNFC does not determine whether a project qualifies for Strategic status. Rather, it functions as a monitoring instrument, enabling evaluators to identify project strengths, gaps, and potential bottlenecks (UNECE, 2024).

Project promoters are therefore responsible for preparing and submitting their project classification according to UNFC as part of their Strategic Project application. The accompanying documentation must substantiate the classification by providing details on the project's resource potential, technological feasibility, economic viability, and environmental and social performance. Following submission, the classification is subject to review by the European Commission in consultation with technical experts and UNFC specialists, who assess its consistency and accuracy.

The classification process involves two main stages. First, project promoters conduct a self-assessment and classify their project in accordance with UNFC principles; this initial step is expected to be efficient and evidence-based, generally requiring less than a day to complete once supporting materials are assembled. Second, upon the Commission's completeness check, a technical verification is performed by independent UNFC experts, whose findings are incorporated into the Commission's assessment. The final outcome is communicated back to the promoter through an evaluation consensus report.

Importantly, the UNFC class assigned to a project is not determinative of its selection as a Strategic Project under the CRMA. Instead, it provides structured insight into the project's maturity and sustainability dimensions, supporting evidence-based policy decisions and facilitating the identification of areas requiring regulatory or financial support. For instance, projects classified under categories reflecting pending development (e.g., *E2; F2.1; G2*) may be prioritized for permitting acceleration or investment facilitation. This systematic approach allows the European Commission to integrate UNFC results into its Strategic Project monitoring and foresight framework, providing a consistent mechanism for tracking progress toward CRMA objectives by 2030 (European Commission, 2024).

The classification of Strategic Projects according to UNFC follows a structured, hierarchical approach, progressing from broad-level assessment to detailed categorization. This top-down methodology ensures coherence between the project's overall viability and the specific parameters assessed under each axis:

1. **UNFC Class Assignment**
   The process begins with the determination of the UNFC Class, providing a general indication of the project's viability — whether *Viable*, *Potentially Viable*, or *Non-Viable*. This establishes the baseline for subsequent classification steps.

2. **Sub-Class Identification**
   The next step refines the classification by identifying the appropriate Sub-Class, which specifies the project's developmental or operational status (e.g., *Development Pending*, *On Production*, *Justified for Development*).

3. **Categories and Sub-Categories (E, F, G Axes)**
   Each project is then assigned categories under the UNFC's three principal axes:

   - **E (Socio-economic Viability)** — assessing the project's environmental, social, and economic context.
   - **F (Technical Feasibility)** — evaluating the level of technological development, permitting status, and operational readiness.
   - **G (Degree of Confidence in Estimates)** — reflecting the reliability and uncertainty of geological or resource data.
     Sub-categories are then defined based on the level of evidence and maturity corresponding to each axis.

4. **Overall Classification and Verification**
   Once the E, F, and G categories are determined, they are combined into a composite UNFC code (e.g., *E1.1; F2.1; G2*). This integrated classification is reviewed for coherence and internal consistency by technical experts.

5. **Linkage with the CRMA Strategic Projects Form**
   Finally, each classification is cross-referenced with the relevant fields in the

CRMA's Strategic Project Application Form, where specific questions and documentation requirements act as Controlling Factors (CFs) for the corresponding UNFC axes (UNECE, 2024).

This systematic progression from Class-level determination to detailed categorization enables project promoters to derive a holistic understanding of their project's sustainability profile, maturity level, and developmental readiness (Figure XXV). The full and detailed guidance and methodology for the classification of Strategic Projects applications in UNFC by project promoters is published online, under the UNECE Sustainable Resource Management Knowledge Hub (link[1]).

[1] https://unece.org/sed/documents/2025/07/working-documents/guidance-classifying-strategic-projects-according-unfc

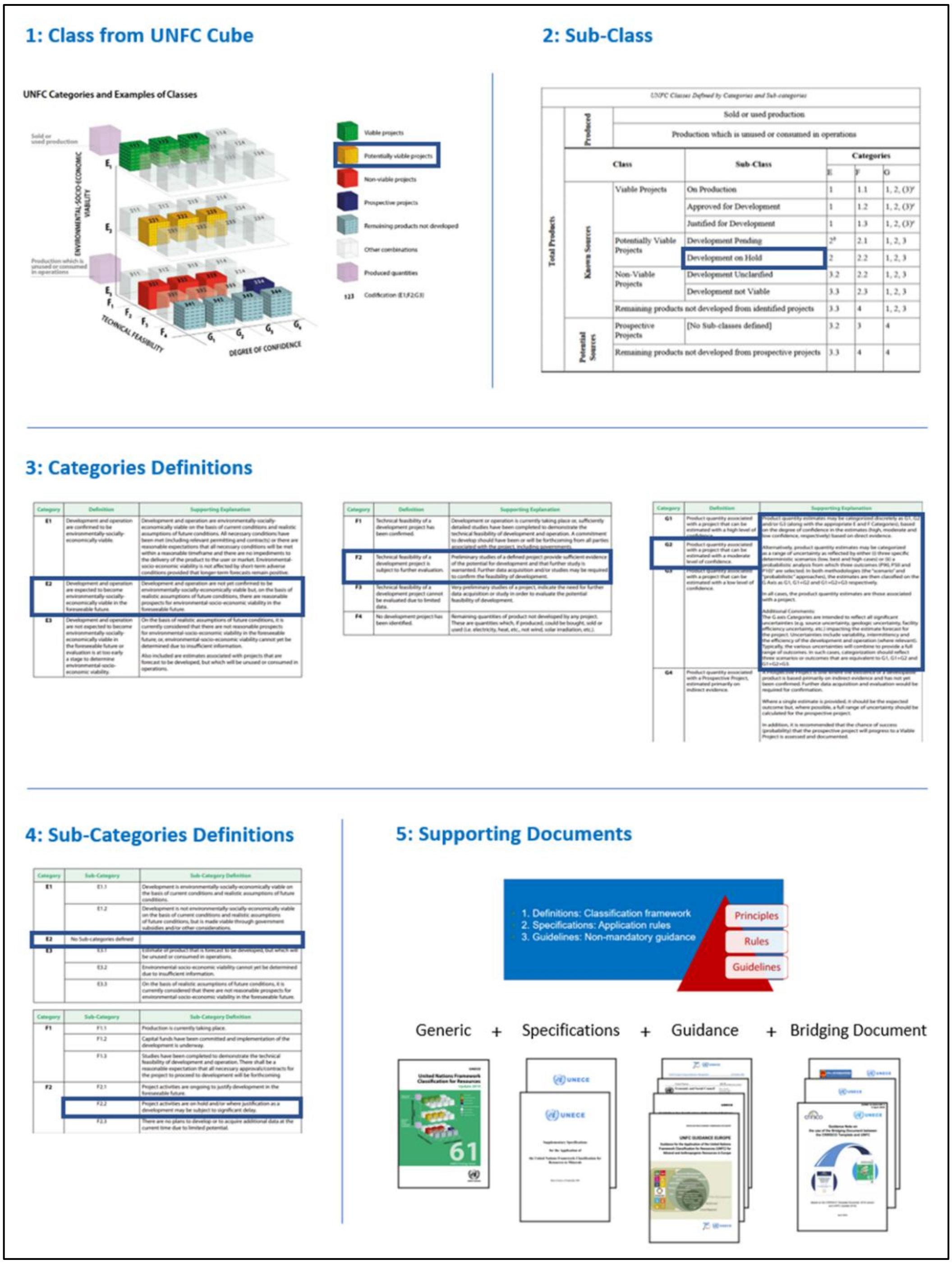


Figure XXV: Proposed Top-down methodology for Classifying Strategic Projects according to UNFC

3.2.2 Methodology for Verifying the UNFC Classification of Strategic Projects by UNFC Experts

Developed under the coordination and support of UNECE colleagues, this proposed methodology aims to support UNFC experts in validating and, where appropriate, refining the UNFC classifications submitted by project promoters under CRMA. Its purpose is to ensure that the technical assessment of Strategic Project applications is consistent, transparent, objective and reproducible, while remaining aligned with the information requirements of the Strategic Project Application Form (SPF) and the policy objectives of CRMA. The guidance recognizes that the evaluators will operate within a time-constrained, multi-expert review environment organized by the European Commission (DG GROW), and therefore specifies a pragmatic, evidence-based workflow, supported by an evaluation grid that maps SPF requirements to UNFC axes and categories.

The evaluation framework is founded on three basic assumptions. First, the SPF is the primary source document for the UNFC evaluation and should be treated as the canonical summary of the project; supporting documents are used to clarify or corroborate, not to replace, the SPF submission. Second, UNFC experts operate on a presumption of good faith regarding the promoter's submission; the role of the evaluator is to assess the information presented against UNFC criteria rather than to perform a full due-diligence audit. Third, the methodology aims to balance speed and rigor: it must be capable of producing defensible classifications within the timeframes allocated for the CRMA technical assessment while preserving traceability and reproducibility of decisions.

The UNFC verification methodology proposed here aligns with the top-down classification approach expected of promoters. To standardize judgments and reduce subjectivity, the methodology uses two complementary tools: (i) a list of "Key Terms" that serve as quick indicators of maturity and evidence in the SPF (Table 4); and (ii) an Evaluation Grid that translates SPF responses and documentary evidence into mapped UNFC categories for each axis. The process is iterative: an initial scan of the SPF and Key Terms yields an early classification hypothesis that is then tested and refined through systematic completion of the Grid and, if needed, consultation with additional domain experts (financial, technical, ESG).

Table 4: List of possible "Key Terms" provided by the Project Promoter within the SPF

Key Terms		Possible E axis Category/ies	Possible F axis Category/ies	Possible G axis Category/ies
Technical Study	Feasibility	1	1	1, 2
	Prefeasibility	2	2	1, 2
	Scoping Study	2	2	1, 2, 3
Reserve/Resource Assessment Results	Proved Reserve			1
	Probable Reserve			2
	Measured Resource			1
	Indicated Resource			2
	Inferred Resource			3
Confidence Level in Estimates	High			1
	Moderate			2
	Low			3
	Secured Supply			1
	Supply Continuity Agreements			1
Technical Study based on recognizable standards		1, 2	1, 2	1, 2
Reserve / Resource Estimates Compliant with National / International Standards				1, 2, 3
Permit Status*	Acquired	1		
	Pending	2		
	Not Permitted	3		
Technical Development	In Production	1	1	
	Construction Ongoing	1	1	
	Advanced Development Stage	1	1, 2	
	Planning Stage	2	2	
	Available Infrastructure		1, 2	
	Infrastructure Support Needed		2, 3	
	Confirmed Development		1	
	Detailed Engineering Phase	1	1, 2	

	Region with Significant Mining History	1, 2		
	TRL (UNFC Guidance Europe)		1, 2, 3	
	Intellectual Property Rights	1, 2	1	
	Commercially Available Technology		1, 2	
Environmental Impact	EIA available	1		
	SEIA available	1		
	Other environmental impact assessment reports available	1		
Social Impact	SLO available	1		
	Health and Safety Measures	1		
	Local Support	1		
	Compliance with Social Standards / Protocols	1		
	Social Adversary / Opposition	3		
Financially Viable		1, 2	1, 2	

* This applies to all types of permit/license necessary for the project to go in production

The Evaluation Grid is organized into three sections that mirror the SPF input types: (1) Direct Input (closed questions), (2) Summarization (open answers requiring quality judgement), and (3) Supporting Documentation. Each cell in the grid contains predefined response options that are explicitly mapped to UNFC categories. Direct Input fields produce immediate mappings (e.g., "Permit granted" could be an E1), summarization fields are assessed against three quality bands (satisfactory / adequate / unsatisfactory) which are mapped to UNFC options, and supporting documentation is categorized as "provided / incomplete / not provided" with corresponding UNFC implications. This structure ensures that the same evidentiary standard is applied across evaluators and projects, and provides a clear audit trail of how each SPF item influenced the final axis assignment. The proposed evaluation grid is included in the guidance developed for UNFC experts, published online under the UNECE Sustainable Resource Management Knowledge Hub (link[2]). The guidance also includes additional instructions on verifying the UNFC classification of Strategic Projects, particularly for the G axis, under the same webpage.

Practical evaluation steps

The recommended stepwise procedure for the individual evaluator is as follows:

1. **Initial Review:** Read the SPF in full to establish the project scope, objectives for Strategic recognition (e.g., permitting acceleration, access to finance), key materials targeted and the promoter's self-declared UNFC classification. Note any immediate gaps or ambiguities.

2. **Key Terms Scan:** Use the pre-prepared Key Terms checklist to capture phrases and claims indicative of class-level maturity (e.g., "feasibility completed", "extraction permit issued", "pilot plant operating", "independent reserve estimate signed by Competent Person"). These entries provide an initial signal for E/F/G categories but are not determinative.

3. **Populate the Evaluation Grid:** For each SPF field, select the predefined option that best reflects the promoter's response and supporting documentation. Ensure consistency between related fields (for example, a claim of "production within 24 months" should correspond with F1 options).

4. **Axis-by-axis Assessment:** Derive candidate E, F and G categories from the completed Grid. Pay attention to internal coherence: a high F (near-production) combined with a low G (poor data) or low E (weak economics/ESG) indicates a potential inconsistency that must be resolved or documented.

5. **Apply Decision Rule:** Determine whether to apply Balanced Judgment or Lowest-Rank Prevails. The guidance recommends using balanced judgment when strengths in one axis plausibly mitigate moderate weaknesses in another (e.g., strong financial backing offsetting technical scale-up risk), and reserving the lowest-rank approach where minimum standards must be enforced (e.g., environmental compliance required for permitting). The choice should be justified explicitly in the evaluator's notes.

[2] https://unece.org/sed/documents/2025/07/working-documents/guidance-evaluating-strategic-projects-classification-unfc

6. **Sub-category and Subclass Alignment:** Translate the axis categories into the appropriate UNFC Class/Sub-class (e.g., E1.1; F2.1; G2) using the top-down check: the selected UNFC Class must be consistent with the axis outcomes.

7. **Document Discrepancies:** If the evaluator's classification diverges from the promoter's declaration, document the precise reasons and reference the SPF fields or supporting documents that justify the alternative view.

8. **Finalize Individual Evaluation Form:** Complete the Individual UNFC Evaluation Form capturing the Grid results, axis rationales, any caveats and a preliminary recommendation for the consensus stage.

E, F and G axis verification — guidance and common issues

When verifying the **E axis**, evaluators should focus on legal/regulatory status, market assumptions, cash-flow viability, environmental permits and social license elements. Key evidence includes business plans, permitting decisions, environmental impact statements, and an explicit statement of compliance with applicable EU and national standards. The evaluator must flag areas where economic assumptions are unsupported or contingent on optimistic scenarios.

For the **F axis**, the evaluator examines project stage (scoping, prefeasibility, feasibility, pilot, production), technology readiness, infrastructure availability, and technical risks. Evidence comprises feasibility studies, pilot test results, engineering designs, and third-party technical reviews. Where infrastructure or technology access is conditional (e.g., dependency on third-party processing), the evaluator should reflect the contingent nature of technical feasibility in the F assignment.

The **G axis** frequently raises nuanced issues. The SPF constrains submissions to a single G value (G1, G2 or G3) whereas UNFC permits composite statements (e.g., G1+G2). Evaluators should normally prefer a single G assessment that reflects the promoter's best supported estimate of probability (G1 >90 %, G2 50–90 %, G3 <50 %) consistent with the project's investigations and independent verifications. If the promoter presents a range (or multiple estimates), the evaluator must determine whether this represents a legitimate "position in uncertainty range" or an inconsistent reporting approach; use of ranges should be justified with methodological transparency. Evaluators should consult the G-axis Task Force recommendations where needed.

Supporting documentation is essential when G assignments are borderline or when composite G reporting is used. Drilling logs, reserve reports certified by recognized Competent Persons (e.g., CRIRSCO/ PERC), statistical confidence intervals and clearly described extrapolation methods all strengthen a higher-confidence G assignment.

Handling discrepancies and consensus building

Discrepancies between the promoter's declared UNFC classification and the evaluator's assessment are to be expected. Each evaluator must record these divergences in their Individual UNFC Evaluation Form with concise, evidence-backed explanations. Where significant disagreements arise, a consensus meeting is convened with the panel of evaluators (technical, financial, ESG and UNFC specialists). The consensus process follows structured deliberation: each expert presents their rationale, evidence is collectively reviewed, and a final consensus classification is arrived at and documented. If consensus cannot be achieved, the dissenting views are recorded and escalated to the Commission's technical lead for resolution. Transparency of reasoning is critical; the consensus report must capture the arguments, the final agreed classification and any recommendations for remediation or further information requests.

Reporting, traceability and reproducibility

All evaluation outputs, the completed Grid, Individual Evaluation Forms (Table 5), the consensus report, and references to SPF evidence, must be retained in a manner that supports auditability and future reclassification. The proposed methodology recommends standardized templates and mandatory fields for rationale, key references and the decision rule applied (balanced judgment or lowest rank). This documentation is essential both for Commission oversight and for subsequent monitoring: UNFC classifications are living records that may be updated as projects progress or as new information emerges.

Evaluators should apply the Grid methodically, justify any departures from promoter classifications with clear evidence, prefer single G assignments unless ranges are rigorously justified, and use balanced judgment selectively while reserving lowest-rank rules for matters of minimum compliance or high risk. Above all, decisions must be transparent and defensible: the goal of the guidance is not to restrict projects arbitrarily, but to ensure that recognition as a Strategic Project rests on a consistent, evidence-based interpretation of UNFC tied directly to the SPF and CRMA policy objectives.

Table 5: Strategic projects applications assessment under the CRMA Call

Evaluator Name	
Application ID	
Project Promoter	
Project Name	
Project Location	
Project Type	
Strategic Raw Material/s	

E axis Classification - Environmental-Socio-Economic Viability	**Category and Sub-category:**
	Key Terms:
	Justification: Legal Framework: Economic Aspects: Environmental Considerations: Social Impact: Governance Practices:
F axis Classification - Technical Feasibility	**Category and Sub-category:**
	Key Terms:
	Justification:
G axis Classification – Degree of Confidence	**Category:**
	Key Terms:
	Justification:
UNFC Classification of the Project by Evaluator	**UNFC Code:**
	UNFC Class and Sub-class:
	Key Terms:
	Justification:
Does the Evaluator's UNFC Classification differ from the Project Promoter's UNFC Classification?	☐ **YES** ☐ **NO**
	Justification:

3.3 Overview of the Recognized Strategic Projects in Italy under CRMA's First Call for Applications

Italy has emerged an active Member States in advancing projects recognized under the first call for applications of Strategic Projects. Four Italian projects were officially recognized as Strategic Projects. These projects span across the recycling value chain for several key strategic raw materials, including lithium, nickel, cobalt, copper, PGMs, and REEs. Each of these projects contributes uniquely to the EU's targets for securing access to CRMs, promoting circularity, and supporting the green and digital transitions through recycling and recovery technologies. Table 6 summarizes their main features and UNFC classification (Figure XXVI).

Table 6: List of designated Strategic Projects in Italy, 2025

Name	Type of Project	Strategic Raw Materials	Estimated Production	UNFC Code	UNFC Class	UNFC Sub-Class
Alpha Project	Recycling	PGMs	2027	E1.1; F2.1; G1	Viable	Development Pending
LIFE-22-ENV-IT-INSPIREE	Recycling	REEs	2026 (full capacity 2029)	E2; F1.3; G3	Potentially Viable	Justified for Development
Portovesme CRM Hub	Recycling	Lithium, Nickel, Cobalt, Copper	2029	E2; F2.1; G3	Potentially Viable	Development Pending
RECOVER-IT	Recycling	Copper, Nickel, PGMs	2026 (full capacity 2029)	E1.1; F1.1; G1	Viable	On Production / Near Production

Alpha Project (Rosignano Solvay, Tuscany) — The Alpha Project represents a flagship recycling initiative focused on the recovery of palladium from industrial catalysts, aiming to establish a fully circular, in-house palladium recovery and catalyst production facility. This project is expected to become operational by 2027 and is classified as *E1.1; F2.1; G1*, indicating a *viable* project that is *development pending* under the UNFC system. By closing the loop on PGMs, Alpha will strengthen the resilience and competitiveness of the European industrial ecosystem, reducing dependence on imports from high-risk suppliers (European Commission, 2025).

LIFE-22-ENV-IT-INSPIREE (Frosinone, Lazio) — INSPIREE focuses on the recovery of rare earth elements (REEs) from end-of-life NdFeB permanent magnets sourced from hard disks and electric motors. The project applies a two-stage process combining mechanical disassembly and hydrometallurgical recovery to yield REE oxides, oxalates, carbonates, and other compounds. Operational readiness is expected by 2026, with full capacity by 2029. The project has been assigned *E2; F1.3; G3*, corresponding to a *potentially viable* project *justified for development* (European Commission, 2025). Its innovative design directly contributes to the EU's objective of increasing REE recycling capacity, a critical bottleneck identified in the CRMA (European Commission, 2025).

Portovesme CRM Hub (Portovesme, Sardinia) — This initiative, located within an established metallurgical site in Sardinia, is designed to recover lithium, nickel, cobalt, and copper from black mass derived from pre-treated end-of-life batteries and scrap materials across Europe. Employing advanced hydrometallurgical processes, the project will enable the production of battery-grade materials domestically, thereby reducing supply chain vulnerability for European giga-factories. Classified as *E2; F2.1; G3*, *potentially viable, development pending*, it represents one of the largest circular battery material projects in Southern Europe (European Commission, 2025).

RECOVER-IT — RECOVER-IT applies a proprietary low-carbon intensity process to extract CRMs such as nickel, copper, and PGMs from industrial wastewater streams. The process, which is already operational at pilot scale, positions the project as a near-production initiative under UNFC (*E1.1; F1.1; G1*). The project's environmental co-benefits are particularly relevant: it integrates waste treatment and resource recovery, aligning with the EU's circular economy and decarbonization targets (European Commission, 2025). RECOVER-IT exemplifies the transition from waste management to resource valorization, a key tenet of sustainable raw materials management under the CRMA framework (European Commission, 2025).

Figure XXVI: Selected Strategic Projects from first call of applications in Italy (European Commission, 2025)

The inclusion of four Italian projects among the EU's first Strategic Projects under CRMA demonstrates Italy's growing role in securing strategic raw material supply chains within the EU. These projects reflect a deliberate policy alignment between Italy's industrial strategy and the EU's objective of enhancing supply resilience, reducing import dependence, and strengthening technological sovereignty. All four recognized projects are recycling projects. This reinforces

Italy's commitment to circularity measures within its national resource strategy, consistent with both the *EU Circular Economy Action Plan* and national legislative efforts. The uptake on domestic recovery of SRMs from industrial residues, black mass, catalysts, and magnets, reduces pressure on primary extraction and mitigate associated environmental impacts, supporting the EU's sustainability objectives. From a regulatory and monitoring standpoint, the UNFC classifications assigned to these projects provide a structured assessment of project maturity. This information will be instrumental in developing Italy's secondary raw materials inventory, ensuring that progress in project development can be tracked transparently over time and integrated into national and EU monitoring frameworks.

Collectively, these Strategic Projects advance Italy's contribution to the CRMA benchmarks, namely the 25% target from recycling for the EU's annual consumption of strategic raw materials domestically by 2030 (European Commission, 2024). They also serve as pilot cases for integrating UNFC-based classification into industrial policy, supporting data-driven decision-making and enabling cross-country comparability within the EU resource governance framework. In this context, Italy is positioning itself not only as a consumer but also as a circular supplier of CRMs, enhancing its strategic importance within the European raw materials ecosystem.

3.4 Supply Risk Analysis based on UNFC

The proposed methodology introduces a UNFC-based approach for assessing the progress and contribution of EU-recognized Strategic Projects toward the supply of SRMs, as defined under the CRMA benchmarks (European Commission, 2024). It is necessary to note that this methodology is only sound in the case of designated Strategic Projects, where estimated production in aggregated form from all projects is indicated, as well as a defined benchmark timeframe. That said, this methodology is transferrable to other cases where such targets are indicated. This approach builds directly on the verified UNFC classification of each Strategic Project following the technical assessment phase conducted by the European Commission with the support of external experts. Once all projects are classified and validated in UNFC, the results can be consolidated into a UNFC-based SRM Inventory, forming a structured database to support a foresight assessment on supply risk, based on periodic monitoring of project maturity, production timelines, and contribution to EU supply targets (Figure XXVII).

Name	Type of Project	Country	Strategic Raw Materials	UNFC Code	UNFC Class	UNFC Sub-Class
Ageli	Integrated: Extraction and processing	France	Lithium (battery grade)	E2; F2.1; G2	Potentially Viable	Development Pending
Aguablanca Project	Extraction	Spain	Cobalt, Platinum Group Metals, Nickel (battery grade), Copper	E1.2; F1.3; G1	Viable	Justified for Development
Alpha Project	Recycling	Italy	Platinum Group Metals	E1.1; F2.1; G1	Viable	Development Pending
BAM4EVER (Phase I&II)	Processing	France	Graphite (battery grade)	E1.2; F1.2; G1	Viable	Approved for Development
Barroso Lithium Project	Extraction	Portugal	Lithium (battery grade)	E1.2; F1.2; G2	Viable	Approved for Development
CAREMAG	Processing	France	Rare Earth Elements for Magnets, Boron (metallurgy grade)	E1.2; F1.3; G1+G2	Viable	Justified for Development
Chvaletice Manganese Project	Integrated: Extraction and processing	Czechia	Manganese (battery grade)	E1.2; F1.3; G1	Viable	Justified for Development
Cinovec lithium project	Integrated: Extraction and processing	Czechia	Lithium (battery grade)	E2; F2.1; G2	Potentially Viable	Development Pending
CirCular	Recycling	Spain	Copper, Platinum Group Metals, Nickel	E1.1; F1.2; G3	Viable	Approved for Development
CO2 Graphite	Processing	Estonia	Graphite (battery grade)	E2; F2.1; G3	Potentially Viable	Development Pending
Emili	Integrated: Extraction and processing	France	Lithium (battery grade)	E2; F2.1; G1+G2+G3	Potentially Viable	Development Pending
European Initiative for Strategic and Sustainable Graphite Production	Processing	France (main location), Namibia, Germany	Graphite (battery grade)	E2; F2.1; G1	Potentially Viable	Development Pending
GALLICAM	Processing	France	Nickel (battery grade), Cobalt (battery grade), Lithium (battery grade), Graphite (battery grade), Manganese (battery grade), Copper	E2; F2.1; G2	Potentially Viable	Development Pending
GePETO	Processing	Belgium	Germanium	E1.1; F1.1; G1	Viable	On Production / Near Production
Hycamite TCD Technologies Ltd	Processing	Finland	Graphite (battery grade)	-		
HYDRO-BATTERY	Recycling	France	Lithium (battery grade), Cobalt, Nickel (battery grade), Manganese, Graphite (battery grade)	E2; F1.3; G3	Potentially Viable	Justified for Development
Jervois Finland Cobalt Refinery Expansion Project	Processing	Finland	Cobalt	E1.2; F1.3; G1	Viable	Justified for Development
KELIBER LITHIUM PROJECT	Integrated: Extraction and processing	Finland	Lithium (battery grade)	E1.2; F1.2; G2	Viable	Approved for Development
Kolmisoppi	Extraction	Finland	Nickel (battery grade), Cobalt	E1.1; F1.1; G1	Viable	On Production / Near Production
La Parrilla Mine (P6 Metals)	Integrated: Extraction and processing	Spain	Tungsten	-		
LAS NAVAS	Extraction	Spain	Lithium (battery grade)	E2; F2.1; G2	Potentially Viable	Development Pending
LIFE-22-ENV- IT- INSPIREE	Recycling	Italy	Rare Earth Elements for Magnets	E2; F1.3; G3	Potentially Viable	Justified for Development
Lift One	Processing	Portugal	Lithium (battery grade)	E2; F2.1; G2	Potentially Viable	Development Pending
Lithium Hydroxide Converter Guben	Processing	Germany	Lithium (battery grade)	E2; F2.1; G2	Potentially Viable	Development Pending
MagFactory	Recycling	France	Rare Earth Elements for Magnets	E1.2; F2.1; G1+G2+G3	Viable	Development Pending
Metlen BAUX-EU, GALLANT, LEADER	Integrated: Extraction and processing	Greece	Bauxite/alumina/aluminium, Gallium	E2; F1.3; G2	Potentially Viable	Justified for Development
MINA DOADE PROJECT	Extraction	Spain	Lithium (battery grade)	E2; F3.1; G2	Potentially Viable	-
Mining project EL MOTO	Extraction	Spain	Tungsten	E1.2; F1.3; G2	Viable	Justified for Development
Neves Corvo - 3RD SILO, LOMBADOR, Semblana	Integrated: Extraction and processing	Portugal	Copper	E1.1; F1.1; G1	Viable	On Production / Near Production
				E1.1; F1.1; G3	Viable	On Production / Near Production
				E2; F2.1; G2	Potentially Viable	Development Pending
NorthCYCLE	Recycling	Sweden	Manganese (battery grade), Lithium (battery grade), Graphite (battery grade), Nickel (battery grade), Cobalt	-		
POLVOLT	Recycling	Poland	Nickel (battery grade), Copper, Cobalt, Lithium (battery grade), Platinum Group Metals, Manganese (battery grade)	E2; F1.3; G2	Potentially Viable	Justified for Development
Polymetallic primary sulphite project PMR project	Integrated: Extraction and processing	Spain	Copper	E1.2; F1.3; G2	Viable	Justified for Development
Portovesme CRM Hub	Recycling	Italy	Lithium (battery grade), Nickel, Cobalt, Copper	E2; F2.1; G3	Potentially Viable	Development Pending
ProHiPerSi	Substitution	Germany	Graphite (battery grade)	E1.2; F1.3; G2	Viable	Justified for Development
Project Fortum Hydromet	Recycling	Finland	Lithium (battery grade), Copper, Nickel (battery grade), Cobalt	E1.1; F1.3; G1	Viable	Justified for Development
Pulawy Rare Earths Separation Plant	Processing	Poland	Rare Earth Elements for Magnets	E2; F2.1; G2	Potentially Viable	Development Pending
RECOVER-IT	Recycling	Italy	Copper, Nickel (battery grade), Platinum Group Metals	E1.1; F1.1; G1	Viable	On Production / Near Production
ReeMAP Project: Malmberget, Lulea Industrial Park, Per Geijer	Integrated: Extraction and processing	Sweden	Rare Earth Elements for Magnets	E2; F2.1; G3	Potentially Viable	Development Pending
ReGAIN	Substitution	Belgium	Germanium	E2; F2.1; G3	Potentially Viable	Development Pending
Romano Mine	Extraction	Portugal	Lithium (battery grade)	E2; F2.1; G2	Potentially Viable	Development Pending
Rovina	Extraction	Romania	Copper	E1.2; F1.2; G1	Viable	Approved for Development
Sakatti Project	Integrated: Extraction and processing	Finland	Cobalt, Platinum Group Metals, Copper, Nickel (battery grade)	E1.2; F2.1; G1+G2	Viable	Development Pending
SALROM Baia de Fier	Extraction	Romania	Graphite (battery grade)	E2; F2.1; G3	Potentially Viable	Development Pending
Talga Natural Graphite ONE	Extraction	Sweden	Graphite (battery grade)	E1.2; F1.3; G2	Viable	Justified for Development
Verde Magnesium	Extraction	Romania	Magnesium Metal	E2; F2.1; G3	Potentially Viable	Development Pending
Viridian Lithium	Processing	France	Lithium (battery grade)	E1.2; F1.3; G2	Viable	Justified for Development
Zero Carbon Lithium	Extraction	Germany	Lithium (battery grade)	E1.1; F1.2; G1+G2	Viable	Approved for Development

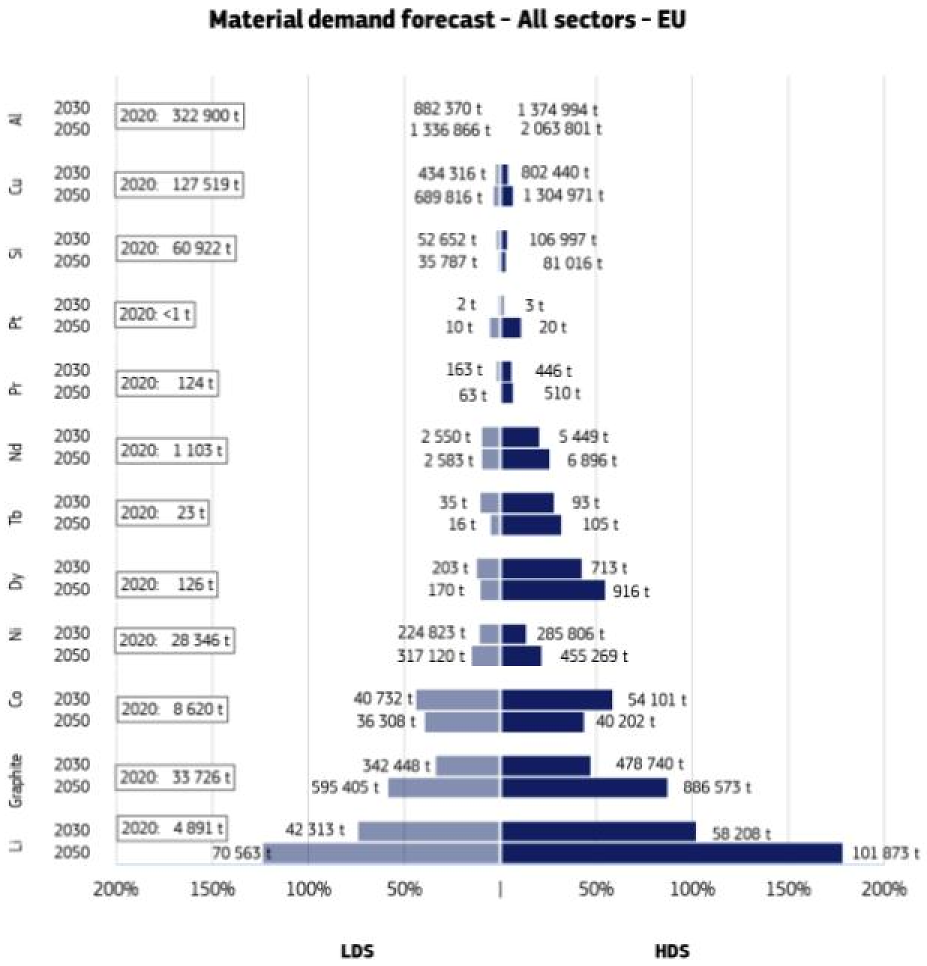
Figure XXVII: List of Recognized Strategic Projects from the first call of application, with the respective verified UNFC classification (European Commision, 2025)

The creation of a UNFC-based inventory allows all targeted SRM to be consistently mapped according to their respective E (environmental–socio-economic viability), F (technical feasibility), and G (degree of confidence) axes. This mapping provides a transparent and comparable overview of which SRMs are "in the pipeline," which are near production (classified as *Viable*), and which remain at earlier development stages (*Potentially Viable* or *Justified for Development*) i.e., UNFC can be a direct indicator of the time-to-market for each SRM. By associating UNFC classes with specific Strategic Projects, policymakers and analysts can visualize the overall supply readiness of SRMs across the EU and at the national level. For instance, projects classified as *E1.1; F1.1; G1* (Viable, On Production) can be considered low-risk contributors to the CRMA benchmarks, whereas projects in *E2; F2; G3* (Potentially Viable, Development Pending) reflect intermediate or high supply risk (Figure XXVIII).

UNFC Code	E			F					G					UNFC	UNFC Class	UNFC Sub-Class
Strategic Raw Material (Project #)	1.1	1.2	2	1.1	1.2	1.3	2.1	3.1	1	1+2	1+2+3	2	3			
Bauxite/alumina/aluminium (26)			■			■						■		2; 1.3; 2	Potentially Viable	Justified for Development
Boron - metallurgy grade (6)		■				■				■				1.2; 1.3; 1+2	Viable	Justified for Development
Cobalt (2)		■				■			■					1.2; 1.3; 1	Viable	Justified for Development
Cobalt (13)			■				■					■		2; 2.1; 2	Potentially Viable	Development Pending
Cobalt (16)			■			■							■	2; 1.3; 3	Potentially Viable	Justified for Development
Cobalt (17)		■				■			■					1.2; 1.3; 1	Viable	Justified for Development
Cobalt (19)	■			■					■					1.1; 1.1; 1	Viable	On Production / Nearing Production
Cobalt (31)			■			■						■		2; 1.3; 2	Potentially Viable	Justified for Development
Cobalt (33)			■				■						■	2; 2.1; 3	Potentially Viable	Justified for Development
Cobalt (35)	■					■			■					1.1; 1.3; 1	Viable	Justified for Development
Cobalt (42)		■					■			■				1.2; 2.1; 1+2	Viable	Development Pending
Copper (2)		■				■			■					1.2; 1.3; 1	Viable	Justified for Development
Copper (9)	■				■								■	1.1; 1.2; 3	Viable	Approved for Development
Copper (13)			■				■					■		2; 2.1; 2	Potentially Viable	Development Pending
Copper (29)	■			■					■					1.1; 1.1; 1	Viable	On Production / Nearing Production
Copper (31)			■			■						■		2; 1.3; 2	Potentially Viable	Justified for Development
Copper (32)		■				■						■		1.2; 1.3; 2	Viable	Justified for Development
Copper (33)			■				■						■	2; 2.1; 3	Potentially Viable	Development Pending
Copper (35)	■					■			■					1.1; 1.3; 1	Viable	Justified for Development
Copper (37)	■			■					■					1.1; 1.1; 1	Viable	On Production / Nearing Production
Copper (41)		■			■				■					1.2; 1.2; 1	Viable	Approved for Development
Copper (42)		■					■			■				1.2; 2.1; 1+2	Viable	Development Pending
Gallium (26)			■			■						■		2; 1.3; 2	Potentially Viable	Justified for Development
Germanium (14)	■			■					■					1.1; 1.1; 1	Viable	On Production / Nearing Production
Germanium (39)			■				■						■	2; 2.1; 3	Potentially Viable	Development Pending
Lithium - batterty grade (1)			■				■					■		2; 2.1; 2	Potentially Viable	Development Pending
Lithium - batterty grade (5)		■			■							■		1.2; 1.2; 2	Viable	Approved for Development
Lithium - batterty grade (8)			■				■					■		2; 2.1; 2	Potentially Viable	Development Pending
Lithium - batterty grade (11)			■				■				■			2; 2.1; 1+2+3	Potentially Viable	Development Pending
Lithium - batterty grade (13)			■				■					■		2; 2.1; 2	Potentially Viable	Development Pending
Lithium - batterty grade (16)			■			■							■	2; 1.3; 3	Potentially Viable	Justified for Development
Lithium - batterty grade (18)		■			■							■		1.2; 1.2; 2	Viable	Approved for Development
Lithium - batterty grade (21)			■				■					■		2; 2.1; 2	Potentially Viable	Development Pending
Lithium - batterty grade (23)			■				■					■		2; 2.1; 2	Potentially Viable	Development Pending
Lithium - batterty grade (24)			■				■					■		2; 2.1; 2	Potentially Viable	Development Pending
Lithium - batterty grade (27)			■					■				■		2; 3.1; 2	Potentially Viable	
Lithium - batterty grade (31)			■			■						■		2; 1.3; 2	Potentially Viable	Justified for Development
Lithium - batterty grade (33)			■				■						■	2; 2.1; 3	Potentially Viable	Development Pending
Lithium - batterty grade (35)	■					■			■					1.1; 1.3; 1	Viable	Justified for Development
Lithium - batterty grade (40)			■				■					■		2; 2.1; 2	Potentially Viable	Development Pending
Lithium - batterty grade (46)		■				■						■		1.2; 1.3; 2	Viable	Justified for Development
Lithium - batterty grade (47)	■				■					■				1.1; 1.2; 1+2	Viable	Approved for Development
Magnesium metal (45)			■				■						■	2; 2.1; 3	Potentially Viable	Development Pending
Manganese - battery grade (7)		■				■			■					1.2; 1.3; 1	Viable	Justified for Development
Manganese - battery grade (13)			■				■					■		2; 2.1; 2	Potentially Viable	Development Pending
Manganese - battery grade (16)			■			■							■	2; 1.3; 3	Potentially Viable	Justified for Development
Manganese - battery grade (31)			■			■						■		2; 1.3; 2	Potentially Viable	Justified for Development
Natural Graphite - battery grade (4)		■			■				■					1.2; 1.2; 1	Viable	Approved for Development
Natural Graphite - battery grade (10)			■				■						■	2; 2.1; 3	Potentially Viable	Development Pending
Natural Graphite - battery grade (12)			■				■		■					2; 2.1; 1	Potentially Viable	Development Pending
Natural Graphite - battery grade (13)			■				■					■		2; 2.1; 2	Potentially Viable	Development Pending
Natural Graphite - battery grade (16)			■			■							■	2; 1.3; 3	Potentially Viable	Justified for Development
Natural Graphite - battery grade (34)		■				■						■		1.2; 1.3; 2	Viable	Justified for Development
Natural Graphite - battery grade (43)			■				■						■	2; 2.1; 3	Potentially Viable	Development Pending
Natural Graphite - battery grade (44)		■				■						■		1.2; 1.3; 2	Viable	Justified for Development
Nickel - battery grade (2)		■				■			■					1.2; 1.3; 1	Viable	Justified for Development
Nickel - battery grade (9)	■				■								■	1.1; 1.2; 3	Viable	Approved for Development
Nickel - battery grade (13)			■				■					■		2; 2.1; 2	Potentially Viable	Development Pending
Nickel - battery grade (16)			■			■							■	2; 1.3; 3	Potentially Viable	Justified for Development
Nickel - battery grade (19)	■			■					■					1.1; 1.1; 1	Viable	On Production / Nearing Production
Nickel - battery grade (32)			■			■						■		2; 1.3; 2	Potentially Viable	Justified for Development
Nickel - battery grade (33)			■				■						■	2; 2.1; 3	Potentially Viable	Development Pending
Nickel - battery grade (35)	■					■			■					1.1; 1.3; 1	Viable	Justified for Development
Nickel - battery grade (37)	■			■					■					1.1; 1.1; 1	Viable	On Production / Nearing Production
Nickel - battery grade (42)		■					■			■				1.2; 2.1; 1+2	Viable	Development Pending
Platinum Group Metals (2)		■				■			■					1.2; 1.3; 1	Viable	Justified for Development
Platinum Group Metals (3)	■						■		■					1.1; 2.1; 1	Viable	Development Pending
Platinum Group Metals (9)	■				■								■	1.1; 1.2; 3	Viable	Approved for Development
Platinum Group Metals (31)			■			■						■		2; 1.3; 2	Potentially Viable	Justified for Development
Platinum Group Metals (37)	■			■					■					1.1; 1.1; 1	Viable	On Production / Nearing Production
Platinum Group Metals (42)		■					■			■				1.2; 2.1; 1+2	Viable	Development Pending
Rare Earth Elements for Magnets (6)		■				■				■				1.2; 1.3; 1+2	Viable	Justified for Development
Rare Earth Elements for Magnets (22)			■			■							■	2; 1.3; 3	Potentially Viable	Justified for Development
Rare Earth Elements for Magnets (25)		■					■				■			1.2; 2.1; 1+2+3	Viable	Development Pending
Rare Earth Elements for Magnets (36)			■				■					■		2; 2.1; 2	Potentially Viable	Development Pending
Rare Earth Elements for Magnets (38)			■				■						■	2; 2.1; 3	Potentially Viable	Development Pending
Tungsten (28)		■				■						■		1.2; 1.3; 2	Viable	Justified for Development

Figure XXVIII: UNFC-based inventory of the selected Strategic Projects

In parallel, the European Commission's *Factsheets on Strategic Projects* along with the material demand forecasts across all sectors in EU provide a clear integration of the demands forecasted and the expected contributions to 2030 benchmarks (Figure XXIX).



Source: JRC analysis (Li = lithium, Co = cobalt, Ni = nickel, Dy = dysprosium, Tb = terbium, Pr = praseodymium, Pt = platinum, Si = silicon metal, Cu = copper, Al = aluminium).

Figure XXIX: Projected demand for key raw materials under both high- and low-demand scenarios by 2030 (European Commission, 2023).

These forecasts serve as a foundation for evaluating the adequacy of Strategic Projects in meeting CRMA targets. For each SRM, the forecasted total demand is compared against the expected production output of recognized Strategic Projects (as published by the European Commission factsheets) (Figures XXX and XXXI). This comparison provides a direct measure of each project's quantitative contribution to the 2030 benchmarks. The innovative element of the proposed framework is the use of UNFC classification as a risk signal within supply monitoring (Table 7). Each project's UNFC Class corresponds to a relative risk factor reflecting the project's maturity and likelihood of timely delivery.

Table 7: The relationship between UNFC class and supply risk

UNFC Class	Indicative Supply Risk Factor
Viable	Very Low to Low
Potentially Viable	Intermediate to High
Justified for Development	High
Not Viable	Very High

Applying this logic to the verified Strategic Projects (European Commission, 2024), the table below (Table 8) summarizes the aggregate supply risk by SRM category and project type (extraction, processing, or recycling):

Table 8: Aggregated supply risks by strategic raw materials and project type

Strategic Raw Materials	Type of Project	# of Projects	Expected Outcome by 2030 (t)	Major UNFC Class	Overall Supply Risk Factor
Cobalt	Extraction	2	4,328	Mostly Viable Projects	Low
	Processing	3	10,280		
	Recycling	5	23,264		
Lithium (battery grade)	Extraction	5	46,566	Mostly Potentially Viable	High
	Processing	8	32,014		
	Recycling	5	14,552		
Manganese (battery grade)	Extraction	0	0	Mostly Potentially Viable	Intermediate–High
	Processing	2	105,080		
	Recycling	3	56,980		
Natural Graphite (battery grade)	Extraction	2	38,299	Divided	Intermediate
	Processing	5	90,961		
	Recycling	3	40,693		
Nickel (battery grade)	Extraction	2	122,897	Divided	Low–Intermediate
	Processing	2	120,039		
	Recycling	7	57,161		
REEs	Extraction	0	0	Divided	Intermediate
	Processing	3	6,120		
	Recycling	2	816		

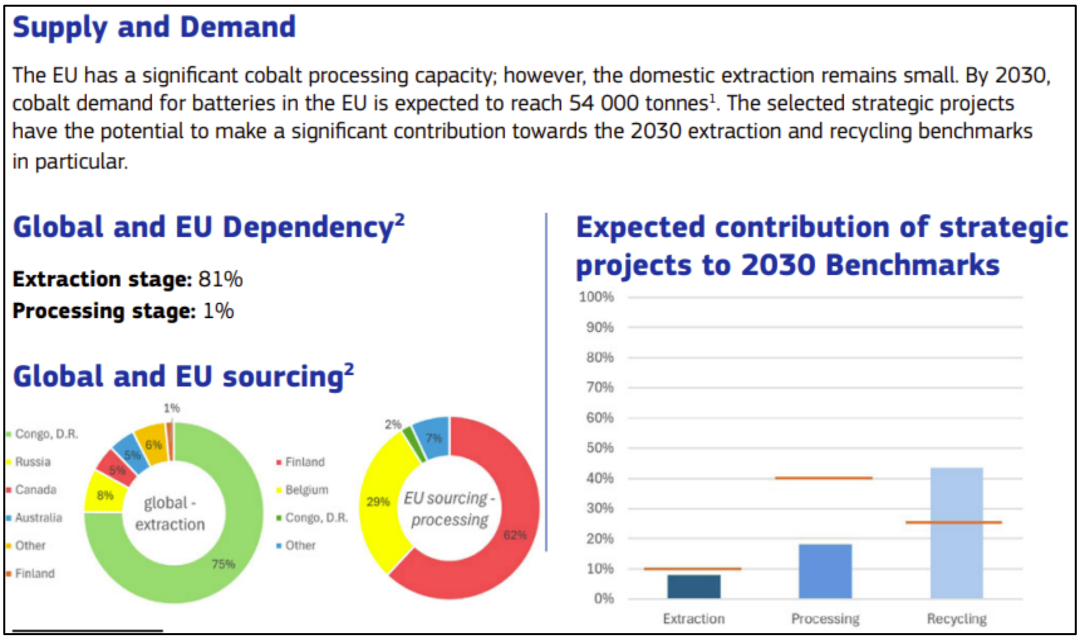


Figure XXX: Factsheet on Cobalt supply and demand, and the expected contribution of strategic projects (European Commission, 2025)

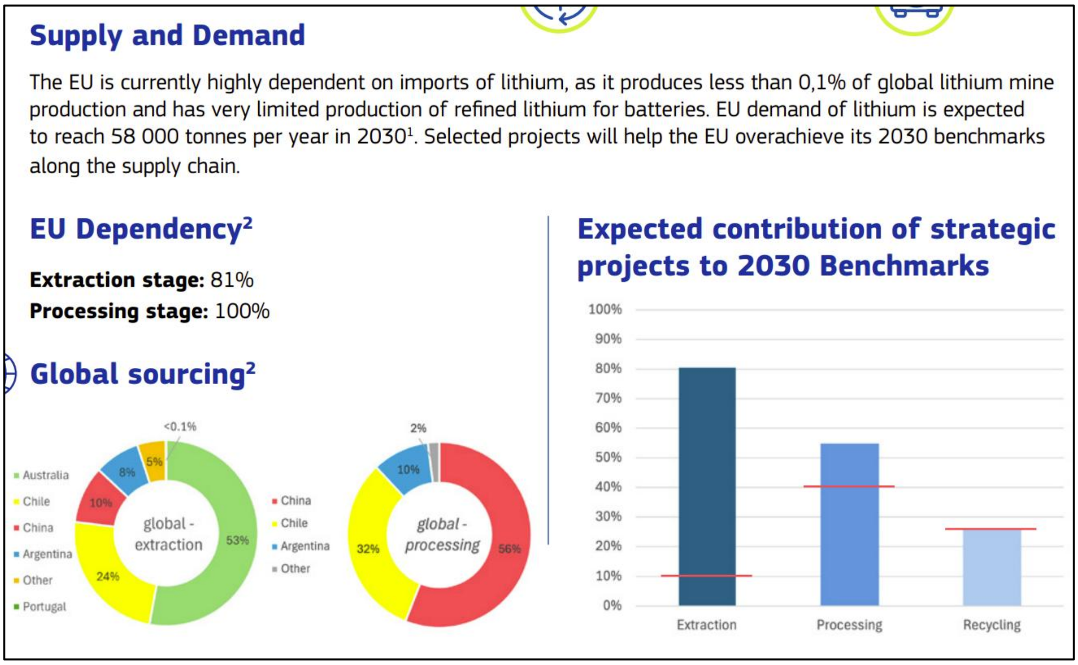


Figure XXXI: Factsheet on Lithium supply and demand, and the expected contribution of strategic projects (European Commission, 2025)

This approach allows classification-based quantification of supply confidence, linking the F axis and E axis to benchmark delivery potential. For example, lithium and manganese exhibit high supply risk due to the predominance of *Potentially Viable* projects at the feasibility or pre-feasibility stage (F2), while cobalt projects, most of which are recycling-based and viable, carry low supply risk. The demonstration of how UNFC can be linked to the progression of project development stages, from scoping study to production, and their corresponding potential to contribute to 2030 benchmarks is represented in the figure below (Figure XXXII). The interlinkage with UNFC shows that projects classified as *F1* (technical feasibility confirmed, final permits secured, on production) exhibit high potential to contribute, *F2* projects (undergoing feasibility confirmation or awaiting permitting) show intermediate potential, and *F3* projects (conceptual or technically immature) are assigned low potential.

The color-coded evaluation (green, yellow, orange) provides a visual mechanism to track collective SRM progress. This visualized maturity continuum can serve as a policy tool for identifying bottlenecks, such as permitting delays or financing barriers. Policy-Relevant insights and foresight integration are corroborated through the proposed UNFC-based SRM inventory, where evaluators and policymakers can extract foresight indicators linking project maturity to future supply security. For instance, several policy-relevant patterns emerge from the analysis of UNFC classified Strategic Projects from the first call of application:

- **Lithium and Nickel projects**: Predominantly *Potentially Viable* (F2), indicating technical needs.
- **Natural Graphite and REEs projects**: Often *E2; F2*, permitting and investment constraints slow development.
- **Cobalt and PGMs projects**: High technical readiness but moderate E2 scores, suggesting socio-environmental or permitting hurdles.

These findings highlight a value of integrating UNFC into criticality and foresight assessments, complementing existing EU methodologies. Connecting UNFC classes to quantitative supply forecasts can develop a dynamic monitoring process that not only assesses current project performance but also anticipates future bottlenecks. A reasonable extension of this framework involves embedding UNFC-based classifications into criticality and foresight analyses, allowing the European Commission to forecast SRM supply risk dynamically. Linking UNFC maturity levels with economic, geopolitical, and technological parameters would enhance resilience planning and improve the EU's ability to anticipate and mitigate future supply chain disruptions.

SRMs / UNFC	*111*	*111+2*	*112*	*113*	*121*	*121+2*	*121+2+3*	*121*	*121+2*	*121+2+3*	*122*	*123*	*212*	*213*	*221*	*221+2+3*	*222*	*223*	*232*	*total*
Cobalt	xxxx								x				x	x			x	x		37,870.70
Lithium	x	x	xxx										x	x		x	xxxxxxx	x	x	93,132.80
Manganese	x												x	x			x			162,060.00
Graphite	x		xx											x	x		x	xx		169,952.70
Nickel	xxxx			x					x				x	x			x	x		300,096.30
REEs		x	x							x				x			x	x		6,936.00

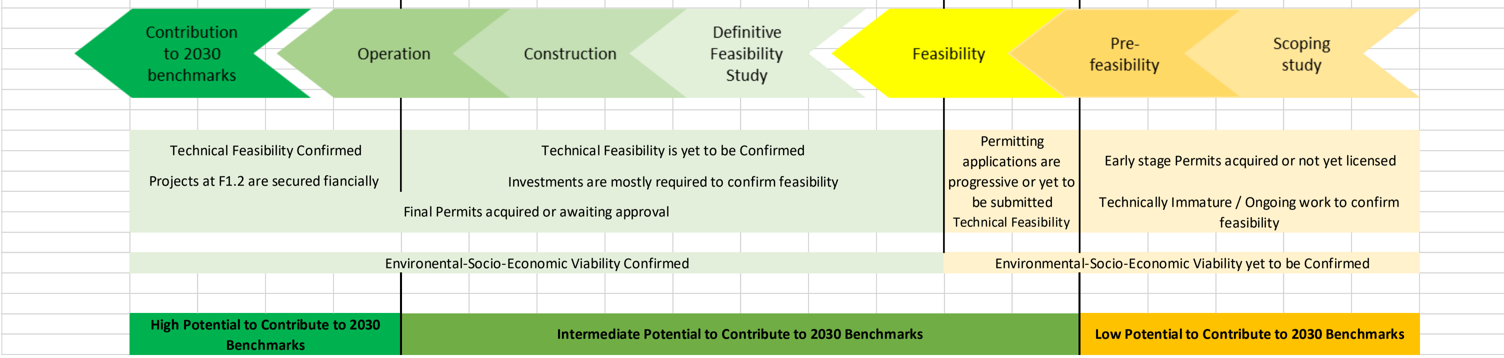


Figure XXXII: Project progression linked with UNFC classification, based on a UNFC-based SRM inventory

3.5 UNFC Monitoring Model for Strategic Projects Development Over Time

As the implementation of CRMA advances, the need for a harmonized, transparent, and repeatable monitoring mechanism for Strategic Projects becomes increasingly evident. Monitoring these projects over time i.e., tracking their progress, delays, and reclassification, is central to assessing the EU's ability to meet its 2030 benchmarks. To this end, the use of UNFC provides a robust and flexible structure for continuous monitoring, building directly on the verified baseline classification of each recognized Strategic Project.

The proposed monitoring methodology was designed alongside colleagues from UNECE. It is designed for the European Commission, as the user of the classification, to oversee the progress of Strategic Projects in a consistent, data-driven manner. The methodology uses an automated checklist template linked to controlling factors that define each UNFC axis: Environmental-socio-economic Viability (E), Technical Feasibility (F), and Degree of Confidence (G). The full template is appended to this dissertation, under the **Appendix A**. This checklist forms the basis of an Excel-based monitoring template composed of three modules:

1. **Project Information**
2. **Operational Monitoring**
3. **Financial Viability and Bankability**

1. Project Information

The first module compiles the project's essential identification and performance data. Each project record includes:

- Project ID and Name;
- Project Promoter or Company;
- Country;
- Project Type (Extraction, Processing, or Recycling);
- Main and secondary SRMs;

- Project lifetime;
- Estimated start of production; and
- Verified UNFC classification at the time of Strategic Project recognition.

For extraction projects, the module captures the estimated annual production of extracted raw materials and their content in tonnes, distributed across the 2025–2030 timeframe. For processing and recycling projects, both material input (annual feed and SRM content) and material output (production in tonnes and SRM yield) are recorded by year. This temporal structuring allows a clear visualization of production ramp-up, stagnation, or decline in parallel with reclassification outcomes. This baseline data is directly linked to the initial UNFC classification as verified during project evaluation, forming the reference point for subsequent monitoring updates.

2. Operational Monitoring

The operational monitoring module is the core analytical component, designed to capture and evaluate annual updates on project performance under the three UNFC axes. Each axis is defined by Controlling Factors (CFs), standardized into drop-down inputs to minimize subjectivity and allow automated reclassification.

a. Environmental-socio-economic Viability (E Axis)

The E-axis evaluates whether the project remains economically and socially justified under evolving conditions (Figure XXXIII). It is determined by CFs such as, with the dropdown options in brackets:

- Raw materials policy at national level (favorable, neutral, unknow, not favorable) and regulatory approval process (efficient, neutral, unknow, inefficient). This CF is indicative of time and efficiency in permitting procedures as per national practices. For instance, achieving high investment attractiveness is partly due to favorable mining policies and efficient, predictable permitting processes (Mejía & Aliakbari, 2026). These conditions reduce regulatory uncertainty and shorten approval timelines, thereby enhancing project viability (Mejía & Aliakbari, 2026);
- Permitting status, including extraction, environmental, industrial, and land-use permits (acquired, applied, to be applied, rejected);

- Economic viability including development stage (production, construction, definitive feasibility study, feasibility study, pre-feasibility study, scoping study), net present value and internal rate of return (strongly positive, positive, negative), off-take agreements (none, partially signed, secured), and risk mitigation (limited, partial, comprehensive);

- Social acceptance including public consultation (meaningful, initiated, non-existent), job creation (significant, limited, minimal), opposition (none, minor, strong), skills development (active, planed, none), and Indigenous engagement (meaningful, initiated, non-existent). In practice, social license to operate (SLO) may be inferred from the extent and quality of stakeholder engagement processes, the degree of public support or opposition, and the project's capacity to generate local benefits. Studies indicate that SLO is strongly influenced by early and transparent communication, trust in project developers and authorities, perceived fairness in decision-making, expected local economic benefits, and the management of environmental concerns (E1) (Eerola, 2023). Conversely, projects characterized by opaque communication, or limited local benefit-sharing tend to experience stronger opposition (E3) (Eerola, 2023);

- Environmental performance including air emissions, water and soil management, biodiversity protection, waste and tailings management, and energy efficiency (fully compliant, strong commitments, weak commitments). Some national or regional environmental legislations may suggest responsible environmental practices, often adhered through a positively yielded EIA; and

- Governance practices ensuring transparency and ESG compliance (fully compliant, strong commitments, weak commitments).

These CFs determine the E axis category (E1–E3) and its sub-categories (E1.1, E1.2), following explicit decision rules:

- **E1.1** – Fully viable, permitted, compliant, and socially accepted.

- **E1.2** – Viable mainly due to Strategic Project status; conditional compliance or minor opposition.

- **E2** – Viability uncertain, with pending or partial permits.

- **E3** – Non-viable before 2030; major risks or refusals.

b. Technical Feasibility (F Axis)

The F-axis monitors the project's progress along its technical development pathway. CFs include:

- Development stage (Scoping Study, Pre-feasibility Study, Feasibility Study, Definitive Feasibility Study, Construction, Production);
- Activities status (ongoing, on hold);
- Technology Readiness Level (TRL, particularly for recycling and processing projects);
- Infrastructure readiness (available, partial, none); and
- Financing secured (secured, partial, needed).

The F axis classification follows these sub-categories:

- **F1.1** – On production;
- **F1.2** – Feasibility confirmed and financing secured;
- **F1.3** – Advanced feasibility confirmed, but investment required;
- **F2.1** – Feasibility under study, financing needed;
- **F2.2** – Significant delay beyond 2030;
- **F2.3** – No plans for development;
- **F3** – Too early to determine feasibility.

c. Degree of Confidence (G Axis)

The G axis reflects the reliability of resource or production estimates.

- For **extraction projects**, this corresponds to alignment with CRIRSCO codes and geological confidence in resources or reserves.

- For **processing and recycling projects**, it reflects supply security, availability and consistency of feed materials.

Confidence categories are:

- **G1** – High confidence,
- **G2** – Moderate confidence, and
- **G3** – Low confidence.

These are entered manually each year, serving both as a qualitative measure and a visual dimension in the monitoring graphs. However, in the case of extraction projects where a CRIRSCO compliant code is used, the classification on the G axis is automatic.

Environmental-Socio-Economic Viability	2026			1st Update Date			2nd Update Date		
	Status	UNFC	Note	Status	UNFC	Note	Status	UNFC	Note
Legislative Framework									
Raw Materials Policy at National Level		#N/A			#N/A			#N/A	
Regulatory Approval Process		#N/A			#N/A			#N/A	
E axis									
Permitting Status									
Extraction / Mining		#N/A			#N/A			#N/A	
EIA		#N/A			#N/A			#N/A	
Operational / Industrial		#N/A			#N/A			#N/A	
Water Use		#N/A			#N/A			#N/A	
Waste Management		#N/A			#N/A			#N/A	
Construction / Land use		#N/A			#N/A			#N/A	
Health & Safety		#N/A			#N/A			#N/A	
Others		#N/A			#N/A			#N/A	
E axis									
Economic Viability									
Development Stage		#N/A			#N/A			#N/A	
NPV		#N/A			#N/A			#N/A	
IRR		#N/A			#N/A			#N/A	
Off-takes Agreement		#N/A			#N/A			#N/A	
Risk Mitigation		#N/A			#N/A			#N/A	
E axis									
Social Acceptance									
Public Consultations		#N/A			#N/A			#N/A	
Public Opposition		#N/A			#N/A			#N/A	
Jobs Creation		#N/A			#N/A			#N/A	
Skills Development		#N/A			#N/A			#N/A	
Indigenous Engagement		#N/A			#N/A			#N/A	
E axis									
Environmental Commitments									
Air Emissions		#N/A			#N/A			#N/A	
Water Use / Protection		#N/A			#N/A			#N/A	
Soil Use		#N/A			#N/A			#N/A	
Biodiversity Impacts		#N/A			#N/A			#N/A	
Waste / Tailings		#N/A			#N/A			#N/A	
Hazardous Substances		#N/A			#N/A			#N/A	
Noise / Vibrations		#N/A			#N/A			#N/A	
Energy Use		#N/A			#N/A			#N/A	
E axis									
Governance Practices									
Transparent operations		#N/A			#N/A			#N/A	
E axis		#N/A			#N/A			#N/A	
Final E axis Category / Sub-category									

Figure XXXIII: E axis classification in the Operational Monitoring Module

3. Financial Viability and Bankability

This module complements the operational monitoring by tracking the financial dimension of each project, recognizing its close link to both the E and F axes. The fields include:

- Project development stage and completion percentage;
- Total and stage-specific CAPEX and OPEX;
- Financing secured versus funding gap; and
- Investment types (equity, loans, grants).

These parameters help assess whether a project remains financially viable and bankable, supporting periodic UNFC reclassification under the E and F axes. The distinction between economic viability (E axis) and financial feasibility (F axis) is maintained: while the E axis evaluates the overall market and policy context, the F axis focuses on the availability of funds and technical capacity to proceed with implementation.

Guiding Principles for the Monitoring Template

The monitoring tool is designed to be:

- **Simple to use**, ensuring compatibility with Excel-based or digital platforms;
- **Built upon the verified 2025 UNFC baseline** classification for each Strategic Project;
- **Graphically interpretable**, using bubble and radar charts to visualize the evolution of E and F categories over time; and
- **Consistent**, employing standardized drop-down inputs and annual updates from 2026 to 2030.

Each project is visualized through bubble charts, where:

- The **X-axis** represents the update date timeframe;
- The **Y-axis** shows numerical mappings of E or F categories;

- **Bubble size** reflects the project's estimated annual production (in tonnes);
- **Bubble color** corresponds to the G-axis confidence category (G1 = Green, G2 = Orange, G3 = Blue).

This enables a dynamic visual trace of project evolution, showing how maturity, production, and confidence evolve simultaneously. Missing data for a given year results in an empty gap, flagging the need for clarification or follow-up.

Classification Logic and Decision Rules

Each controlling factor generates a preliminary category suggestion (for example, *Permitting: Acquired means E1*). The dominant value across all CFs defines the final axis classification, while each individual CF's classification remains documented for detailed trend analysis. In case of a tie between categories (e.g., equal E1 and E2 CFs), the classification defaults to the less mature category, ensuring conservative reporting. Sub-categories (e.g., E1.1 vs E1.2, F1.2 vs F1.3) are applied where the CFs allow finer granularity. This logic ensures consistency with the UNFC evaluation guidance developed for the Strategic Project Application Form (European Commission, 2024).

Analytical Use and Policy Implications

The usability of this monitoring framework extends beyond project tracking. It supports the European Commission in:

- Evaluating collective progress of Strategic Projects toward 2030 benchmarks;
- Detecting early warning signs of project delays or regressions;
- Identifying systemic bottlenecks (e.g., permitting, financing, or supply security); and
- Supporting targeted interventions under the CRMA's enabling measures (European Commission, 2024).

The ultimate graphs should project data into visual, time-based trends as portrayed in the figure below (Figure XXXIV). The UNFC-based monitoring tool transforms static classification into dynamic performance assessment, enabling evidence-based decision-making. The Excel-based monitoring template, appended to this thesis, provides a practical implementation of this methodology and can be integrated into the Commission's reporting systems or adapted for use by Member States to track their national Strategic Projects.

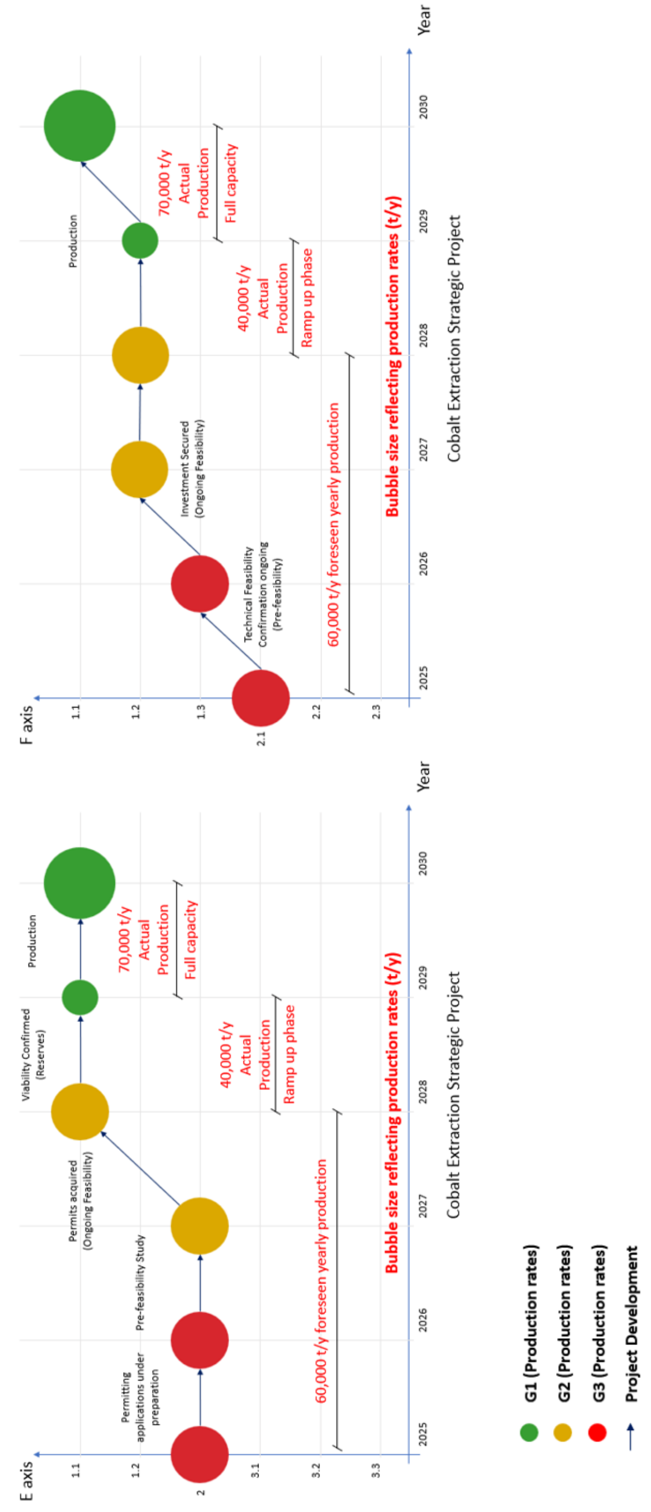


Figure XXXIV: Optimal Outcome of UNFC-based operational monitoring of selected Strategic Projects

Chapter 4

National Exploration Programme in Italy

4.1 Scope of Work

As established, the secure and sustainable supply of CRMs is essential for Europe's green and digital transitions, industrial competitiveness, and strategic autonomy. However, to ensure this goal, one must look at the earliest stages of the supply chain, that is exploration. To this point, CRMA mandates the development of National Exploration Programmes (NEPs) in each Member State.

Under Article 19 of the CRMA, all Member States must, by May 2025, establish a national programme for general exploration targeting CRMs and their carrier minerals. These programmes must be reviewed at least every five years and include measures to enhance geological knowledge of potential CRM occurrences. Specifically, they should integrate activities such as mineral mapping, geochemical and geophysical campaigns, data processing and predictive modelling, and reprocessing of historical datasets to identify previously unrecognized occurrences. Furthermore, CRMA requires Member States to make exploration data publicly available through free-access portals, including the classification of identified occurrences using UNFC (European Commission, 2024).

In parallel with this EU-level obligation, Italy adopted Decree Law No. 84/2024, which introduces urgent measures on raw materials of strategic interest. This decree represents the country's legal mechanism to implement CRMA's provisions domestically. Among its key articles, it designates the Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA), which includes the Geological Survey of Italy, as the competent authority responsible for preparing and implementing Italy's National Exploration Programme (Programma Nazionale di Esplorazione), under the supervision of the Ministry of Enterprises and Made in Italy (MIMIT) and the Ministry of Environment and Energy Security (MASE). The decree streamlines permitting and coordination for exploration by introducing single contact points within ministries and simplifying early-stage procedures. Most notably, Article 7 exempts exploration permits of less than two years for CRMs from Environmental Impact Assessment requirements, significantly accelerating data acquisition and preliminary geological investigations. This provision directly supports the early implementation of the NEP, facilitating rapid generation of baseline data and the identification of new CRM targets. The NEP, as foreseen under both CRMA and Decree Law No. 84/2024, thus serves as a strategic foundation for Italy's contribution to EU's CRM supply chains. It aims to systematically enhance national geological knowledge, identify resource potential from primary raw materials, and strengthen the scientific and institutional basis for sustainable resource management.

Taking Italy for illustrative purposes, the following sections present the framework of the Italian NEP, its exploration targets and CRMs of interest, and a proposed UNFC-based methodology to classify occurrences and integrate exploration results within Italy's emerging CRMs inventory.

4.2 Overview of the Italian National Exploration Programme

The National Exploration Programme (Programma Nazionale di Esplorazione, PNE) developed by ISPRA responds directly to CRMA's mandate to prepare a national programme for general exploration targeted at CRMs and their carrier minerals. The PNE is structured to deliver an operational roadmap for Italy's exploration priorities, data acquisition and management, and phased field investigations. Its explicit objectives are to increase the availability of geological information on CRM occurrences, to priorities areas with the highest exploration potential, and to produce standardized and accessible outputs (maps, databases, predictive products) that will feed Italy's national inventory (Figure XXXV) (ISPRA, 2025).

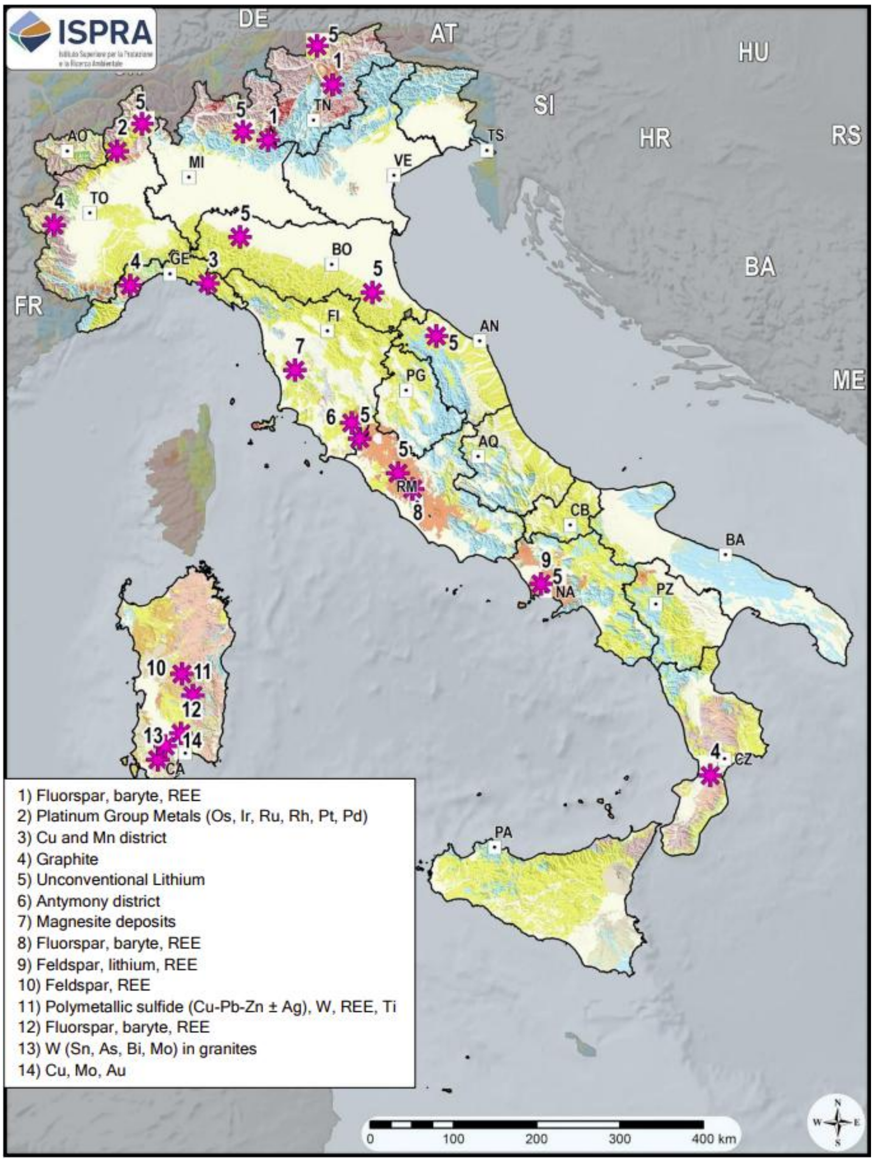


Figure XXXV: Points of study and respective targeted CRMs, as defined by PNE (ISPRA, 2025)

ISPRA's programme is organized in a staged fashion: an initial Phase-1 of targeted, higher-priority investigations followed by subsequent phases of more detailed (operational) exploration where warranted. Phase-1 defines 14 thematic/territorial study areas that reflect Italy's most promising contexts for CRMs and carrier minerals: alpine fluorite systems (possible REE), PGE occurrences in the Ivrea-Verbano / Finero ultramafic complexes, copper–manganese districts of eastern Liguria, graphite localities (Calabria, Piemonte, Liguria), unconventional lithium targets (geothermal and brine systems across several regions), the antimony district of Maremma (Tuscany), magnesite bodies in central Tuscany, several fluorite–REE provinces in Sardinia and Lazio, industrial minerals and CRMs in Campania volcanic products, feldspar/REE in Sardinia's acid magmatism, polymetallic sulphide systems (Cu–Pb–Zn ± Ag ± W ± REE) in central Sardinia, and tungsten-related granite-hosted systems in southwestern Sardinia (Figure XXXVI) (ISPRA, PNE, pp. 49–159). These Phase-1 targets were selected on the basis of a synthesis of historical data, regional geology, known mineralization, and the likelihood of containing CRMs or carrier minerals (ISPRA, 2025).

The CRMs targeted by the NEP, and their corresponding exploration areas are listed in details below:

1. Fluorspar, baryte, REE (Southern Alps)
2. Platinum Group Metals (Os, Ir, Ru, Rh, Pt, Pd) (Eastern Piedmont)
3. Cu and Mn district (Eastern Liguria)
4. Graphite (Piedmont, Liguria, Calabria)
5. Unconventional Lithium (Tuscany, Latium, Emilia-Romagna, Piedmont, Lombardy, Marche, Trentino-South Tyrol)
6. Antimony district (Tuscany)
7. Magnesite deposits (Tuscany)
8. Fluorspar, baryte, REE (Latium volcanoes)
9. Feldspar, lithium, REE (Campania volcanoes)
10. Feldspar, REE (Sardinia felsic magmatism)
11. Polymetallic sulfide (Cu-Pb-Zn ± Ag), W, REE, Ti (South Sardinia)
12. Fluorspar, baryte, REE (South Sardinia)
13. W (Sn, As, Bi, Mo) in granites (SW Sardinia)
14. Cu, Mo, Au (SW Sardinia)

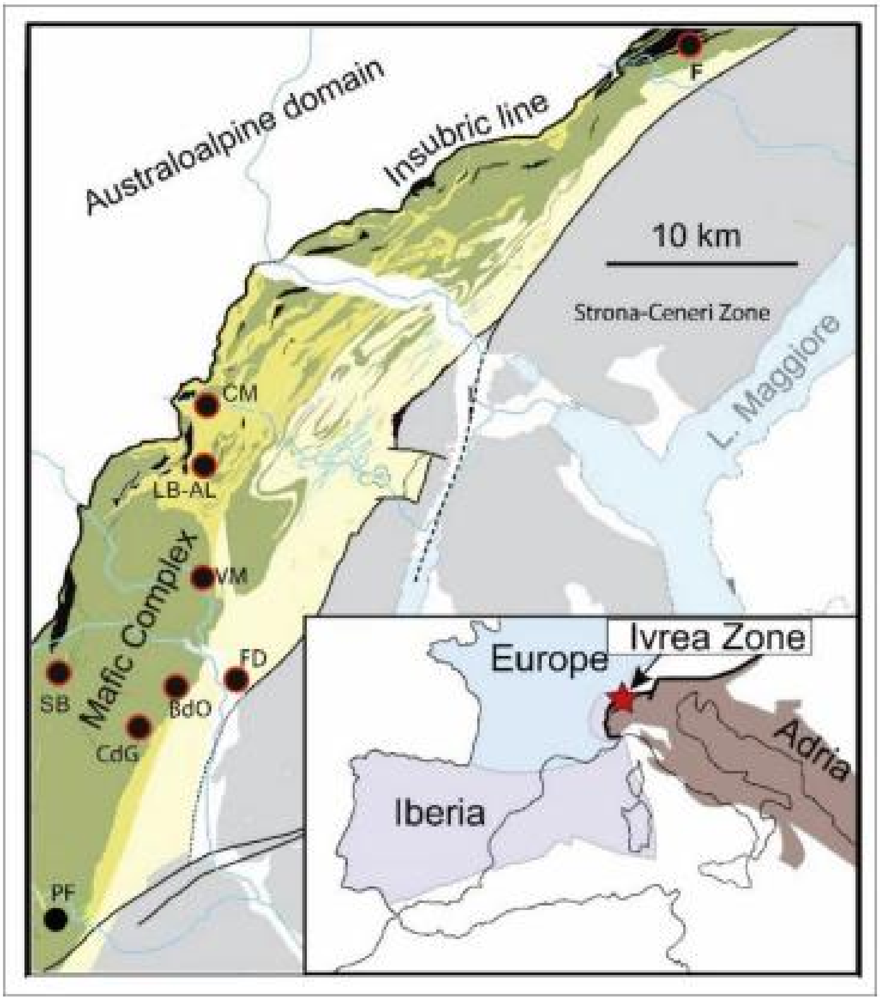


Figure XXXVI: Example of targeted area in the Ivrea-Verbano Zone, showing the location of the Finero complex and ultramafic intrusions enriched in Ni-Fe-Cu-PGE sulfides (ISPRA, 2025)

The PNE provides spatial syntheses (maps) identifying regions with the highest potential for CRMs and compiles available historical records (mines, occurrences, and extractive-waste sites) into the national database. The principal CRMs and carrier minerals singled out by the programme include: rare earth elements (REE), platinum-group elements (PGEs), lithium (both unconventional resources in geothermal/thermal fluids and pegmatite/spodumene-style occurrences), natural graphite, cobalt (as associated with certain sulphide systems), nickel (in ultramafic complexes), tungsten, antimony, magnesite, copper, manganese, and various industrial minerals that may host critical elements. The programme includes thematic mapping (e.g. map of national areas with higher CRM potential; maps of known occurrences, mine sites and extractive-waste deposits) that spatially locate these commodities and the proposed Phase-1 study areas (Figure XXXVII).

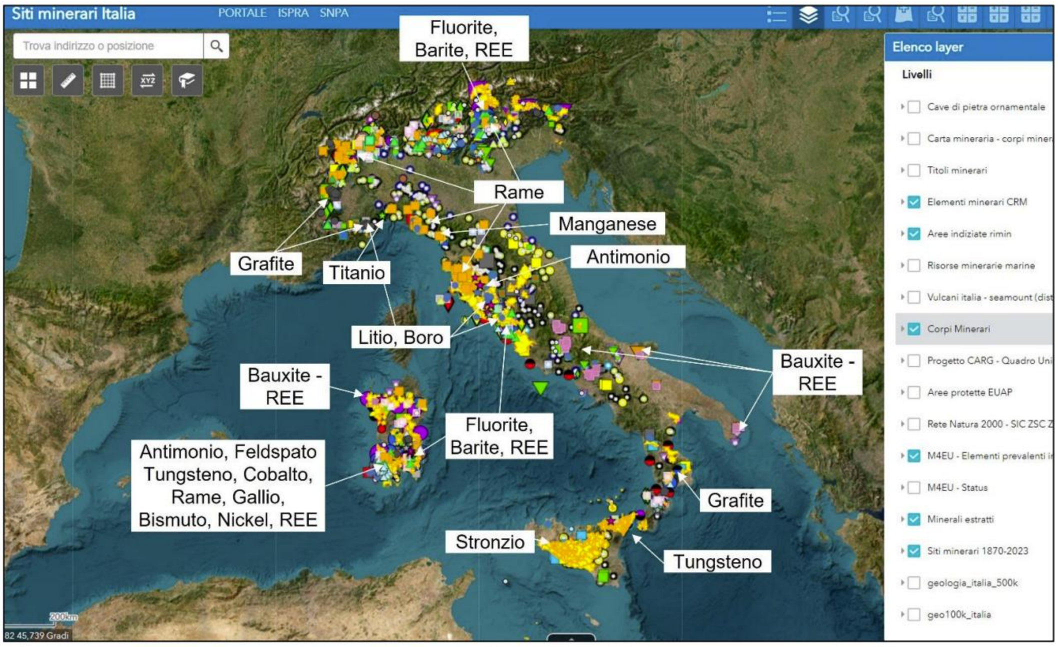


Figure XXXVII: Map of national areas with the greatest potential for Critical Raw Materials (ISPRA, 2025)

The PNE provides short, targeted write-ups for each Phase-1 theme that describe the geological rationale, past work, proposed field activities and expected outputs. Examples include:

(a) the Alpine fluorite belts, where historic data and hydrothermal contexts suggest unexploited potential for fluorite and associated REEs and barite (ISPRA, PNE, Phase-1 area 1);

(b) the Finero / Ivrea-Verbano ultramafic bodies with known PGM-bearing chromitites and nickel-sulphide mineralization (Phase-1 area 2);

(c) graphite occurrences in Calabria (Monterosso Calabro) and Piemonte, where field sampling already shows mineralised horizons worthy of systematic re-evaluation (Phase-1 area 4);

(d) unconventional lithium targets—both geothermal brines and lithium-bearing granitoids and clays—mapped across Tuscany, Lazio, Campania, Emilia-Romagna and several northern regions (Phase-1 area 5; ISPRA, PNE, Figures 20–22);

(e) for Sardinia, multiple Phase-1 items (fluorite, hydrothermal REE, polymetallic sulphides, tungsten) identify the island as a high-priority province for CRM follow-up.

It is necessary to note that the PNE is explicit about the heterogeneity of historical data and the generally limited availability of comprehensive, modern resource estimates across many Italian targets. While historical mine records, technical reports and legacy sampling deliver useful directional information, the PNE notes that quantitative tonnage and grade estimates are often fragmentary, inconsistent in methodology, or absent for many occurrences, particularly for deposits that were worked prior to modern reporting standards. An illustrative example is the legacy mining district of Montevecchio (Sardinia), where the PNE compiles mine-site and waste-dump inventories that indicate extremely large cubic-meter volumes of extractive waste (~3 million m^3 in some districts), but analytical coverage of these materials is limited and not always representative beyond shallow horizons. Similarly, the PNE reports measured lithium concentrations in geothermal and thermal fluids and highlights promising hotspots, but it does not present nation-wide, consolidated tonnage or reserve figures comparable to modern resource/reserve reporting standards. The programme is therefore framed as expressly designed to fill these gaps, through targeted field campaigns, reprocessing of historical datasets, and standardized data collection. A central pillar of the programme is the standardization, digitalization and open dissemination of geological data. An updated to the national mineral database as the main repository for the exploration outputs is proposed. This shall include occurrence records, geochemical and geophysical survey results, processed predictive maps and high-resolution geological maps. The PNE specifies protocols for data acquisition (sampling, QA/QC, metadata standards), data processing (e.g., re-interpretation of legacy geophysical datasets), and web dissemination (public free-access interfaces for basic occurrence data with the option to request higher-resolution datasets) in line with CRMA reporting obligations (ISPRA, 2025).

For each Phase-1 theme ISPRA outlines a sequence of activities: critical review of legacy literature and datasets, targeted surface sampling and mapping, selective geophysical surveys, and systematic geochemical sampling (soils, stream sediments, rock outcrops). Where warranted, ISPRA foresees trenching, shallow drilling or re-analysis of mine waste and tailings to characterize both primary occurrences and extractive-waste deposits as potential secondary sources of CRMs. The programme also emphasizes the use of predictive mapping (GIS-based models) to prioritize follow-up work and to improve detection of blind or buried deposits (ISPRA, 2025). In keeping with the CRMA and Decree Law provisions concerning marine resources, the PNE includes marine exploration considerations (e.g., coastal sands and seamount sampling) and identifies seafloor or near-coast targets where CRMs may occur (Figure XXXVIII). It also explicitly addresses unconventional lithium, notably lithium in geothermal fluids and thermal waters, by mapping fluid chemistry datasets and proposing follow-up geochemical campaigns where preliminary data indicate economic concentrations.

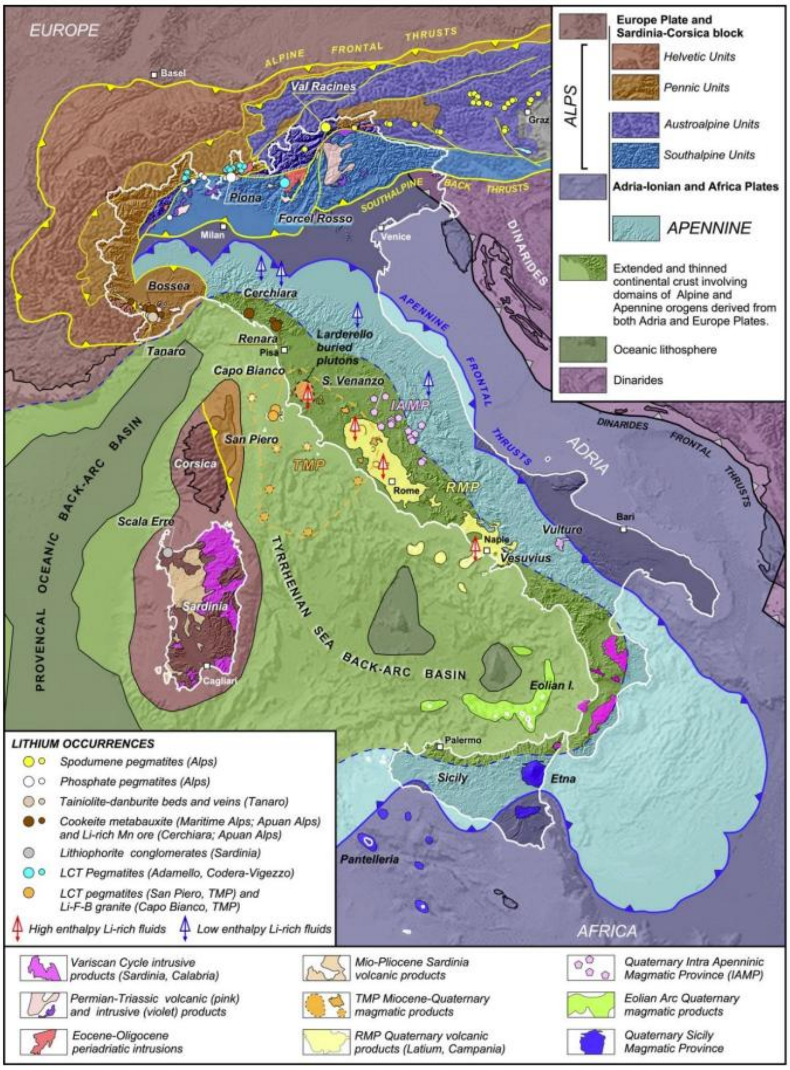


Figure XXXVIII: Italian techtonic setting, with indicated lithium occurrences (ISPRA, 2025)

The PNE explicitly links its outputs to CRMA's reporting architecture: Member States must make maps showing basic information on CRM occurrences publicly available and include UNFC classification of identified occurrences where applicable. ISPRA therefore positions the NEP outputs as inputs to both national inventories, enabling Italy to report progress on exploration measures and to meet the reporting schedule required by Article 45 of the CRMA. Additionally, the programme lso includes an organizational plan (roles for ISPRA, regional authorities and other stakeholders), a monitoring plan, and a training and communication plan to engage regional administrations, industry, academia and local communities. This is intended to ensure the technical skills required for modern exploration, to harmonize permitting and data collection practices, and to enhance transparency and public dissemination.

For the purposes of this dissertation, the ISPRA PNE provides:

(i) a defensible, peer-reviewed identification of priority CRMs and geographic targets in Italy;

(ii) an explicit methodology and timeline for data acquisition, standardization and public dissemination, which can be directly linked to UNFC-based classification workflows; and

(iii) a staged list of Phase-1 target studies (14 thematic areas) that will serve as practical testbeds for applying UNFC to occurrences, for developing resource confidence assessments (G axis), and for integrating exploration outcomes into a UNFC-based Italian inventory.

However, the PNE's careful presentation of historical data quality and the absence of comprehensive modern resource estimates for many targets underline a key methodological implication: the classification of occurrences under UNFC will in many cases initially rely on qualitative and semi-quantitative indicators (e.g., presence/absence, sampling density, observed mineralization) and will require explicit protocols for uncertainty treatment and conservative reporting. The programme therefore anticipates that many occurrences will initially receive UNFC classifications with low G-axis confidence until further field and analytical work can improve data density and reproducibility (ISPRA, 2025).

4.3 Proposed Methodology for the Application of UNFC to National Exploration Results

The application of UNFC to the results of NEP represents a key step toward harmonizing exploration data reporting within the CRMA framework. To reiterate, in accordance with Article 19 of the CRMA, Member States must establish and periodically review their national programmes for general exploration targeting CRMs and their carrier minerals. The results of these programmes must be communicated to the European Commission and made publicly available, including classification according to UNFC where applicable (ICE-SRM EU, 2025).

To operationalize this requirement, the following section unpacks a proposed methodology to classify the results from NEPs in UNFC. This structured methodology follows the approach developed by the ICE-SRM EU, elaborated in the document "*UNFC Guidance on the European Union's National Exploration Programme Results (NEP-R)"*. The methodology was developed in collaboration and contribution of Hendrik Falck *(chair of Minerals Working Group of EGRM)*, Snježana Miletić, and Slavko Šolar *(both from ICE-SRM EU)*. This proposed methodology aims to ensure consistency, comparability, and transparency in reporting at EU levels, and enabling Member States to transform exploration data into actionable knowledge for policy development, industrial planning, and investment decisions. Given that UNFC is a universally applicable classification tool, and allows for the management of mineral resources projects, while integrating geological, technical, environmental, and socio-economic dimensions, it supports CRMA, in particular for NEP reporting in several key policy objectives (ICE-SRM EU, 2025):

- **Standardization and comparability:** Establishing a harmonized lexicon for reporting exploration results across Member States.

- **Transparency and traceability:** Enabling a common baseline for evaluating national CRM potential.

- **Dynamic monitoring:** Allowing occurrences identified by NEPs to be tracked over time as they progress, or not, from early exploration to development, recycling, or recovery stages.

Articles 7, 19, 21, 27, and 45 of the CRMA collectively integrate UNFC as the reference system for resource classification and reporting, thereby strengthening coherence between national and EU-level resource management.

The main purpose in the use of UNFC to the exploration results is to transform geologic data into knowledge. This knowledge base serves as a starting point to spike up the interest of investors and junior mining companies to explore further the classified NEP results. However, the classification would need to carry enough granularity to showcase the potential from the results. Thus, the methodology proposed intends to provide such depth and standardize the approach to classify NEP results across all Member States (ICE-SRM EU, 2025). This stepwise methodology to classify exploration data according to UNFC's three-dimensional framework is therefore put in the context of NEPs, going systematically axis by axis. It is to be noted that the most probable classification of an occurrence from NEPs will be that of a Prospective Projects (mainly E3; F3; G4), where environmental-socio-economic information limits the determination of viability, and technical immaturity is confirmed. To elaborate more, given that a majority of occurrences will not undergo invasive exploration (e.g., as indicated in the Italian NEPs), permitting does not go beyond research purposes (and in some cases not needed), which renders the E and F axis within the Prospective Projects range. The measures to enhance the information on national CRMs availability are listed in CRMA (*Article 19*), aimed to increase geologic knowledge on those occurrences in EU (European Commission, 2024). To establish harmony, the proposed methodology adopts exploration-related terminologies as defined by CRMA:

- Exploration: all activities aimed at identifying and establishing the properties of mineral occurrences (European Commission, 2024);

- Mineral Occurrences: any single mineral or combination of minerals occurring in a mass or deposit of potential economic interest (European Commission, 2024);

- Reserves: all mineral occurrences that are economically viable to extract in a particular market context (European Commission, 2024);

- General exploration: exploration at national or regional level, not including targeted exploration (European Commission, 2024);

- Targeted exploration: detailed investigation of an individual mineral occurrence (European Commission, 2024).

4.3.1 G Axis – Degree of confidence, geological knowledge

Most occurrences identified by NEPs are expected to fall within the G4 category, often corresponding to Prospective Projects from *Potential Sources*, defined as areas where geological indications suggest potential for CRMs, but the available data is limited. Seeing that the UNFC (2019) defines the subcategorization of G4 in a generic form, this methodology contextualizes and refines the G4 sub-categories to reflect user needs at early exploration stage, alongside the nuance with G3 category. An illustration of the terms, differences, and approach is provided below to corroborate this harmonized use of the G axis (Tables 9, 10, and 11).

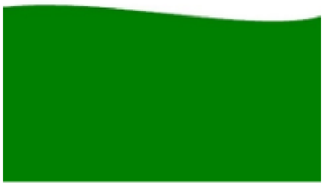
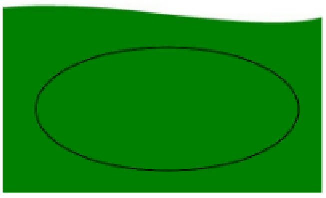
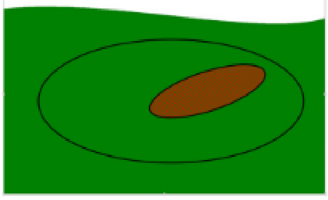
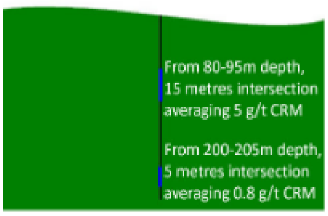
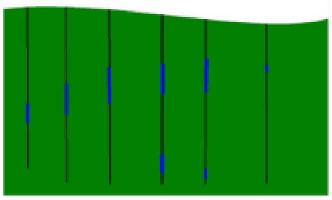
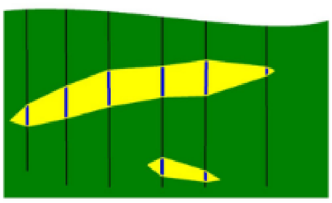
Table 9: Proposed definitions of relevant Sub- categories of G axis relevant to NEPs (ICE-SRM EU, 2025)

Category / Sub-category	Proposed Terminology for NEPs	Definition according to UNFC (2019)
G4.3	Assumed Indication	Earliest stage of exploration where mineral occurrences are postulated based on regional-scale geological interpretations, geophysical anomalies, or geochemical patterns, essentially from indirect evidence with minimal supporting data from desktop research (existing data, studies). The assumption of mineralization is plausible, but it remains a speculative assumption. No physical verification (e.g., drilling, trenching) has been performed. This stage of exploration usually does not require any sort of permission or clearance.
G4.2	Confirmed Indication	Indication of mineral occurrence supported by more detailed data, such as reconnaissance-level fieldwork or preliminary sampling. Still, the indication remains insufficient to define continuity or commercial significance. Geologically plausible, and preliminary results support the presence of a mineral-bearing unit, but tonnage/grade remain speculative. At this stage, an exploration permit may also not be required, yet in some cases, a research permit may be needed (possibly environmental clearance).
G4.1	Explored Indication	Very early direct exploration evidence supports the presence of a mineral indication, though full resource delineation remains incomplete. Volumes and grades are partially understood. Legal permission to carry out such exploration is required, including permits on land and environmental clearance.
G3	Product quantity associated with a project that can be estimated with a low level of confidence	Existence of a developable product based on preliminary direct evidence. Further data acquisition and evaluation would be required for confirmation.

Table 10: Differentiation between the G3 Category and G4 Sub-categories (ICE-SRM EU, 2025)

Category/Sub-categories	Proposed Terminology for NEPs	Differentiation
G4.3	Assumed Indication / Occurrence	Area: wide Source of data: literature, conceptual, digital Permit: NO Tonnage and grade reporting: range
G4.2	Confirmed Indication / Occurrence	Area: wide Source of data: field work Permit: NO Tonnage and grade reporting: range
G4.1	Explored Indication / Occurrence	Area: small / focused, targeted Source of data: field work Permit: YES (drilling, trenching) Tonnage and grade reporting: range or "exact / one" number
G3	Low level of confidence	Area: small / extension of known site Source of data: field work Permit: YES Tonnage and grade reporting: "exact / one" number (inferred resources)

Table 11: Example of the use of the G axis to an occurrence, in the context of NEPs (ICE-SRM EU, 2025)

Category /Sub-category	Illustration	Proposed terminology and explanation
?		A greenfield exploration project. (Adapted from Correia and Henley, International Lithological Conference, 2014)
G4.3		**Assumed Indication / Occurrence** Areas of general interest for future targeted exploration. Example: A large area geophysical anomaly detected in an area with favorable geological conditions but lacking surface exposure or historical exploration data. Data source is literature: Regional surveys, remote sensing data, geological analogues, and conceptual models These areas do not require an exploration permit. We have no site-specific knowledge – but indications something may be there, deposit could be small or large
G4.2		**Confirmed Indication / Occurrence** Data source from recently accomplished field work: Surface mapping, initial geochemical sampling ... These works usually do not require an exploration permit. Reported an Exploration Target G4.2 / GKZ: D1, as a range of possible tonnages and grades
G4.1		**Explored Indication/ Occurrence** An exploration permit needed to carry out such activities (drilling, trenching, etc.) at this stage is required. An exploration permit needed to carry out such activities (drilling, trenching, etc.) at this stage is required. Example: Area with drilled intersections showing continuous mineralization, albeit with variable grades thicknesses, still requiring closer-spaced drilling to define a resource. Drillhole intercepts can be reported as on the ground. Exploration with G4.1 as a range of possible tonnages and grades or not in a range,
G4.1		**Explored Indication / Occurrence (P < 10) or G3 – Product quantity estimated with low confidence (P = 10) *** (* According to UNFC G probability) The difference between G4.1 and G3 depends on the degree of exploration works, namely on drilling density, estimates probability, (P below 10 is G4.1), calibration, data analysis, data integration, etc.
G3		**Low confidence - Inferred Resources - C2 according GKZ** Requirements according to G3 (UNFC), inferred resources (CRIRSCO Template) and C2 (GKZ) should be met. Existence of a developable product based on preliminary direct evidence. Further data acquisition and evaluation is required.

This differentiation attempts to provide the necessary granularity to NEP data and for future monitoring of the advancement of occurrences as new geophysical, geochemical, or structural date is acquired through successive exploration campaigns.

As mentioned earlier, UNFC is useful for cross-country comparison, as it allows the bridging from National or International classification systems into the classes and categories of UNFC. This provides a common language at EU-levels of all the received exploration results from Member States. To this point, a quick mapping of the defined terminologies of the G axis categories can be linked to other classification systems used in Europe, in order to harmonize the lexicon for reporting exploration results across Member States (Table 12) (ICE-SRM EU, 2025).

Table 12: Mapping G axis Categories/Sub-categories to other classification systems (ICE-SRM EU, 2025)

Category / Sub-category	UNFC (2019)	NEP Context	CRIRSCO	GKZ-based
G4	Product quantity associated with a Prospective Project, estimated primarily on indirect evidence	A Prospective Project is one where the existence of a developable product is based primarily on indirect evidence and has not yet been confirmed. Further data acquisition and evaluation would be required for confirmation	Correspond with the CRIRSCO Exploration Target which is a statement or estimate of exploration potential for a mineral deposit where there has been insufficient exploration to estimate Mineral Resources. Exploration Targets must be expressed as a range of quantity and quality	Resources, which are divided according to the level of exploration C_2 (narrower area) D_1, D_2 (wider area)
G4.3	Incremental amount to G4.1+G4.2 such that G4.1+G4.2+G4.3 equates to a high estimate of the quantities	Assumed Indication	Undiscovered unquantified: o These require exploration to determine whether any potential exists.	Assumed Resources – D_2
G4.2	Incremental amount to G4.1 such that G4.1+G4.2 equates to a best estimate of the quantities	Confirmed Indication	Discovered unquantified Exploration Target, a statement or estimate of the exploration potential of a mineral deposit in a defined geological setting where the statement or estimate, quoted as a range of tonnes and a range of grade or quality, relates to mineralisation for which there has been insufficient exploration to estimate Mineral Resources.	Expected Resources – D_1
G4.1	Low confidence in estimate of the quantities	Explored Indication	Exploration Result, an update of data and information generated by mineral exploration programmes that might be of use to investors, but which do not form part of a declaration of Mineral Resources ~~or Mineral Reserves~~	Prospective Resources (greenfield, $P < 10$) – C_2
G3	Product quantity associated with a project that can be estimated with a low level of confidence	Existence of a developable product based on preliminary direct evidence. Further data acquisition and evaluation would be required for confirmation	Corresponds with an Inferred Resource category of confidence. In certain situations, Exploration Targets may be assigned to this category.	Prospective Resources (partially explored by research work or extension of known deposits, $P > 10$) – C_2

4.3.2 F Axis – Technical Feasibility

The F axis captures the maturity of exploration and project feasibility. In the case of NEP-derived results, most occurrences are expected to align with **F3** (*Conceptual Studies*) or **F4** (*No Project Identified*), reflecting the early stage of assessment. **F3** denotes that a conceptual plan exists to evaluate the technical feasibility of a potential extraction operation, whereas **F4** indicates that a project has yet to be defined and data acquisition is needed. It is necessary to mention that in cases where pre-feasibility assessments or pilot studies are available, they may be classified as **F2** (*Pre-Feasibility*) (Table 13) (ICE-SRM EU, 2025).

Table 13: Relevant definitions of F Categories and Sub-categories in the context of NEPs (ICE-SRM EU, 2025)

Category/ Sub-categories	*Definition* and supporting explanation (according to UNFC (2019))	Indicator
F2	*Technical feasibility of a development project is subject to further evaluation*. Preliminary studies of a defined project provide sufficient evidence of the potential for development and that further study is warranted. Further data acquisition and/or studies may be required to confirm the feasibility of development.	**Subject to further evaluation**
F2.1	Project activities are ongoing to justify development in the foreseeable future.	Justifiable development
F2.2	Project activities are on hold and/or where justification as a development may be subject to significant delay.	Development on hold / delay
F2.3	There are no plans to develop or to acquire additional data at the current time due to limited potential.	No plans / additional data / limited potential
F3	*Technical feasibility of a development project cannot be evaluated due to limited data*. Very preliminary studies of a project, indicate the need for further data acquisition or study in order to evaluate the potential feasibility of development.	**Limited data**
F3.1	Site-specific studies have identified a potential development with sufficient confidence to warrant further testing.	Early stage in favor - on site
F3.2	Local studies indicate the potential for development in a specific area but require more data acquisition and/or evaluation in order to have sufficient confidence to warrant further testing.	Early stage in favor - local level
F3.3	At the earliest stage of studies, where favorable conditions for the potential development in an area may be inferred from regional studies.	Early stage in favor - regional level
F4	*No development project has been identified*. Remaining quantities of product not developed by any project. These are quantities which, if produced, could be bought, sold or used (i.e. electricity, heat, etc., not wind, solar irradiation, etc.).	**Development not identified yet**
F4.1	The technology necessary is under active development, following successful pilot studies, but has yet to be demonstrated to be technically feasible for this project.	Technology under active development after pilot studies, yet proven to be feasible
F4.2	The technology necessary is being researched, but no successful pilot studies have yet been completed.	Research, no success study completed yet
F4.3	The technology is not currently under research or development.	Currently not research or development

4.3.3 E Axis – Environmental-Socio-Economic Viability

The E axis assesses whether development of a resource project is environmentally, socially, and economically viable. For exploration-stage occurrences, these aspects are generally indeterminate, thus **E3** is the most representative category, signifying that viability cannot yet be evaluated or is currently not expected within the foreseeable future. In rare instances where NEP results intersect with existing mining projects or mine waste, **E2** may apply if a degree of environmental-socio-economic viability is demonstrated (Table 14) (ICE-SRM EU, 2025).

Table 14: Relevant definitions of E Categories and Sub-categories in the context of NEPs (ICE-SRM EU, 2025)

Category/ Sub-categories	*Definition* and supporting explanation (according to UNFC (2019)	Indicator
E2	*Development and operation are expected to become environmentally-socially-economically viable in the foreseeable future.* Development and operation are not yet confirmed to be environmentally-socially-economically viable but, on the basis of realistic assumptions of future conditions, there are reasonable prospects for environmental-socio-economic viability in the foreseeable future.	**To become environmentally-socially-economically viable in the foreseeable future**
E3	*Too early stage / insufficient information.* Development and operation are not expected to become environmentally-socially-economically viable in the foreseeable future or evaluation is at too early a stage to determine environmental-socio-economic viability. On the basis of realistic assumptions of future conditions, it is currently considered that there are not reasonable prospects for environmental-socio-economic viability in the foreseeable future; or environmental-socio-economic viability cannot yet be determined due to insufficient information. Also included are estimates associated with projects that are forecast to be developed, but which will be unused or consumed in operations.	**Not expected in foreseenable future**
E3.1	Estimate of product that is forecast to be developed, but which will be unused or consumed in operations.	Forecast to be developed
E3.2	Environmental-socio-economic viability cannot yet be determined due to insufficient information.	Insufficient information
E3.3	On the basis of realistic assumptions of future conditions, it is currently considered that there are not reasonable prospects for environmental-socio-economic viability in the foreseeable future.	Non reasonable prospects in foreseeable future

4.3.4 Operationalizing UNFC for NEP Results within Italy

To implement this framework within the Italian NEP, a systematic data workflow is required, integrating:

1. **Geological Data Acquisition:** Using national-scale mapping, geochemical and geophysical surveys.
2. **Data Processing and Predictive Modelling:** Application of GIS, machine learning, and 3D modelling to delineate potential CRM-bearing zones.

3. **UNFC Classification:** Assigning each identified occurrence an E-F-G code.

4. **Integration and Reporting:** Harmonization with EU data platforms, and reporting to the European Commission per CRMA Article 45.

This workflow ensures that exploration results are not static data points, but components of a dynamic knowledge system, capable of guiding future exploration investments and policy interventions.

Hence, applying UNFC to the Italian NEP supports alignment with EU resource governance objectives. Specifically, in standardized classification to enhance comparability of Italian CRM occurrences with those in other Member States. Data integration enables ISPRA and the Ministry of the Environment and Energy Security (MASE) to feed classified data directly into European platforms, improving transparency and knowledge transfer. Additionally, resource evolution monitoring and documenting is necessary to dynamically reassess exploration targets as new information is generated, which supports adaptive policy implementation. With UNFC, evidence-based prioritization is prone to be made noticeable for national authorities to focus on occurrences with higher potential, and for follow-up exploration or inclusion in strategic assessments under Article 7 of CRMA. In essence, UNFC operationalizes a structured, transparent, and evolving classification for exploration results, directly supporting Italy's compliance with CRMA and enhancing the nation's contribution to the EU's secure and sustainable CRM supply chain (ICE-SRM EU, 2025). It is imperative to keep the focus on the primary objective of NEPs, that is to make the results accessible to junior exploration companies for further exploration. On this point, besides indications on the degree of exploration carried, UNFC remains non-granular as opposed to what exploration investors generally require.

4.4 Case Study: Piampaludo Titanium Exploration Project, Italy

This case study demonstrates the application of UNFC to a titanium exploration project in Liguria, Italy. It is an attempt to introduce UNFC to Italy. The Piampaludo exploration project is reported to be one of the largest deposits of titanium in Europe with the potential for significant economic importance, yet its development is constrained by environmental and social considerations. The case study serves as a demonstration of how UNFC can be used to classify exploration projects. Given that the study was developed in 2023, it should be noted that more recent developments (permits, data) may alter the classification (UNECE, 2023).

Although the only mention of this deposit within the Italian NEP states that the proven titanium deposit in the Savona area is well known, along with the tied environmental issues, this case study remains highly relevant for Italy's broader exploration strategy and for demonstrating the methodology presented in Chapter 3. In relevance to the Italian NEP, the study demonstrates how an exploration occurrence can be mapped, assessed and classified in UNFC, while pinning real-world challenges (e.g., protected area status, permitting constraints, data gaps) that influence the E-axis and F-axis classifications for NEP results. In fact, this is directly instructive for how ISPRA might prioritize follow-up exploration in protected or contested regions. Moreover, the classification of Piampaludo offers a baseline for how ISPRA's priority Phase-1 studies can be structured and reported, starting with conceptual mapping, assigning G4/G3 confidence levels, and then progressively upgrading as more data are gathered. A UNFC classification of early exploration stages (most occurrences will lie initially in categories such as E3/F3/G4) therefore provides enough granularity to value an occurrence, and trigger systematic re-classification as additional data emerges.

The case study is appended in full under **Appendix B** of this dissertation, as originally prepared.

4.5 Extractive Waste

Extractive waste is defined within the European regulatory framework as waste resulting from the exploration, extraction, treatment, and storage of mineral resources and the working of quarries (European Parliament and Council of the European Union, 2006). This includes a broad range of materials such as overburden, waste rock, tailings, and residues from mineral processing operations (European Parliament and Council of the European Union, 2006). These materials are typically managed in dedicated waste facilities, including tailings ponds and waste rock dumps, which may remain active for extended periods or persist as legacy sites after mine closure (European Parliament and Council of the European Union, 2006). The scale of extractive waste generation is substantial, reflecting both the material intensity of mining activities and the declining grades of mineral deposits, which require increasingly large volumes of material to be handled for the recovery of economically valuable components (Mehta et al., 2018). In 2014, the extractive industry was the second-largest source of waste in the EU, accounting for 28.1% of total waste, about 703 million tonnes (Dino et al., 2018). Overall, the cumulative volume of extractive waste stored across the EU exceeds 5.9 billion tonnes (Dino et al., 2018). In current times, extractive waste has increasingly been considered within the context of resource efficiency and circular economy strategies. Historical and active mining waste facilities may contain significant quantities of valuable materials, including CRMs, which were not economically recoverable at the time of initial extraction but may become viable under changing technological and market conditions (Maraboutis et al., 2021). For context, in the United States, recovering 90% of by-products from current domestic metal mining found in wastes, could satisfy almost all of the United States' demand for CRMs, while even a 1% recovery rate would significantly cut dependence on imports (Holley et al., 2025). Advancements in technology and supportive policies could make CRM recovery from waste feasible, offering a resource-efficient way to secure CRMs while minimizing environmental impacts, and geopolitical vulnerabilities (Holley et al., 2025). This shift reflects a broader transition from viewing extractive waste solely as an environmental liability toward recognizing its potential role as a secondary resource. However, the feasibility of reprocessing such materials is highly context-dependent, influenced by geology, processing technologies, extractive metallurgy, regulations, environmental and social aspects, and economic conditions (Holley et al., 2025).

At the European Union level, the management of extractive waste is governed by Directive 2006/21/EC on the management of waste from extractive industries, which establishes a comprehensive framework aimed at preventing or reducing negative effects on the environment and human health (European Parliament and Council of the European Union, 2006). A central element of the Directive is the requirement for operators to develop and implement a waste management plan, to minimize waste generation, encourage recovery where feasible, and ensure the safe disposal of waste in both the short and long term (European Parliament and Council, 2006). It further introduces obligations related to the classification of waste facilities, the prevention of major accidents, the rehabilitation of sites following closure, and the provision of financial guarantees to cover environmental liabilities. Following a series of accidents in Europe related to mismanaged extractive waste, the Directive established stringent requirements for waste prevention, recovery and environmental safeguards (European Parliament and Council of the European Union, 2006). The Directive distinguishes between waste in active sites, which require an Extractive Waste Management Plan (Article 5), and waste in closed or abandoned sites, which must be inventoried and monitored for their potential to cause serious environmental or human health impacts (Article 20) (European Parliament and Council of the European Union, 2006). Most recently, CRMA introduced specific provisions related to extractive waste under national circularity measures, and within the broader objective of securing a sustainable and resilient supply of CRMs. Article 27 of CRMA establishes a structured approach for assessing and promoting the recovery of CRMs from extractive waste, thereby formally recognizing such materials as a potential component of the EU's resource base (European Commission, 2024). Under this provision, operators subject to waste management planning obligations pursuant to Directive 2006/21/EC are required to conduct a preliminary economic assessment of the potential recovery of CRMs from both existing extractive waste and, where relevant, from material flows prior to their classification as waste (European Commission, 2024). This requirement introduces, for the first time at EU level, a systematic obligation to evaluate extractive waste not solely from a risk management perspective, but also in terms of its resource potential. The assessment must include, at a minimum, estimates of the quantities and concentrations of CRMs contained in the waste, as well as an evaluation of their technical and economic recoverability, with explicit documentation of the methods used (European Commission, 2024). Additionally, CRMA requires Member States to establish inventories of closed extractive waste facilities and to assess their potential for the recovery of CRMs, thereby integrating extractive waste into the resource management framework of the European Union (European Commission, 2024). The aim is to support the identification of secondary raw materials opportunities while improving knowledge of existing stocks within the EU. At the same time, it reinforces the need for systematic data collection, standardized assessment methodologies, and transparent reporting practices. A notable aspect of Article 27 is the explicit reference to UNFC as a potential tool for classifying extractive waste facilities within these national databases.

Despite these developments, the management and potential recovery of extractive waste remain associated with significant challenges. From a technical perspective, extractive waste deposits are often characterized by high heterogeneity, limited data, and uncertainties regarding composition and recoverability (Dino et al., 2018). From an environmental standpoint, the reprocessing of waste materials may involve the disturbance of previously stabilized sites, potentially leading to the release of contaminants if not properly managed (Dino et al., 2018). Furthermore, economic viability remains uncertain, as reprocessing operations must compete with primary resource extraction while accounting for additional costs related to remediation and regulatory compliance (Holley et al., 2025). These considerations highlight that extractive waste occupies a complex position at the intersection of environmental management and resource supply. Its effective integration into sustainable resource management frameworks requires approaches capable of addressing uncertainty, capturing multiple dimensions of feasibility, and supporting informed decision-making.

4.5.1 Extractive Waste in Italy

Italy's mining history has generated a substantial legacy of extractive wastes, representing both a long-standing environmental challenge and an untapped potential of CRMs (Lucarini et al., 2020). Past mining operations have left behind approximately 150 million m^3 of waste, stored in legacy and often structurally compromised waste facilities (ISPRA, 2025). In 2014 in Italy, volumes of extractive wastes from mining and quarrying activities were estimated at 47.5 million tonnes, representing 37% of Italy's total waste volume, which include waste rock, tailings, and residues from drilling and processing (Lucarini et al., 2020). Many old deposits in Italy contain elevated concentrations of metals, including several of CRMs, as a product of past mining practices focused on a single commodity and the technological limitations of earlier eras (Lucarini et al., 2020). These now are thought of as potential secondary raw material sources, especially with the advances in processing technologies, rising demand for CRMs and shifts in market prices (Figure XXXIX) (Lucarini et al., 2020).

Figure XXXIX: Raw materials in mining waste deposits in Italy (ISPRA, 2025)

However, Italy, like many European countries, also faces a significant environmental legacy associated with extractive waste (ISPRA, 2025). The extractive waste deposits are frequently associated with significant environmental degradation, including contamination of soils and surface and groundwater by heavy metals, many of which are CRMs (ISPRA, 2025). Italy focuses strongly on wastes in closed or abandoned sites, which must be inventoried and monitored for their potential to cause serious environmental or human health impacts, as stated in Article 20 of the EU Extractive Waste Directive (2006/21/EC) (European Parliament and Council of the European Union, 2006). Addressing this dual challenge, environmental remediation and resource recovery, has therefore become a core priority within Italy's emerging resource governance framework (ISPRA, 2025). The Italian NEP explicitly incorporates extractive waste mapping as one of its pillars. This activity is implemented through the national mineral resources database of Italy (GeMMA), which is tasked with identifying, characterizing, and digitizing the full inventory of closed extractive waste facilities across the country (ISPRA, 2025). The rationale for including extractive wastes within the NEP is twofold: (1) they represent a substantial secondary CRMs base of potential strategic importance, and (2) their proper management is necessary for environmental protection, safety, and land-use planning (ISPRA, 2025).

This national effort is reinforced by an updated legislative framework under Decree Law No. 84/2024, which introduces Article 9 "Mineral Recovery from Waste" (ISPRA, 2025). Article 9 creates a legal pathway for the extraction of mineral resources from closed or abandoned waste storage facilities, extending, *where compatible*, the application of the historic Royal Decree No. 1443/1927, which governs mining exploration and exploitation in Italy (Senato della Repubblica, 2024). This extension allows mineral recovery from extractive wastes to be regulated under the same principles of mineral concession applied to traditional mining activities. It also establishes that authorizations for waste extraction projects must be accompanied by a Recovery Plan for Raw Materials from Historical Waste, demonstrating: i) economic feasibility, ii) environmental sustainability, and iii) coherence with existing remediation or reclamation plans (Senato della Repubblica, 2024). With this legal update, responsibility for defining eligibility criteria and granting extraction permits is shared between MASE and MIMIT (Senato della Repubblica, 2024). This alignment elevates extractive waste recovery to the level of a national strategic activity and embeds it within the broader framework of sustainable raw materials management (Senato della Repubblica, 2024).

The Italian approach is also strongly influenced by CRMA. Article 27 of the CRMA mandates that all EU Member States develop a dedicated national database of extractive waste, recognizing their potential contribution to security of supply (European Commission, 2024). In anticipation of this requirement, Italy, through ISPRA, successfully proposed a dedicated line of action under PNRR RePowerEU, focusing on nationwide mapping, characterization and classification, digitalization, and prioritization of extractive waste deposits according to their CRM recovery potential. This initiative also extends beyond extractive wastes in the strict sense. Under a broader circularity perspective and beyond mining waste, Italy plans to record additional waste streams that may contain CRM-bearing fractions, such as industrial waste storage facilities, municipal waste infrastructures, and recycling, treatment, and recovery plants handling potential CRM-containing waste (ISPRA, 2025). Within this context, extractive wastes in Italy are moving from being seen solely as environmental liabilities to being recognized as secondary raw materials that can contribute to national and EU-level supply resilience. This shift provides the necessary foundation for the integration of UNFC in subsequent subsections, enabling transparent, consistent, and sustainability-oriented classification of these secondary raw materials.

Under previous initiatives, Italy has established a National Inventory of Mining Waste Facilities, in accordance with Article 20 of Directive 2006/21/EC, transposed into national law through Legislative Decree No. 117/2008 (Decreto Legislativo n. 117, 2008). The inventory focuses specifically on closed or abandoned extractive waste facilities that have caused, or may potentially cause, significant adverse environmental or human health impacts in the short to medium term (ISPRA, 2022). As such, it constitutes a risk-oriented dataset, prioritizing sites classified as hazardous based on ecological health risk (RES) and static-structural risk (RSS) assessments (ISPRA, 2022). Facilities are categorized according to a hierarchical risk classification (medium, medium-high, and high), while lower-risk sites are excluded from detailed investigation, reflecting a targeted regulatory approach to environmental management (Figure XL, Table 15) (ISPRA, 2022). The inventory is updated periodically with contributions from regional authorities. It represents the most comprehensive national effort to document legacy extractive waste liabilities (ISPRA, 2022). However, its primary objective remains environmental risk identification and mitigation, rather than resource classification. Consequently, it offers limited insight into their potential for secondary raw materials.

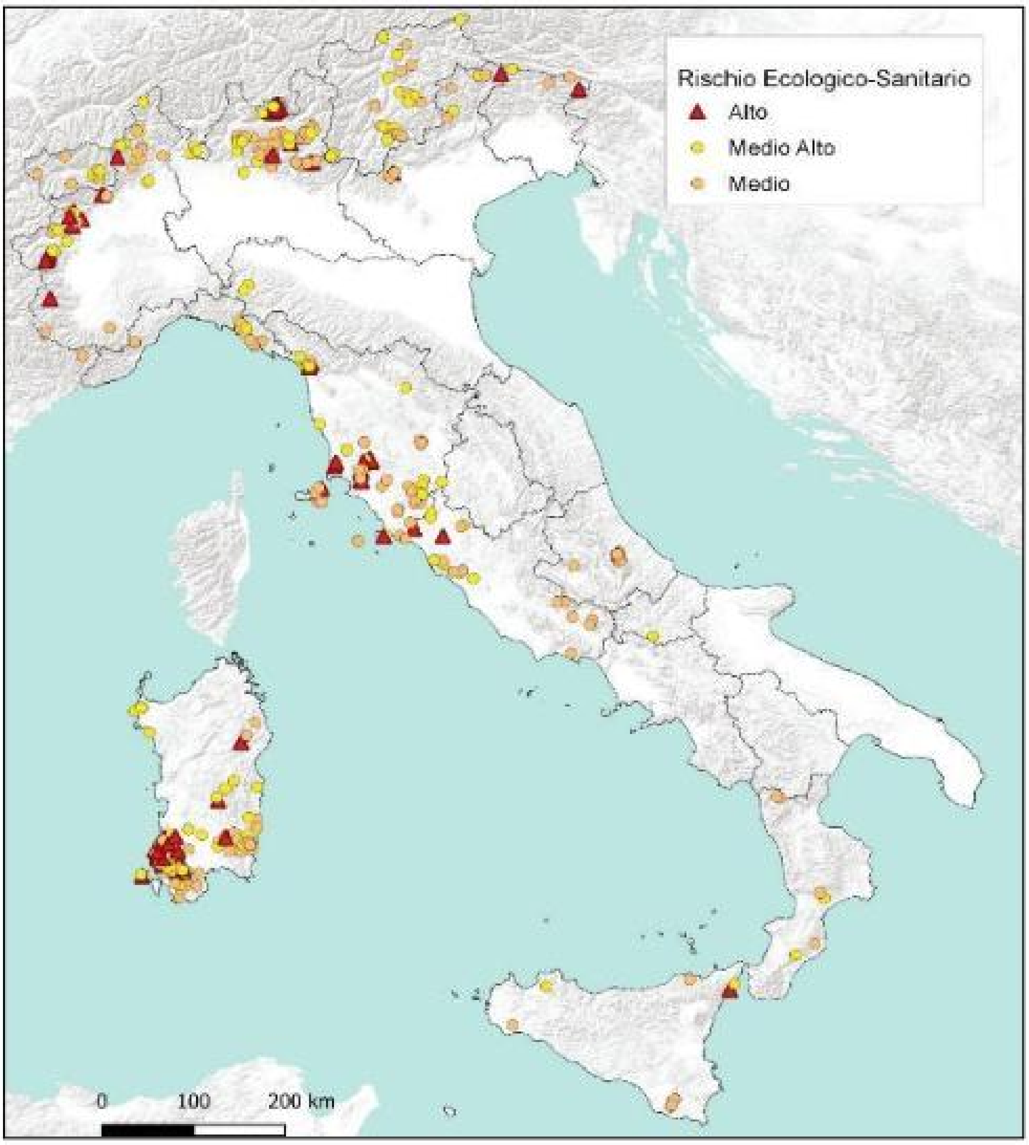


Figure XL: Extractive waste deposits with risk to the environment (Red is High, Yellow is Medium-High, and Orange is Medium) (ISPRA, 2025)

Table 15: National inventory of mining waste facilities updated to 2022 (M= Medium risk, M-H= Medium-High, H= High risk) (ISPRA, 2022)

	RES				**RSS**			
Region / Province	M	M-H	H	**Total**	M	M-H	H	**Total**
Abruzzo	12			**12**				
Calabria	6	2		**8**	1			1
Friuli Venezia Giulia	2	0	1	**3**	1		2	3
Lazio	11	10		**21**				
Liguria	7	4		**11**	5			5
Lombardy	67	37	24	**128**				
Molise		1		**1**				
Piedmont	25	21	11	**57**	7			7
Sardinia	73	80	56	**209**				
Sicily	19	3	1	**23**	1			**1**
Tuscany	44	21	5	**70**				**0**
Trento	2	4	0	**6**	4			**4**
Veneto	9	2	2	**13**				
Total	**277**	**185**	**100**	**562**	**19**		**2**	**21**

Furthermore, under the PNRR framework, Italy has also initiated the URBan mining and Extractive waste information System (URBES) project, listed as part of the actions under the Italian NEP (ISPRA, 2025). URBES is an online platform that displays a systematic mapping and assessment of secondary raw material available in extractive waste deposits from abandoned mines and quarries. However, as it currently stands, the database contains only information on the CRMs available within the waste, without concentrations nor volumes. The visual data on extractive waste facilities includes spatial distribution, deposit typology, and preliminary mineralogical content. Data acquisition is based on a combination of literature review and historical documentation (ISPRA, 2025). The plan to further knowledge about quantities and quality of available CRMs in certain waste deposits is an action listed in the Italian NEP (ISPRA, 2025). Nonetheless, URBES serves as a baseline for potential secondary resource recovery.

ISPRA is developing the Geological, Mining, Museum and Environmental Geodatabase (GeMMA), a national-scale, INSPIRE-compliant system designed to consolidate, harmonize and modernize the country's knowledge base on mining activities, mineral occurrences, extractive waste and related cultural assets. The initiative addresses the absence of a unified national repository of active and ceased extractive activities, a gap unique among major European countries (ISPRA, 2025). The GeMMA Geodatabase is being developed using a PostgreSQL architecture building on the experience from previous European initiatives, mostly the technical know-how and lexicon from Minerals4EU and its later GEOERA-funded successor Mintell4EU (not the content of the database per se), in which ISPRA was a partner. The database is aimed to bring together information from national sources, regional and provincial administrations, mining plans, historical archives, museum networks, and geological mapping projects (including the CARG Programme, national inventory of mining waste facilities, and URBES). The overarching objective is to create a harmonized, interoperable platform capable of supporting policy development, resource assessment and sustainable management of both primary and secondary mineral resources (ISPRA, 2025). GeMMA integrates a wide range of datasets, including: geological and thematic mapping (CARG 1:50,000 and historical maps), national inventories of active and abandoned mining and quarrying sites, mining concessions and plans, mineralogical and lithological information, the national network of mine parks and museums, environmental conditions, contaminants and inspections, and most in focus secondary raw materials from extractive waste facilities (ISPRA, 2025). Each coded mining site is linked to detailed attributes such as type of operation, extracted commodity, state of activity, ownership or management, environmental status, and the presence of museums or rehabilitated structures. To date, all active quarries and mines have been identified and georeferenced, and approximately 90% of the mining sites active since 1870 have been located and encoded within the prototype version of the database (ISPRA, 2025). The development of the GeMMA requires coordinated collaboration across multiple authorities. ISPRA therefore leads a Thematic Table of the Italian Geological Services Network, engaging Regional Mining Offices, ISTAT, MIMIT and MASE. This governance mechanism is fundamental for ensuring data standardization and addressing the complex division of responsibilities between national and regional levels, particularly regarding the estimation of mineral resources and reserves. Ultimately, the GeMMA database aims to deliver a new national vision of mineral resources through:

- a new Mining Map of Italy (the first revision since 1973),

- the GeMMA Geodatabase as a permanent national repository, and
- a Catalogue of Conceptual Models describing groups of similar deposit types across the country.

This new knowledge base will underpin sustainable resource policy, reduce the environmental impacts of extraction, and enhance the efficient use of both primary and secondary raw materials within a circular economy framework (Figure XLI) (ISPRA, 2025). Nevertheless, significant challenges remain in terms of data standardization, methodological consistency, and the integration of environmental, technical, and economic dimensions into a unified assessment framework.

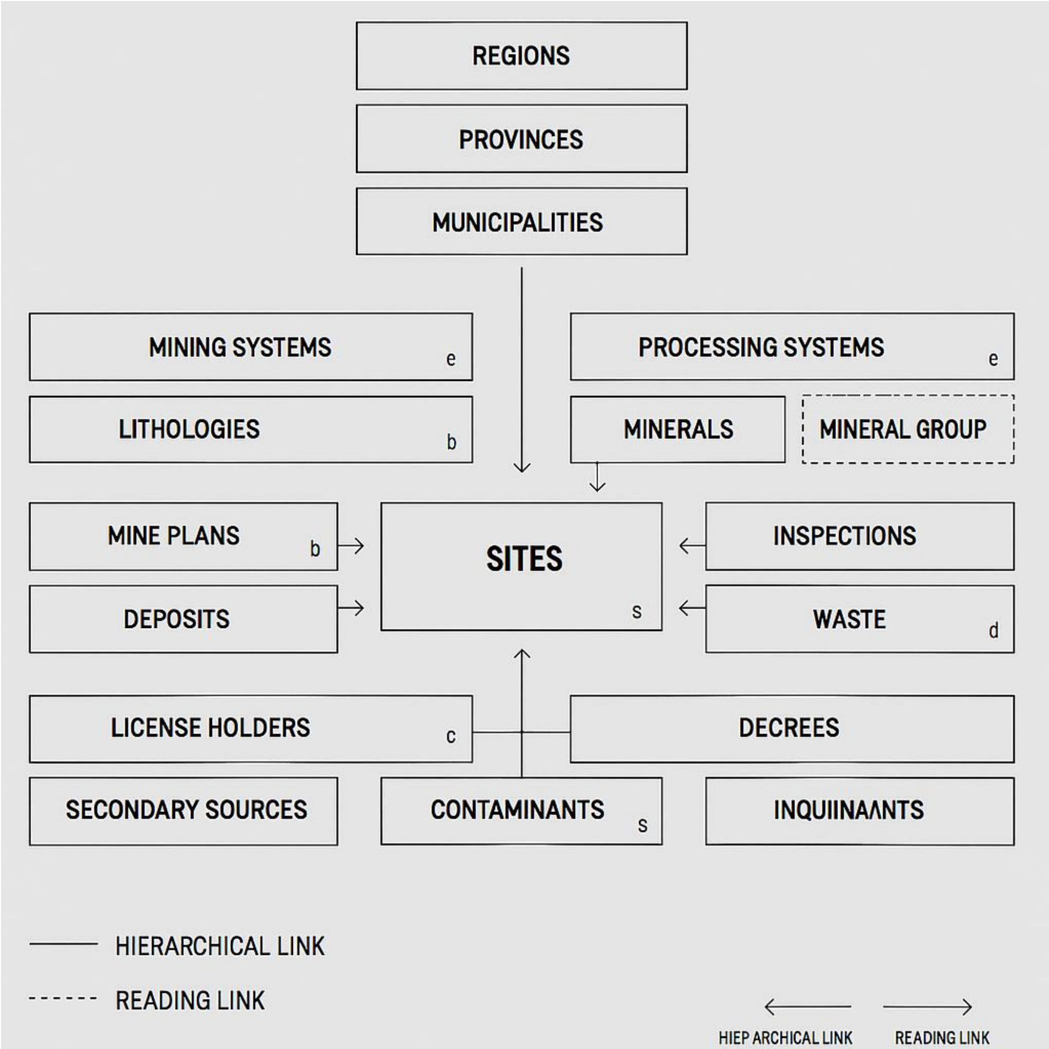


Figure XLI: GeMMA database structure (ISPRA, 2025)

4.5.2 Application of UNFC to Extractive Waste

The application of UNFC to extractive waste in Italy ought to follow a structured and transparent method in a manner consistent with the requirements of CRMA, particularly for circularity measures, and the NEP. The focus is explicitly on extractive waste, including tailings, waste rock, and processing residues. As mentioned earlier, extractive waste, more specifically tailings and processing residues stored in historical waste facilities, represents a potentially significant secondary source of CRMs (Lucarini et al., 2020). However, the assessment of such resources presents distinct challenges compared to primary mineral deposits. In particular, extractive wastes are characterized by fragmented data, heterogeneous material composition, chemical weathering, confined spatial distribution, and limited direct measurements, all of which constrain the robustness of resource classification (Hokka et al., 2026). In Italy, these challenges are further compounded by variable data quality and availability (ISPRA, 2025). As established, the existing datasets on extractive waste are derived from legacy documentation, regional data, or environmental assessments rather than systematic resource evaluation. As a result, key parameters such as volumes, internal structure, density, quality and grade distribution are incomplete, inconsistent, or based on indirect evidence. Italy's policy context, namely the recent extension of mining legislation to waste recovery, creates a solid regulatory foundation for the systematic classification of these materials. With that in mind, the application of UNFC pertains to ISPRA, as in by the national geological survey. UNFC is capable to provide a harmonized framework to capture the geological, technical, and socio-environmental controlling factors that inform, to the extent possible, the recoverability of raw materials from extractive waste. Although ongoing Horizon Europe project "Future Availability of Secondary Raw Materials" (FutuRaM) is expected to deliver a more advanced methodology for the EU, the present section outlines how UNFC can already be applied to the Italian context, using generalized methodological principles and without relying on project-specific details. The application follows the efforts and best-practice guidelines carried out by the Geological Survey of Finland (GTK) for the assessment and classification of CRMs from extractive waste. Accordingly, the UNFC application to extractive waste follows the standard three-axis structure, adapted to the specific characteristics of anthropogenic resources. Generally, for extractive waste, these characteristics include incomplete historical data, variable composition, challenges in quantifying spatial heterogeneity, and the need to integrate recovery rates derived from laboratory-scale testing. As such, extractive waste assessments carried out at national geological survey level are typically classified as prospective projects or remaining products not developed (Hokka et al., 2026). Advanced maturity and viability therefore indicate that the extractive waste deposit is under remediation management, by ISPRA for instance, or under recovery development by a private entity (Hokka et al., 2026). The objective is twofold:

1. **Provide a replicable methodology** for classifying extractive waste sites under UNFC in alignment with CRMA requirements, while explicitly reflecting data limitations and uncertainty; and

2. **Prepare the foundation for integration** of UNFC categories into Italy's GeMMA database, thereby enabling systematic monitoring, comparison, and prioritization of waste recovery opportunities.

The application is conceptually consistent with the approach developed in the ongoing (by the time this dissertation was written) FutuRaM efforts, and GTK's best-practice guidelines, but is presented here independently of any specific case.

G axis: Degree of Confidence

The G axis evaluates the level of confidence associated with the estimation of remaining or available quantities of material within extractive waste facilities (UNECE, 2020). In Italy, due the lack of complete records, the certainty must rely on updated surveys, analyses, and modelling. Key G axis controlling factors include:

- **Volumetric Data:** Waste volumes can be estimated using digital elevation models, geostatistical interpolation, volumetric reconstruction, and geophysical analysis. Similar to primary deposits, detailed exploration increases confidence and assignment to higher G categories.

- **Internal Composition:** Extractive waste is typically heterogeneous. When drill-hole data indicate spatial variability, a simplifying assumption may be applied by treating material as quasi-homogeneous and using median or average grade values.

- **Operational Efficiency:** Uncertainties associated with composition, moisture, oxidation state, and mineral behavior must be explicitly considered.

Most extractive waste assessments at national level correspond to G4, where estimates are based primarily on indirect evidence, and G3, based on limited direct measurements (Hokka et al., 2026). These categories may be predominant with the suggested plan for extractive waste in the Italian NEP (ISPRA, 2025). Only in cases where detailed drilling, density measurements, and three-dimensional modelling are conducted can higher confidence categories be considered (Hokka et al., 2026). Using this systematic approach, extractive waste in Italy can be assigned to appropriate G category, reflecting the quality and completeness of available evidence.

F axis: Technical Feasibility

The F axis assesses the technical feasibility and maturity of potential recovery (UNECE, 2020). In the context of extractive waste, and particularly at geological survey level, this axis is characterized by limited evaluative capacity, as feasibility depends on site-specific engineering studies, processing tests, and industrial commitments (Hokka et al., 2026). Accordingly, most extractive waste assessments in Italy are classified as F3, where feasibility cannot be evaluated due to limited data, or F4, where no development project has been defined (Hokka et al., 2026). While various technologies for CRM recovery from extractive waste exist, their applicability is highly site-specific and requires detailed testing. The mere existence of a technology does not imply feasibility.

E axis: Environmental-Socio-Economic Viability

The E axis captures environmental, social, regulatory, and economic factors influencing project viability (UNECE, 2020). At early stages of extractive waste assessment, this axis is associated with high uncertainty, and most projects are classified as E3, where environmental–socio-economic viability cannot yet be determined (Hokka et al., 2026). Economic evaluations are typically preliminary, based on indicative market conditions and assumed recovery rates, and are insufficient to demonstrate viability. Environmental considerations may include both potential benefits and risks, but these require site-specific assessment However, in the case of Italy, legacy waste facilities are often associated with environmental risks, and recovery may contribute both to CRM supply and to remediation objectives. With respect to social factors, public acceptance of extractive waste recovery projects is highly context-dependent and variable.

Chapter 5

UNFC for Risk Monitoring and Mitigation

5.1 EU Database of Critical Raw Materials Projects

Over the past decade, the EU has developed a comprehensive system for monitoring CRM supply risks through policy, data infrastructure, and classification frameworks. This has culminated in CRMA, with an integrated approach to identifying, classifying, and mitigating supply chain vulnerabilities across Member States. Early EU initiatives laid the foundation for systematic CRM monitoring. The Action Plan on Critical Raw Materials outlined concrete measures to ensure sustainable and diversified supply chains, with *Action 4* focusing on mapping the potential supply of secondary CRMs from EU stocks and wastes, and *Action 5* identifying mining and processing projects and investment needs capable of becoming operational under suitable framework conditions (European Commission, 2020). Following these efforts, the European Commission, through the EU Raw Materials Supply Group (RMSG), began gathering data on viable and potentially viable CRM projects starting in 2018. Initially centered on battery raw materials, the scope expanded to rare earth elements (REEs) in 2019, and to the full list of CRMs by 2020. This initiative led to the establishment of the EU Database of Critical Raw Materials Projects, presenting a dynamic repository of viable, potentially viable, closed, and historical CRM projects validated by Member States (European Commission, 2022).

The CRM Database serves as the EU's central monitoring instrument, designed to identify viable and potentially viable projects, assess progress in permitting, and evaluate environmental and social impacts. The database applies UNFC as its underlying classification system, ensuring consistency, transparency, and comparability of information across all Member States. This structured data collection and monitoring process aligns with the EU's broader strategic, calling for decisive action to secure access to CRMs essential for energy transition technologies, while promoting circular economy principles and resource efficiency (Figure XLII) (European Commission, 2022).

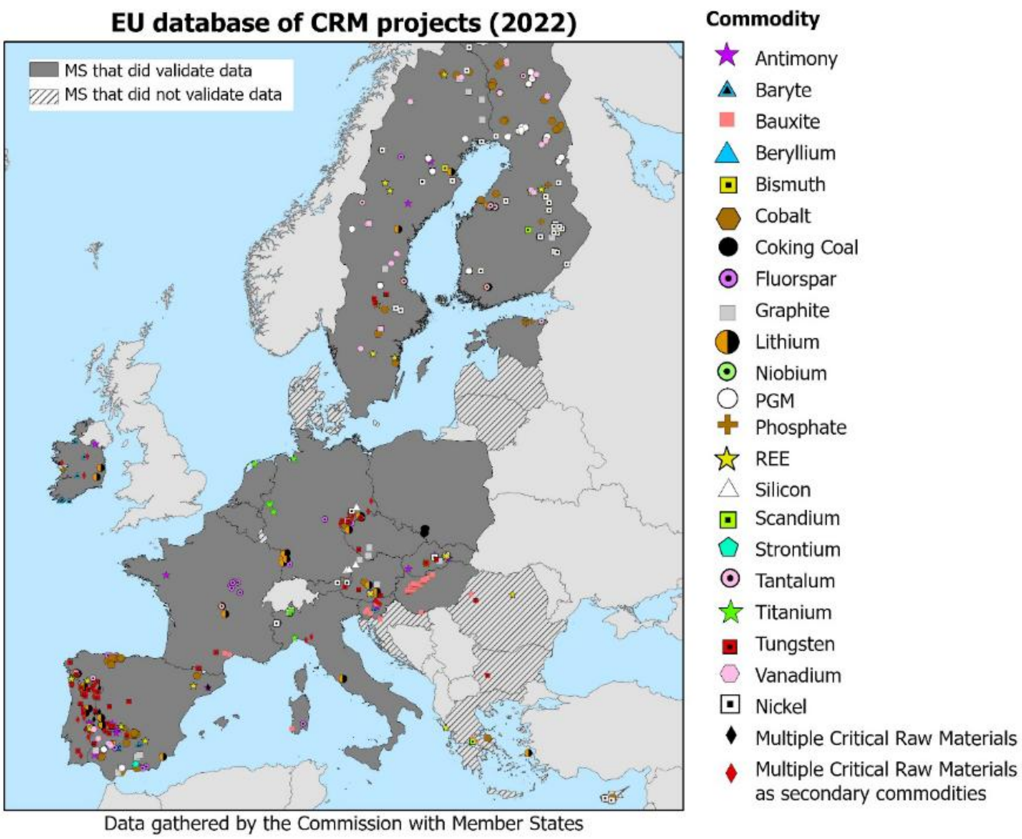


Figure XLII: EU CRM Projects Database as gathered by the European Commission with Member States, 2022

However, the collection thus far has been on a voluntarily basis. Now, articles 20 and 21 of CRMA establish the formal legal framework for risk monitoring and information reporting across the EU. Under Article 20 (Monitoring and Stress Testing), the European Commission is mandated to continuously monitor supply risks related to CRMs, focusing on parameters such as:

- trade flows between the Union and third countries,
- demand and supply dynamics,
- concentration of supply and production capacities,
- price volatility and permitting bottlenecks for Strategic Projects, and

- potential trade obstacles within the internal market (European Commission, 2024).

Complementing this, Article 21 (Information Obligations for Monitoring) requires Member States to provide updated information on new or existing CRM projects within their territory, including their classification according to UNFC. These reports contribute to the EU-wide monitoring system and must also be transmitted to national statistical authorities and Eurostat, ensuring coherence between national and European datasets. This approach enables early identification of supply disruptions and facilitates stress testing of value chains under different economic and geopolitical scenarios.

In line with CRMA requirements, Italy's Decree Law No. 84 includes measures directly relevant to raw materials risk monitoring and mitigation. The decree establishes mechanisms for stockpiling strategic materials, supporting the domestic capacity to respond to supply shocks, and facilitating the systematic assessment of vulnerabilities in CRM supply chains. Moreover, the decree reinforces the mandate of the ISPRA to maintain up-to-date inventories of critical and strategic raw material projects, feeding into both national and EU monitoring frameworks. Italy's national measures also align with the EU's emphasis on stress testing and diversification of supply sources, with the overarching objective of enhancing industrial resilience through improved coordination between exploration, production, processing, and recycling sectors.

In support of the monitoring efforts, the integration of UNFC serves as the cornerstone for harmonized risk assessment across Member States. Article 21 of the CRMA explicitly requires the classification of new projects using UNFC for project comparability and policy evaluation. The multidimensional structure of UNFC enables the monitoring of project progression from early exploration to commercial production, while also serving as an indicator of supply risk and investment potential, as established in earlier chapters. It ensures that both primary and secondary raw material projects are reported using a common lexicon, reducing data fragmentation and strengthening the EU's ability to anticipate supply chain disruptions. In this context, Italy's commitment to the application of UNFC in its NEP and CRM monitoring processes represents a critical advancement toward a coherent and resilient resource management system.

The subsequent sections will elaborate on the methodology for applying UNFC to classify producing or near-producing CRM projects and propose a national template for systematic monitoring in Italy, that could also be expanded for use by other Member States. The monitoring methodology proposed in this section pertains to Article 21 of CRMA, as opposed to Strategic Projects monitoring where a benchmark year and quantities are predetermined. The main purpose for this monitoring action is to support the European Commission with CRMs knowledge, particularly on production.

5.2 Applying UNFC in Compliance with Article 21 of CRMA

The following sub-chapter references the document "*Manual for the Application of the United Nations Framework Classification for Resources (UNFC) for the Monitoring of Critical Raw Materials Projects in the EU*", developed in collaboration with colleagues from UNECE, specifically Erika Ingvald, Victoria Oliver Tenconi, and Minwoo Ki. The document is yet unofficial but proposes a set of detailed instruction on how to apply UNFC in compliance with Article 21 of CRMA. These instructions are intended for national officials responsible for the application of UNFC in accordance with CRMA's provisions on risk monitoring and mitigation. These include, but are not limited to, CRMA reporting coordinators in EU MS, ministerial officials responsible for CRM data collection from industry, industry itself and any stakeholders studying CRMA can all benefit and become more knowledgeable concerning UNFC and its role in the CRMA. The use of this document is intended for all levels of knowledge on UNFC. The purpose, scope, and detailed methodology is outlined in the subsequent paragraphs (UNECE, 2025).

The purpose of this methodology is to provide systematic guidelines on how to apply UNFC with regard to Article 21, concerning the monitoring of CRM projects in the EU. To elaborate further, this monitoring action pertains to advanced CRM projects located in the EU, covering extraction, processing, and recycling, as a follow-up to the previous voluntary reporting to the European Commission. The monitoring of these projects therefore differs from Strategic Projects monitoring since the majority are more advanced, producing or near-production, and do not adhere to a specific benchmark. Article 21 requires Member States to report to the Commission on new and existing CRM projects on their territory that are relevant under Article 20(1), point (d), with new projects to be classified according to UNFC. Member States must also ensure that the collected data is transmitted to their national statistical authorities and to Eurostat. Furthermore, a common approach will improve and harmonize the communications on CRM for resource management across the Member States (MS). This approach gives a step-by-step guide on how to apply UNFC to CRM extraction, processing, recycling and substitution projects in the EU for monitoring purposes (UNECE, 2025). The classification and reporting of such projects in UNFC support the European Commission in understanding the EU CRM base and assessing its criticality in terms of economic importance and supply risk.

The scope of reporting as per the monitoring provisions in CRMA involve only active CRM projects that are on production or near-production, encompassing extraction, processing, recycling, and substitution projects. The overarching objective is to identify and monitor *Viable* and *Potentially Viable* CRM projects using UNFC. The methodology lists and provides the diverse functionalities of using UNFC, with sets of suggested Controlling Factors (CF) for each of the three UNFC axes (E, F, and G axis), in line with the proposed application methodology for UNFC to monitoring purposes. Generally, the use of information generated and gathered under the provisions of the CRMA are for the purposes of internal EU policymaking. The level of confidentiality varies according to the jurisdiction, respecting the diversity of EU Member State. Additionally, the publication of data is conducted in an aggregated manner (UNECE, 2025).

5.2.1 Applying UNFC for Monitoring CRM Extraction Projects

In the context of CRMA, Member States are required to report on active CRMs extraction projects, specifically those that are viable and potentially viable, with defined resources and/or reserves, and at advanced development phases (from pre-feasibility through to production)**.** To ensure comparability and interoperability this classification and monitoring process must be harmonized across EU Member States. For this purpose, EU has chosen UNFC to be applied to these projects, reflecting mainly the most mature UNFC categories.

In UNFC, a mineral project is a defined activity or set of activities intended to produce mineral products (commodities) from a mineral source, under specific frame conditions (technical, environmental, socio-economic, legal, and regulatory) that form the basis for evaluation and decision-making. A mineral project encompasses the relevant stages of the minerals cycle, from exploration, extraction, and beneficiation through processing, value addition, and ultimately, site decommissioning and remediation. For CRMA monitoring, only projects with defined mineral resources and/or reserves qualify. Projects at early exploration or scoping stages, as well as mineral occurrences without quantified data are excluded. Projects may employ conventional mining methods (e.g., open pit, underground, placer mining, in-situ recovery, brine mining) or unconventional methods (e.g., seafloor mining, biomining). The method used affects the technical feasibility (F axis) and the parameters for resource/reserve estimation, therefore influences the degree of confidence in product estimates (G axis).

In UNFC terminology, the mineral source corresponds to what is often termed a deposit. It represents a potentially economically recoverable accumulation of one or more minerals. The reference point is a defined stage in the project value chain where the quantity and quality of the product are estimated. However, for extraction projects, the quantity and quality of the product are deduced from the estimations carried out on the source, based on the degree of investigation and knowledge acquired. Hence, the reference point lands at pre-production estimates i.e., before commodity, reflecting the quantities and qualities in the source.

Against this backdrop, both quantity (e.g., tonnage or volume) and quality (e.g., grade, mineral content), estimated with a certain degree of confidence, are classified under the G axis in UNFC. Additionally, recoverability, as in production data (whether actual or anticipated) should be included, especially for in-situ extraction. Cut-off grades and grade–tonnage relationships should also be declared, as these directly impact the resource/reserve estimate and the G axis category. Without both quantitative and qualitative data, a mineral product cannot be defined, and the project cannot be classified beyond F3, G4 in UNFC.

In compliance with CRMA Chapter 4 "Risk Monitoring and Mitigation", active extraction projects, with defined resources and/or reserves, required for reporting, include projects at advanced development phases, starting from pre-feasibility, feasibility, definitive feasibility study, detailed design stages, construction, or operations. Regarding production data, although not the point of classification (reference point as underpinned above), the reported estimates for annual production (in metric tonnes) will be deduced from the classified resource and/or reserve volumes and grades (the source). While for projects on production, the reported annual production data (in metric tonnes) represents the product (commodity actually produced).

Bridging to UNFC

Within the EU, Member States and industry operate under a range of classification and reporting systems regarding primary resources:

1. CRIRSCO-compliant systems, primarily used for public reporting to stock exchanges;
2. Legacy national systems based on the former GKZ classification scheme;
3. Unique national systems developed and applied solely within the national frameworks;
4. Jurisdictions without legally binding classification and reporting requirements; and
5. UNFC-aligned national systems.

For extraction projects, this diversity is particularly significant, as mineral sources are classified (either by industry or competent authorities) according to the nationally legislated code. To avoid duplication of effort and the need to reclassify projects directly in UNFC, these national classifications should be transposed into UNFC through an internationally or nationally approved Bridging Document, such as is the case for CRIRSCO (e.g., PERC, JORC, NI 43-101). When transferring quantities from UNFC to an aligned classification system, all requirements of the aligned system shall apply, including the applicable quality assurance and quality control provisions. Quality Assurance and Quality Control requirements, including competency criteria and disclosure obligations, should be established by national governments in alignment with CRMA. Classifiers are expected to have the necessary education and professional experience to competently evaluate the specific type of mineral deposit being reported. A Guidance Note on competency standards and resource reporting requirements is available on the UNECE website (UNECE, 2022).

Several Bridging Documents are currently available, including: the CRIRSCO template, from GKZ-based national systems (e.g., Hungary, Slovenia, Poland), from unique national systems (e.g., Czech Republic, Austria), and for jurisdictions with no formal classification system (e.g., France tailored UNFC decision-trees adapted to national requirements).

UNFC Categories and Sub-categories

For active extraction projects, the expected UNFC Categories/Sub-categories for each axis are defined as follows (Table 16):

E axis (Environmental–Socio–Economic Viability)

- **E1** – *Confirmed Viability*: Development and operation are environmentally, socially, and economically viable under current conditions and realistic future assumptions. All necessary conditions are met, or there are reasonable expectations they will be met in a reasonable time frame.

  - **E1.1** – Fully viable under current and foreseeable future conditions.
  - **E1.2** – Made viable through government subsidies or special considerations.

- **E2** – *Expected Viability in Foreseeable Future*: Reasonable prospects for viability based on future conditions, but not yet confirmed.

F axis (Technical Feasibility)

- **F1** – *Confirmed Feasibility*: Technical feasibility demonstrated by sufficiently detailed studies; commitment to develop expected.
  - **F1.1** – In production/operation.
  - **F1.2** – Capital committed; development underway.
  - **F1.3** – Feasibility demonstrated; awaiting final approvals/contracts.
- **F2** – *Feasibility Pending*: Preliminary evidence exists; further studies required.
  - **F2.1** – Project activities ongoing toward justifying development.
  - **F2.2** – Project on hold; significant delays possible.

G axis (Degree of Confidence)

- **G1** – High confidence (e.g., "proved reserves"; "measured resources"; up to 20% estimation error; A or B categories for most GKZ-based systems).
- **G2** – Moderate confidence (e.g., "probable reserves"; "indicated resources"; up to 50% estimation error).
- **G3** – Low confidence (e.g., "inferred resources"; more than 50% estimation error)

It is necessary to note that degree of confidence in product estimates is influenced by the density, quality, and calibration of direct (e.g., drill core, assay) and indirect (e.g., geophysics) data.

Table 16: UNFC combinations for the classification of extraction projects under the scope of CRMA reporting for monitoring

UNFC Class	Sub-class	Possible Project Stage	E; F; G Categories
Viable Projects	On Production	Operating mine	E1.1; F1.1; G1
	Approved for Development	Definitive Feasibility, Construction phase	E1.1; F1.2; G1,2,3
	Justified for Development	Feasibility complete, awaiting final permits	E1.1; F1.3; G1,2,3
Potentially Viable	Development Pending	Pre-feasibility	E2; F2.1; G1,2,3
	Development on Hold	Delays in progress	E2; F2.2; G1,2,3

The application of UNFC to active extraction projects follows a systematic approach, with a top-down workflow that begins with classifying the project based on its viability for the project's Class (assigning the E-axis Category/Sub-category), then the technical viability based on the project's development stage for the Sub-class (assigning the F-axis Category/Sub-category), and lastly the G-axis (degree of confidence in resource/reserve estimates). In simple words, the E and F axes classification is explicitly linked to the documented project developments (permits, financing, studies, contracts, social and environmental analyses), while for the G axis based on the level of investigation and source knowledge (if direct application of UNFC) or the use of a Bridging Document if available. The application process is outlined as follows:

Pre-classification preparations: scope, data and governance

- **Scope:** The classification pertains only *active* extraction projects with defined resources/reserves or at advanced development phases (pre-feasibility and onward), plus producing operations.
- **Relevant documentation:** project description, resource/reserve statement (tonnage + grade), feasibility studies (PFS/FS/DFS), environmental and social impact assessments, permitting status, offtake/contracting, financing/commercial commitments, production history or forecasts, mining method, recovery assumptions, QA/QC reports, UNFC Bridging Document

Top-level UNFC Class - classifying the E axis (environmental-socio-economic viability)

- Allocate E-axis Category/Sub-category to the project by assessing environmental-socio-economic viability

- **Suggested Controlling factors:** Permitting status (granted / pending / refused); Environmental and social approvals and conditions (ESIA acceptance, community agreements, remediation plans, etc.); Economic indicators (positive NPV/IRR under current base case; sensitivity to prices; presence of offtake contracts; fiscal/tax considerations; presence/absence of meaningful long-term market or logistics impediments); Commercial and fiscal commitments (signed offtake, royalty/tax agreements, land access, indigenous consultations)

    - "Reasonable expectations" vs "reasonable prospects": Depending on the confidence on viability status: high confidence (E1.1) or moderate confidence (E2).

    - E1.2 is used only where project viability depends on government support or subsidy.

- **Classification premise:** if all essential viability conditions are met (or there is demonstrably high confidence they will be met in a defined reasonable timeframe), an E1.1 is most suitable. If viability depends on confirmed public support E1.2 is most apt. An E2 if viability is expected but not yet reasonably certain.

- **UNFC Class:** The project is *Viable* if E1, and *Potentially Viable* if E2.

UNFC Sub-class – classifying the F axis (technical feasibility)

- Assigning the F-axis Category/Sub-category to reflect technical maturity and project activity. F axis is explicitly linked to technical developments and capital commitment.

- **Sub-categories and Suggested Controlling factors:**

    - **F1.1** – production is occurring (operational throughput, measured production volumes)

- **F1.2** – capital is committed, and implementation is underway (financing documents, construction contracts, drawdowns)
- **F1.3** – technically feasible on basis of completed studies (PFS/FS/DFS), with reasonable expectation approvals/contracts will follow
- **F2.1** – ongoing activities to justify development (drilling campaigns, pilot tests, advanced engineering studies, etc.)
- **F2.2** – activities paused or on hold (delays in progress or unresolved constraints).

- **Classification premise:** F-axis Sub-categories are assigned according to what best matches the highest confirmed project activity (i.e., construction and funding supersede technical studies; production supersedes construction).

- **UNFC Sub-class:** *On Production* if F1.1; *Approved for Development* if F1.2; *Justified for Development* if F1.3; *Development Pending* if F2.1; and *Development on Hold* if F2.2.

Resource / Reserve information – classifying the G axis (degree of confidence)

- Classifying the project's resource/reserve information on the G axis based on geological data quality and estimation methods. If a Bridging Document is available, the classification on the G axis can be done through a simple translation mechanism.

- **Suggested Controlling Factors for direct application of UNFC:** drill-hole density and spacing, sampling and modelling, QA/QC (assay labs), geophysics and geochemical analyses, resource/reserve classification (International or National codes), statistical and geostatistical studies, etc.

- **Classification premise:** G axis classification needs to reflect the highest-confidence, most abundant, and evidence-based category that matches the documented data and estimation methodology.

5.2.2 Applying UNFC for Monitoring CRM Processing Projects

In the context of UNFC, processing projects fall under the broad definition of *minerals project*, that involve the transformation of extracted raw materials (source of processing projects) into concentrates or refined *mineral products* suitable for downstream use. These projects are an essential link in the raw materials value chain and typically involve physical, chemical, hydrometallurgical, pyrometallurgical, or electrometallurgical methods such as crushing, beneficiation, leaching, smelting, refining, or electrolysis. Processing projects differ fundamentally from extraction projects. While the latter classify in-situ "resources" and "reserves", processing projects classify the quantities of products expected to be recovered from source inputs. Hence, the classification of processing projects depends on the certainty of source supply and the quality and quantity of the recoverable output (product), along with the technical feasibility and socio-economic viability of processing operations. This means that, in terms of the G axis, the degree of confidence reflects the *quantities of product expected to be recovered from the source* (material input).

Processing projects often operate near extraction sites to minimize transportation costs, reduce logistical complexity, and limit environmental impact, in many cases under the same project. It is important to separate the different operations within an integrated project (extraction + processing within the same overall operation) when classifying and reporting. Integrated projects should be separated into two distinct projects to prevent double counting of reported quantities. To elaborate, the extraction activities of an integrated project report on the in-situ mineral estimates (resource/reserves), while the processing activities report on quantities of marketable products expected to be recovered from the source (e.g., a mine reports on resource/reserve, concentrator on concentrate production, smelter on refined metal output).

Processing projects progress through similar broad development stages as extraction projects, but with emphasis on source certainty, process design, and product yield (scoping study, pre-feasibility, feasibility, definitive feasibility study, planning and design, construction, operation). In the frame of CRMA's monitoring requirements, only projects at pre-feasibility stage or more advanced should be reported:

- **Pre-production projects:** Must be at least at *pre-feasibility* stage (PFS) or equivalent to be eligible for reporting.

- **On-production projects:** Operating plants must be reported using recent production history and forecasts.

The development stages typically include:

1. **Screening and Scoping** (not reported).
2. **Pre-feasibility and Feasibility Studies** (reportable).
3. **Construction** (reportable).
4. **Operation/Production** (reportable).
5. **Closure and Rehabilitation** (not reported under CRMA).

Processing projects require a clear distinction between source and product. The source refers to the input material to the processing facility (e.g., ore, concentrate, stockpile, tailings, or extractive waste), whereas the product refers to the output material from the processing facility (e.g., concentrate, cathode, ingot, refined powder). For *pre-production* processing projects, the reference point is at the input stage, but classification reflects the product estimates in terms of expected output volumes and concentration. For processing projects, estimated quantities must be limited to the production expected during the project's lifetime, defined in accordance with economic limits, design life, contracts period, permitting span. It is necessary to note that replacements or major expansions constitute a *new project* and require new evaluations. Reporting on processing projects includes source data, product data, and origin of feedstock (Product quantities = Product Output (tonnes) × Material Content (%)).

For active processing projects, the expected UNFC categories/sub-categories for each axis are defined as follows (Table 17):

E axis – Environmental–Socio–Economic Viability

- **E1 –** *Confirmed Viability*: Development and operation are environmentally, socially, and economically viable under current conditions and realistic future assumptions. All necessary conditions are met, or there are reasonable expectations they will be met in a reasonable time frame.
    - **E1.1 –** Fully viable under current and foreseeable future conditions.

    - **E1.2** – Made viable through government subsidies or special considerations.

- **E2** – *Expected Viability in Foreseeable Future*: Reasonable prospects for viability based on future conditions, but not yet confirmed.

F axis – Technical Feasibility

- **F1** – *Confirmed Feasibility*: Technical feasibility demonstrated by sufficiently detailed studies; commitment to develop expected.

    - **F1.1 –** In production/operation.

    - **F1.2 –** Capital committed, development underway.

    - **F1.3 –** Feasibility demonstrated; awaiting final approvals/contracts.

- **F2** – *Feasibility Pending*: Preliminary evidence exists; further studies required.

    - **F2.1 –** Project activities ongoing toward justifying development.

    - **F2.2 –** Project on hold; significant delays possible.

G axis – Degree of Confidence in Quantities Estimate

- **G1:** High confidence in product output based on secured source and proven recovery factors. Secured feedstock is often formalized by legally binding agreements.

- **G2:** Moderate confidence based on moderately secured source and/or less proven recovery factors.

- **G3:** Low confidence based on unsecured source or conceptual recovery assumptions.

Table 17: UNFC combinations for the classification of processing projects under the scope of CRMA reporting for monitoring

UNFC Class	Sub-class	Project Stage	E; F; G Categories
Viable Projects	On Production	Operating plant (confirmed source and proven recovery)	E1.1; F1.1; G1
	Approved for Development	Definitive Feasibility, Construction phase (secured source)	E1.1; F1.2; G1,2
	Justified for Development	Feasibility complete, awaiting final permits (proven designs, committed source)	E1.1; F1.3; G1,2,3
	Justified for Development	Feasibility stage project relying partly on potential source	E1.2; F1.3; G2,3
Potentially Viable	Development Pending	Pre-feasibility	E2; F2.1; G1,2,3
	Development on Hold	Delays in progress	E2; F2.2; G1,2,3

The application of UNFC to active processing projects follows a systematic approach, with a top-down workflow that begins with classifying the project based on its viability for the project's Class (assigning the E-axis Category/Sub-category), then the technical viability based on the project's development stage for the Sub-class (assigning the F-axis Category/Sub-category), and lastly the G-axis (degree of confidence in quantities estimate). In simple words, the E and F axes classification is explicitly linked to the documented project developments (permits, financing, studies, contracts, social and environmental analyses), while for the G axis based on the certainty of source supply and the quality and quantity of the recoverable output. The application process is outlined as follows:

Pre-classification Preparations

- **Scope:** Active and advanced-stage processing projects (Pre-feasibility and onwards).

- **Documentation Required:** Project description and flowsheet; Supply security statement (source tonnage and concentration); Feasibility studies (PFS/FS/DFS); Environmental and social impact assessments; Permitting status; Offtake/contracting arrangements; Financing and commercial commitments; Production history or forecasts; and Recovery assumptions and QA/QC data.

Top-level UNFC Class - classifying the E axis (environmental-socio-economic viability)

- Allocate E-axis Category/Sub-category to the project by assessing environmental-socio-economic viability

- **Suggested Controlling factors:** environmental approvals, social license to operate, economic viability, contractual security of source and products.

- **Classification premise:** if all essential viability conditions are met (or there is demonstrably high confidence they will be met in a defined reasonable timeframe), an E1.1 is most suitable. If viability depends on confirmed public support E1.2 is most apt. An E2 if viability is expected but not yet reasonably certain.

- **UNFC Class:** The project is *Viable* if E1, and *Potentially Viable* if E2.

UNFC Sub-class – classifying the F axis (technical feasibility)

- Assigning the F-axis Category/Sub-category based on project development stage and technical maturity.

- **Suggested Controlling factors:** stage of technical studies (PF/FS/DFS), level of process testing, infrastructure readiness, technological readiness level, process routes, capital commitment.

- **Classification premise:** F-axis Sub-category is assigned according to what best matches the highest confirmed project activity (i.e., construction and funding supersede technical studies; production supersedes construction).

- **UNFC Sub-class:** *On Production* if F1.1; *Approved for Development* if F1.2; *Justified for Development* if F1.3; *Development Pending* if F2.1; and *Development on Hold* if F2.2.

Source / Product information – classifying the G axis (degree of confidence)

- Classifying the project on the G axis based on reliability of source and recovery assumptions.

- **Suggested Controlling Factors:** estimates based on process flow and source characteristics; confidence levels (G1–G3) relate to reliability of source supply and predictability of product yield; and known and confirmed sources allow higher confidence categorization.

- **Classification premise:** G axis classification needs to reflect the highest-confidence, most abundant, and evidence-based category that matches the documented data. G1 if high confidence (secured and confirmed source and proven recovery); G2 if moderate confidence (confirmed source or less certain recovery); and G3 if ow confidence (unsecured source or conceptual recovery).

Verification and assurance

- Provide traceable inputs, calculations and assumptions; state the effective date; disclose whether quantities include co-/by-products and whether outputs are sales or non-sales; confirm classifier competence; retain evidence for authority audit. Update the classification when permits, contracts, technology performance or source availability.

5.2.3 Applying UNFC for Monitoring CRM Recycling Projects

In UNFC, recycling projects are covered under “anthropogenic resources”. These projects are developments that recover materials from anthropogenic sources, defined as concentrations or occurrences of solid, liquid or gaseous material of economic interest within the technosphere in a form, quality, or quantity, from which there are reasonable prospects for eventual economic extraction. The sources are defined in situations where the quantity, quality, and location of an anthropogenic source can be identified. Sources can either change over time (e.g., post-consumer residues) or remain static (e.g., residues in heaps, tailings, or landfills). Sources provide the feedstock to projects from which products can be developed.

Typical recycling projects recover material from post-consumer scrap and end-of-life products, production residues, extractive wastes (heaps, tailings), sludges, brines and landfill-derived materials using combinations of collection, pre-treatment (sorting, shredding, dismantling, roasting, leaching), concentration and refining (hydro-/pyro-/bio-metallurgy, solvent extraction, electrowinning), and waste management. UNFC classifies such projects at an effective date of evaluation i.e., each classification is a snapshot in time that must be updated when material changes occur.

In the context of recycling projects, UNFC defines a source as the feedstock supplying the recycling project. Sources may be static (e.g., tailings, heaps, landfills) or dynamic (e.g., post-consumer flows). It is necessary to note that UNFC distinguishes known sources (demonstrated by direct) and potential sources (indicated primarily by indirect evidence). This distinction is necessary to understand the reporting basis of recycling projects i.e., projects at conceptual stage refer to potential sources. A product is defined as the material outputs of the recycling project (sales or non-sales; main products, co-products or by-products) reported by quality and quantity. It is required for the classification of recycling projects to indicate the reference point, for user to understand the stage at which quantities are estimated. Reference points are defined locations within a development where the reported estimate or measurement of the quantity with its current quality of product is made. In an early project phase, the sources might be characterized in terms of quantity and composition with only a conceptual project with conceptual recoverability. In this case, a reference point may be located at the input of the project. Reported quantities are limited to those expected to be produced over the project lifetime, typically defined by economic limit, design life and/or contract/permit period.

Recycling projects consist of several development stages:

1. **Screening**: In this first stage of the project lifecycle the presence of sources may be hypothesized but is not yet known or poorly defined at this stage. The entity doing screening may apply techniques such as estimates on feedstock supply in terms of quantity and composition;

2. **Under development**:

   (i) Scoping study: An initial study used to define a project's potential treatment and recovery process and provide an overview of unit operations required;

   (ii) Pre-feasibility study: A more detailed and informative study that contains information such as feedstock composition, demonstrators and advanced process designs;

   (iii) Feasibility study: Definitive or Bankable Feasibility Studies are advanced stage works based on finalized process designs for the Project;

3. **Planning**: During the planning phase, which in practice may overlap with the completion of feasibility studies, all aspects of the recovery are planned in detail. This includes planning related to treatment and recovery, as well as site infrastructure needs, schedules for construction and commissioning of facilities, and all planning associated with environmental aspects of operations;

4. **Construction**: The construction phase includes site preparation, the construction of treatment and recovery facilities, and infrastructure;

5. **Operating**: The facilities are operating, and products are generated;

6. **Closure/reclamation**: The treatment and recycling facilities are dismantled, and land might be reclaimed for other purposes.

For CRMA monitoring requirements, Member States shall report on active recycling projects that are on production or at advanced development (pre-feasibility and onward). Projects at screening or scoping study levels are excluded, as well as those at closure/reclamation. No bridging documents apply to recycling projects, since there is no alternative internationally used classification for recycling projects. UNFC shall therefore be applied directly. For active recycling projects, the expected UNFC Categories/Sub-categories for each axis are defined as follows (Table 18):

E axis (Environmental–Socio–Economic Viability)

- **E1** - *Confirmed Viability*: Development and operation are environmentally, socially, and economically viable under current conditions and realistic future assumptions. All necessary conditions are met, or there are reasonable expectations they will be met in a reasonable time frame.
  - **E1.1** - Fully viable under current and foreseeable future conditions; typical of operating plants with permits and offtake in place.
  - **E1.2** - Not viable on a standalone basis but made viable via subsidies or other considerations and/or reliance on a mix of known and potential sources over the life of project. Recycling projects may depend on a combination of known and potential sources to maintain economic viability. Therefore, E1.2 may be selected for viable projects that involve sources that rely on some additional production from a linked project.

- **E2** - *Expected Viability* in Foreseeable Future: Reasonable prospects for viability based on future conditions, but not yet confirmed.

F axis (Technical Feasibility)

- **F1** - *Confirmed Feasibility*: Technical feasibility demonstrated by sufficiently detailed studies; commitment to develop expected.
    - **F1.1 –** In production/operating;
    - **F1.2 -** Capital committed and implementation under way;
    - **F1.3** - Feasibility completed with reasonable expectation of approvals/contracts.
- **F2** - *Feasibility Pending*: Preliminary evidence exists; further studies required.
    - **F2.1 -** Active work to justify development (e.g., completed PFS, pilots);
    - **F2.2 -** Activities on hold or at early scoping/bench scale.

G axis (Degree of Confidence in quantities estimate)

- **G1** high confidence in product output based on feedstock supply security, composition, and process recovery.
- **G2** moderate confidence in product output based on feedstock supply security, composition, and process recovery.
- **G3** low confidence in product output based on feedstock supply security, composition, and process recovery.

Table 18: UNFC combinations for the classification of recycling projects under the scope of CRMA reporting for monitoring

UNFC Class	Sub-class	Project Stage	E; F; G Categories
Viable Projects	On Production	Operating recycling plant with long-term feedstock and offtake in place	E1.1; F1.1; G1,2
	Approved for Development	Definitive Feasibility, Construction phase (Plant under construction with committed capex and executed feedstock/offtake)	E1; F1.2; G1,2
	Justified for Development	Feasibility complete, awaiting final permits (proven designs, committed source)	E1; F1.3; G1,2
Potentially Viable	Development Pending	Pre-feasibility (partial supply visibility)	E2; F2.1; G2,3
	Development on Hold	Delays in progress	E2; F2.2; G1,2,3

For recycling, the G axis reflects the certainty of feedstock supply and composition, process mass-balance and recovery, and data quality. The estimates shall be based on material flow analysis, including an approach to characterizing data uncertainty. The analysis shall include the sources as input and the products as output of the project, as well as all associated processes within the project, such as physical, chemical and/or biological treatment, conversion and deposition processes, and the transport of materials.

Suggested controlling factors for each axis:

E axis: environmental compliance, social acceptance and labour rights, economic viability (CAPEX/OPEX, incentives, pricing, gate fees), legal/fiscal framework (waste status, Extended Producer Responsibilities (EPR) obligations), and reasonable timeframe for obtaining approvals (Table 19).

F axis: development stage evidence (PFS/FS/DFS), pilot/demonstrator outcomes, technology readiness levels (TRLs), decisions and commitments (board/FID, EPC contracts), operational planning, and infrastructure/utility readiness (power, water, logistics) (Table 20).

G axis: documented material flow analysis (MFA) with uncertainty treatment; sampling plans and representativeness; variability of collection systems; pre-treatment yields; process recovery factors and scale-up risk; Quality Assurance/Quality Control (QA/QC; metrology, assay methods, mass balance closure). Material Flow Analyses (MFA) results should be visualized (e.g., Sankey diagrams) and linked to the chosen reference point. Note that G axis does not indicate project maturity in its own capacity.

Table 19: E axis CFs for recycling projects

Potential issue	Potential basis for defining controlling factors
Environmental Viability	Compliance with environmental legislation and permits, including monitoring, prevention and minimization of environmental impacts during project lifetime. Studies on environmental impact during construction, operation and decommissioning should also be addressed. Measures to prevent scope 1, 2 and 3 emissions
Social Viability	Social acceptance based on the engagement with all communities that are affected by the Project; Respect for and compliance with employee rights; Risks of social resistance to the development of the Project
Economic Viability	CAPEX & OPEX estimates, financing framework, risks affecting the economic viability
Legal and Regulatory Aspects	Status and plans to get permits, which are needed to develop and operate the Project (Status categories: acquired or issued, pending or submitted, under preparation or not in preparation)

Table 20: F axis CFs for recycling projects

Potential issue	Potential basis for defining controlling factors
Project Development phase	Provision of evidence to justify the current project development phase exploration, pre-feasibility, feasibility, and implementation or production.
Decision and commitment	Decisions and commitments by stakeholders that affect the development of the Project
Project value proposition	Company strategy, approach to commercialization, market analysis, key customers, security of feedstock supply, off-take agreements, competitors, opportunities and risks related to the business case and capture or mitigation measures.
Technological maturity	Technology Readiness Levels (TRLs).
Operational Planning	Operational planning for the development, construction and decommissioning stage of the Project, including activities, milestones, operational opportunities and risks and capture/mitigation measures.
Infrastructure status and needs	Status and needs, e.g., energy and transport infrastructure.

The application of UNFC to active recycling projects follows a systematic approach, with a top-down workflow that begins with classifying the project based on its viability for the project's Class (assigning the E axis Category/Sub-category), then the technical viability based on the project's development stage for the Sub-class (assigning the F axis Category/Sub-category), and lastly the G axis (degree of confidence in quantities estimate). In simple words, the E and F axes classification is explicitly linked to the documented project developments (permits, financing, studies, contracts, social and environmental analyses), while for the G axis based on the certainty of feedstock supply and the quality and quantity of the recoverable output. The application process is outlined as follows:

Pre-classification preparations:

- **Scope:** Active and advanced-stage processing projects (Pre-feasibility and onwards).
- **Documentation Required:** project description; feedstock security statement (tonnage and composition, with origin and split of known vs potential sources); PFS/FS/DFS and test-work; ESIA and permitting status; supply/offtake contracts; financing and commercial commitments; production history/forecasts; process flow sheet with recoveries; QA/QC and competency statements.

Top-level UNFC Class – classifying the E axis (environmental-socio-economic viability)

- Assess the environmental-socio-economic viability under current and realistically expected conditions.
- **Classification Premise:** Classify as **E1** (Viable) or **E2** (Potentially Viable). Use **E1.2** if viability depends on subsidies/other policy instruments and/or on a realistic conversion of potential sources into known sources during the project lifetime (this assumption must be explicit, time-bound and evidenced).

UNFC Sub-class – classifying the F axis (technical feasibility)

- **Classification Premise: F1.1** (operating), **F1.2** (construction/implementation), **F1.3** (feasibility completed), **F2.1** (pre-feasibility/pilot ongoing), **F2.2** (on hold). Document tests, pilots, and TRL.

Source / Product information – classifying the G axis (degree of confidence)

- On the effective date, estimate lifetime product quantities at the reference point using MFA. Assign **G1** where feedstock contracts/collection systems and recovery factors are evidenced with high-quality data and stable performance; **G2** where some elements are less certain (variable composition, partial contracts, scale-up pending); **G3** where estimates rely on conceptual assumptions or indirect evidence.

Verification and assurance

- Provide traceable inputs, calculations and assumptions; state the effective date; disclose whether quantities include co-/by-products and whether outputs are sales or non-sales; confirm classifier competence; retain evidence for authority audit. Update the classification when permits, contracts, technology performance or source availability materially change (snapshots should be time-stamped).

Additional considerations specific to recycling projects

- **Known vs potential sources must be explicit.** Where viability over the project life relies on potential sources (e.g., future end-of-life flows), use **E1.2** or **E2** and explain the transition assumptions (timing, collection rates, policy measures).

- **Multiple products.** Report each material/energy product separately by quantity and specification; identify sales/non-sales and co-/by-products. Avoid double counting by tying each reported quantity to a single reference point and project boundary.

- **Project lifetime.** State whether the limiting factor is economic limit, design life, contract period and/or permit period; align lifetime quantities accordingly.

- **QA/QC and competence.** Sampling, assay, and mass-balance procedures shall be documented; classifiers must be suitably qualified and experienced for the specific material streams and technologies.

5.3 Proposed National template for monitoring based on UNFC

The development of a national monitoring template based on the UNFC represents a practical instrument to support national compliance with the monitoring and reporting obligations defined under Articles 21 of CRMA. The template was developed with colleagues from UNECE. This template is designed to facilitate and harmonize the collection and reporting of information on viable and potentially viable CRM projects, while ensuring compatibility with both the EU CRMs Database and national statistical systems. The proposed CRMA Monitoring Template follows the structure of the methodology described in the *Manual for the Application of UNFC for the Monitoring of Critical Raw Materials Projects in the EU*. It provides a systematic approach to gather data across all relevant project stages, that is extraction, processing, and recycling, and links them to UNFC's three-dimensional classification (E, F, and G axes). The goal is to ensure that projects are assessed consistently according to their socio-economic viability, technical feasibility, and product confidence, while also integrating permitting and risk indicators required for national stress testing (UNECE, 2025). The template is structured into eight sections, covering the essential dimensions of CRM project monitoring:

- **Section 1: Reporting Attestation** – Collects the identity and credentials of the reporting entity, ensuring traceability and validation of submitted data.

- **Section 2: Project Basic Information** – Establishes project identity, location, and ownership, serving as a standardized reference for mapping and registry purposes.

- **Section 3: Project Activities** – Captures the type of activity (extraction, processing, recycling, or substitution), the current development stage, and operational status, allowing the identification of near-producing or producing projects.

- **Section 4: Project Permitting Status** – Summarizes the legal framework of the project by tracking progress and validity of relevant permits, a crucial indicator under CRMA monitoring requirements.

- **Section 5: Critical Raw Material Information** – Records quantitative and qualitative data on CRMs, including reserves, resources, material inputs and outputs, and original reporting schemes, providing the technical foundation for UNFC classification.

- **Section 6: Production Data** – Details current or forecasted production volumes, grades, and outputs for extraction, processing, and recycling projects, enabling evaluation of contribution to domestic CRM supply.

- **Section 7: UNFC** – Integrates the UNFC classification framework, with specific controlling factors for the E, F, and G axes. This section enables standardized assessment of the project's maturity and viability and ensures compatibility with EU-level reporting.

- **Section 8: Additional Risk Monitoring Information** – Allows for the inclusion of complementary data relevant to supply risk monitoring, such as geopolitical exposure, technological dependencies, or environmental constraints.

The proposed template could for instance serve as a tool for Italy's national CRM monitoring framework, supporting both domestic policy needs and EU reporting obligations (Table 21). Ultimately, this proposed template provides a transparent, replicable, and scalable model for the systematic monitoring of raw materials projects in Italy, aligning national practices with EU standards, and operationalizing the principles of the UNFC within the framework of risk monitoring and mitigation. A core principle of the template is also to avoid administrative overburden and communication with industry.

Table 21: Proposed National template for monitoring in Italy based on UNFC (UNECE, 2025)

Section 1: Reporting Attestation	
EU Country	
Full Name	
Position	
Affiliation	
Contact Information (phone/email)	
Date of Reporting	

Section 2: Project Basic Information	
Project Name	
Location	
Geographical Coordinates	*LAT.*
	LONG.
Project Owner	
Address	
Website	
Project Contact Person	*Full Name*
	Position
	Email

Section 3: Project Activities	
Project Type	*Extraction, Processing, Recycling, Substitution*
Development Stage	*(Scoping study?), pre-feasibility, feasibility, construction, production*
Activity Status	*Active, On Hold, Inactive*
Project lifetime (years)	
Date of Production / Foreseen Date of Production (years)	*Initial (if producing) or estimated (if yet to become operational)*

Section 4: Project Permitting Status		
Permit	**Acquisition (yes/no)**	**Permit Validity / Application Date**
Extraction / Mining		
Environmental		
Operation / Industrial		
Water Use		
Waste Management		
Construction / Land Use		
Others		

Section 5: Critical Raw Material Information			
For Extraction Projects		**For Processing or Recycling Projects**	
Main CRM		Main CRM	
Commodity Type	(co-product, by-product, etc.)	Commodity Type	(co-product, by-product, etc.)
Reserves	tonnes	Material Input	tonnes
Resources	tonnes	CRM Content	%
Original Scheme	(CRIRSCO, National System, etc.)	Source / Stream	
Additional Information		Additional Information	
Other CRMs		Other CRMs	

Section 6: Production Data			
For Extraction Projects		**For Processing or Recycling Projects**	
Production	*tonnes/year*	Material Output	*tonnes/year*
Volumes Produced	*tonnes*	CRMs Content (list)	*% (CRM 1)*
Average Grades	*%*		*% (CRM 2)* *% (CRM n)*
Product quantities	*(volumes x grade) (t)*	Product quantities	*(output x content) (t)*
Additional Information	Other commodities produced (volumes, grades, quantities…)	Additional Information	
Estimated Production (for projects not yet producing)		*tonnes/year*	

Section 7: UNFC	
E axis	*Suggested Controlling Factors…*
F axis	*Suggested Controlling Factors…*
G axis	*CRM 1 (t):* *CRM 2 (t):* *…*
UNFC Code	
UNFC Class / Sub-class	

Section 8: Additional Risk Monitoring Information

Chapter 6

Applying UNFC to Italian Raw Materials

6.1 Scope of Work

The implementation of UNFC across national contexts requires a practical, operational approach that translates its structure into a usable tool for both public authorities and industry actors. Within the framework of CRMA and Italy's Decree Law No. 147, the integration of UNFC serves as a means to standardize the classification and reporting of projects across the entire raw materials value chain from exploration to extraction, production, processing, and recycling.

While CRMA establishes the legal obligation for Member States to classify CRMs projects across several activities, it does not prescribe a uniform methodology for how this should be operationalized at national level, other than the use of UNFC (European Commission, 2024). As such, there is a pressing need to translate UNFC principles into practical procedures that can be consistently applied national authorities. In Italy, this means aligning UNFC with the existing regulatory framework, such as national environmental and permitting legislation. From an administrative perspective, UNFC enables authorities to move beyond fragmented or purely volumetric data collection toward a decision-support framework that links resource classification with project readiness, sustainability, and investment potential. Moreover, a harmonized national application of UNFC can significantly reduce inconsistencies in reporting, prevent duplication of assessment work between institutions, and foster greater interoperability of geological and economic data at both national and EU levels. This harmonization is crucial for enabling Italy to contribute effectively to EU-wide monitoring and risk mitigation efforts, ensuring that domestic resource data can be aggregated and compared meaningfully with that of other Member States.

Ultimately, the practical application of UNFC at national level represents an essential step toward transforming Italy's raw materials data into strategic intelligence, enabling informed decision-making, risk management, and investment prioritization in alignment with the CRMA's objectives of resilience, sustainability, and transparency. This chapter demonstrates the application of UNFC practically, with the extent possible, to Italian raw materials from different data sources, a "checklist" form template for classifying projects, and through a proposed UNFC decision tree mechanism for each of its axis. Lastly, the chapter will touch upon the development of a National UNFC Guidance document to be proposed for national uptake, and ultimately adoption.

6.2 Methodology

The aim of this section is to showcase the applicability of UNFC in Italy on primary raw materials, using data from different sources collected and harmonized for classification purposes. These sources comprise: (i) industry reporting, (ii) historical datasets, and (iii) extrapolated geological occurrences deduced from publicly available data, research, and academic reports. Each type of dataset required a distinct methodological approach, reflecting the heterogeneous nature of Italy's mineral information landscape, where raw materials data are fragmented across multiple institutional and scientific repositories.

The methodology applied to these datasets is comprehensively explained in Sabra G., Solar S., and Blengini G. (2025), particularly in Chapter 3 of their Mineral Economics paper, which is appended to this dissertation under **Appendix C**. The approach delineates how UNFC can be operationalized to structure and interpret raw materials information in Italy. In summary, the methodology elaborates on the UNFC application to the following datasets:

- Statutory and Publicly Reported Projects: This category encompasses projects for which data are available through statutory reporting requirements or publicly disclosed company documents. It includes mining and quarrying projects with exploration or extraction permits granted under national or regional legislation, as well as those projects subject to environmental and industrial reporting obligations. For these projects, data were primarily extracted from official repositories (e.g., ISPRA, MiTE, and regional mining offices), company disclosures, and other verified public sources. These datasets generally provide higher confidence levels for the G axis (geological knowledge) and F axis (feasibility) under UNFC, given their formal evaluation, technical documentation, and ongoing operational or permitting status. Such projects typically align with UNFC Classes E1–E2, F1–F2, G1–G2, depending on the maturity of operations and economic viability. In Italy, examples include industrial mineral extraction sites and metallic mineral projects under active or recent permitting procedures. The classification process involved mapping reported reserves and resources from CRIRSCO-aligned or national systems into UNFC through the use of bridging principles, ensuring comparability with EU-level CRM monitoring frameworks. These data represent the most direct contribution to Italy's UNFC-based inventory, serving as anchor points for calibrating the classification of less mature occurrences.

- Historical Estimates and Data: The second data stream comprises historical datasets, past exploration campaigns, geological surveys, or academic works where mineral occurrences or resource estimates were documented, often prior to the harmonization of reporting standards. Such data are crucial in reconstructing Italy's broader mineral potential, particularly for CRMs that have not been revisited in modern exploration contexts. In most cases, these data are characterized by a low level of confidence in geological, technical, or economic parameters. Many historical estimates lack supporting documentation on cut-off grades, recovery factors, or updated geological models. Consequently, their classification under UNFC typically falls within Prospective Project categories, such as E3, F3, G4, reflecting early-stage knowledge and uncertain feasibility. The methodology treats these data as valuable input for knowledge enhancement, using UNFC as a dynamic framework to record and progressively update confidence levels as new information becomes available. In the context of the NEP, such data provide a baseline for prioritizing areas for new exploration or for re-evaluating legacy deposits with CRM potential.

- Geological Extrapolation: The third data category involves geological extrapolation, referring to the estimation of potential mineralization based on known geological analogues, mineral associations, and regional geoscientific indicators. This approach leverages geological maps, geochemical surveys, and academic research to deduce possible extensions of mineralized zones or new occurrences not yet verified by direct sampling or drilling. Under UNFC, such extrapolated occurrences correspond to the lowest confidence level (G4), as they represent conceptual models of mineral potential rather than measured data. They are generally paired with F4 (no defined development pathway) and E3 (socio-environmental and economic viability not assessed) categories, classifying them as Potential Source Projects. The approach adopted aligns with the UNFC Guidance for NEP-R and ensures that extrapolated data are incorporated systematically, maintaining transparency on uncertainty and allowing for future reclassification as knowledge increases. This category is particularly relevant in Italy, where modern exploration has been limited for several decades, and substantial parts of the territory remain underexplored. Geological extrapolation enables the inclusion of these areas in national resource mapping efforts and informs strategic planning under the NEP and CRMA Article 19.

6.2.1 UNFC Template for Classifying Italian Raw Materials Projects

For the case of Italy, and with a specific focus on CRMs, under the dataset of statutory and publicly reported projects, the selected ones for UNFC classification were identified from the *Dashboard of Critical Raw Materials* available on ISPRA's website. The Dashboard provides an overview of mineral titles across Italy, categorized into three types: *concession*, *permit application*, and *permit in place*.

The review of CRM-related projects as of 2025 identified the following (Figure XLIII):

- Only one project — "Pianciano Nuova" — is listed as having a concession.
- Five projects have a permit application in process: *Monte Bianco* (operated by Energia Minerals), *Fenice*, *Bruscoline*, *Zanca*, and *Pietra* (operated by Western Metallica).
- Fifteen projects are currently listed as having an active permit.

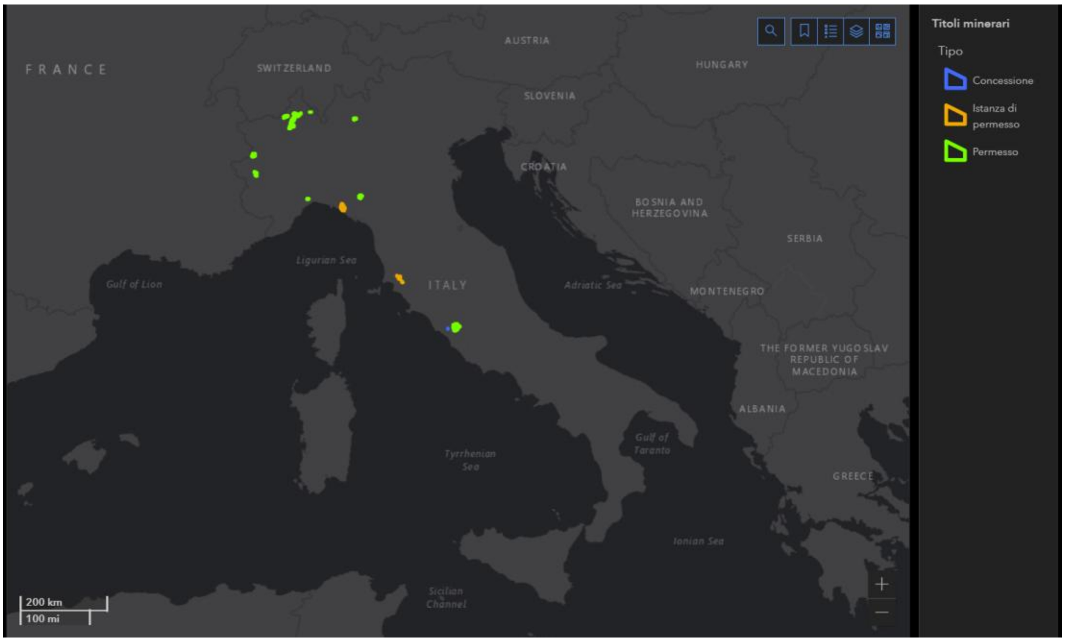


Figure XLIII: Listed CRMs projects in Italy, as per ISPRA's Dashboard on CRMs (ISPRA, 2025)

Given the availability of verifiable information, only projects with a statutory status (either concession, permit, or permit application) were classified under UNFC following a pre-defined template. These projects represent the most suitable dataset for systematic classification, as they have traceable legal documentation, identifiable operators, and basic geological or operational data.

The UNFC Template Sheet used for this purpose was developed as part of this research (and published in *Sabra, Solar & Blengini, 2025, Mineral Economics*). It serves as a standardized reporting and verification framework for classifying Italian raw materials projects in alignment with the UNFC structure.

The compilation of raw materials project data followed the template below, focusing exclusively on CRM-related projects to ensure methodological consistency and alignment with the requirements of CRMA (Table 22). The structured approach allows for the transparent classification and comparison of Italian CRM projects, facilitating the future integration of national data into the European CRM monitoring framework. The data sources used to develop and classify raw materials in Italy are compiled under **Appendix D**.

Table 22: UNFC Template for Italian Raw Materials Projects

Project Name	
Project Location	
Project Type	
Development Phase	
Commodity(ies)	
Date of Classification	

E axis Classification - Environmental-Socio-Economic Viability	**Category and Sub-category:**
	Justification: *If available: Legal, Economic, Environmental, Social, Governance, etc.*
F axis Classification - Technical Feasibility	**Category and Sub-category:**
	Justification: *If available: Project development phase, Activity status, Technology, Infrastructure, et*
G axis Classification – Degree of Confidence	**Category:**
	Justification: *Indicate the data source, documentation of resource/reserve estimation (if availabl degree of geological investigation*
UNFC Classification of the Project	**UNFC Code:**
	UNFC Class and Sub-class:
	Justification:
Sources and additional information	

6.2.2 UNFC Application to Mineral Occurrences

To elaborate further on the dataset derived from geological extrapolation, mineral occurrences considered in this study were identified from ISPRA's Dashboard on CRMs**.** This dashboard provides a geospatial overview of CRM deposits across Italy, with historically recorded occurrences of minerals (Figure XLIV).

Figure XLIV: CRMs deposits in Italy, as per ISPRA's dashboard on CRMs (ISPRA, 2025)

The geological extrapolation dataset primarily includes mineral occurrences but with sufficient, to the degree possible, geological evidence to suggest mineralization of potential economic interest. These occurrences form an important part of the broader resource assessment framework, as they represent potentially valuable but under-studied deposits, which are of high relevance for NEPs in the context of CRMA. It is necessary to note that these occurrences remain very premature, with no volumes or quantities indication. However, they have been located through recorded exploration campaigns, historic data, and research. The classification of such extrapolated data relied on approaches applied exclusively to mineral occurrences, based on the integration of historical data, geological analogues, and spatial interpretation. Unlike mineral resource estimation for defined deposits, extrapolation for occurrences operates under conditions of limited or indirect evidence and must therefore adopt methodologies consistent with early-stage or reconnaissance-level assessments (Bide et al., 2020). As such, the methodological framework adopted in this study draws upon approaches developed for national-scale mineral inventories, particularly the hierarchical classification and extrapolation followed in the United Kingdom (Bide et al., 2020).

In UNFC terms, the G axis is directly linked to the stages of geological investigation, typically progressing through:

1. **Reconnaissance / Prospecting (G4):** Regional surveys, remote sensing, and preliminary field inspections identifying areas of mineral potential.

2. **Prospecting / Early-stage Exploration (G3):** Systematic narrowing of promising zones through geological, geophysical, and geochemical surveys, and limited sampling or drilling.

3. **Targeted Exploration (G2):** Detailed surface and subsurface exploration providing reasonably assured estimates of tonnage and grade.

4. **Advanced Exploration (G1):** Comprehensive drilling, sampling, and modeling, resulting in high-confidence estimates of reserves and resources.

Each of these corresponds to increasing levels of confidence under the UNFC classification:

- **(331)** Measured Mineral Resource
- **(332)** Indicated Mineral Resource
- **(333)** Inferred Mineral Resource
- **(334)** Reconnaissance Mineral Resource

In Italy, extrapolated geological data fell within G3–G4 categories, representing prospecting or reconnaissance-level knowledge, as indicated in the NEP-R document. These include mineral occurrences identified through regional geological mapping, remote sensing, or legacy exploration data, but not yet verified through systematic drilling or feasibility studies. Such data are particularly valuable for national inventory development, as they identify potential CRM-bearing zones where future exploration could be prioritized. In UNFC and the NEP-R document, these occurrences are recorded as “prospective” (334) or “inferred” (333) classes in the national inventory, so as to include the possible potential from early-stage or low-certainty data that may contribute to Italy’s CRM system. Ore estimation principles underpin the geological dimension of UNFC, ensuring that even extrapolated data, when systematically documented and transparently categorized, play a vital role in advancing Italy’s capability to monitor, classify, and manage its raw material potential in line with CRMA requirements. The detailed classification of identified mineral occurrences in Italy is listed in **Appendix D**.

6.3 Development of UNFC Decision-Trees Aligned with Italian Mining Regulations

In order to facilitate the classification of existing resource data according to UNFC, a series of decision-trees have been developed. These tools are intended to assist in interpreting datasets across the three UNFC axes. The decision-trees provide a structured, logical framework to support consistent and transparent classification, particularly when working with heterogeneous datasets managed by national data providers (Bide et al., 2022).

The application of these tools to the Italian context is especially significant given that Italy currently lacks a unified national system or standard for the collection and classification of raw materials data. The exercise has therefore highlighted several challenges related to the country's future raw materials supply. Among these are variations in the level of geological and economic data available for different deposits, inconsistencies in the treatment of co- and by-products, and the scarcity of information regarding minerals critical for emerging technologies. Additionally, differences in methodological approaches across commodity types underscore the need for a harmonized classification framework. In this context, the Italian decision-trees were specifically developed to align with the Mining Legislation Royal Decree No. 1443 of 1927, which remains the foundational legal framework governing the country's mining sector. The decision-trees thus reflect both the principles of UNFC and the specific regulatory, institutional, and operational conditions of Italy. They enable practitioners to interpret the classification criteria within a coherent national framework through a decision-support logic (Bide et al., 2022). Each decision-tree presents a series of binary (yes/no) questions to help determine the appropriate UNFC category based on project-specific information. This approach allows users to identify the main factors that delineate UNFC classes efficiently, promoting consistency while maintaining flexibility for expert judgement (Bide et al., 2022). Although not exhaustive, since the diversity of mineral projects cannot be fully captured in simplified flow diagrams, the decision-trees represent an initial and practical step toward coherent classification at the national level. The overarching aim of these tools is to promote standardization and reproducibility in the application of UNFC in Italy. They were designed as part of a systematic and objective process, reducing subjectivity in classification decisions and supporting users in achieving comparable results across datasets. Nevertheless, it is essential to recognize that these decision-trees are not prescriptive. Given the unique characteristics of each mineral deposit and project, the tools should be regarded as guidelines or frameworks around which informed classification decisions can be structured, rather than as fixed rules (BRGM, 2023; Bide et al., 2022).

The methodology adopted follows each axis separately with a structured decision tree and additional explanations. This could be summarized as follows:

- **E axis, the environmental-socio-economic viability:** The decision tree for the E axis of UNFC guides evaluators through the assessment of a project's environmental, social, and economic viability, as defined by both regulatory compliance and operational status. In Italy, the starting point of classification under the E axis often relates to whether a mine or quarry holds a valid extraction license granted by the relevant competent authority, regional, provincial, or municipal. Possession of such a license typically implies that the project aligns with regional or municipal mining plans, and has successfully completed the Environmental Impact Assessment (EIA) process. These plans and permits include detailed requirements such as the nature and duration of the concession, the methods of mining, extractive waste management, spatial planning including remediation, and payment of royalties. The highest category, E1.1, is assigned when the project is currently operational and delivering mineral products to a market. Projects that have obtained necessary authorizations and secured financing but have not yet commenced production are categorized as E1.2, reflecting near-term viability. Similarly, a project in late-stage permitting or undergoing final development preparations may also qualify as E1.2 provided that there is a realistic expectation of commencement. On the other hand, if the project has submitted but not yet received regulatory approvals, or if there is a reasonable expectation that necessary conditions for development will be met, it may be categorized under E2, indicating a potentially viable project. This includes projects in advanced exploration or feasibility stages with the next steps involving application for extraction permits. Lastly, projects lacking required exploration permits or those at an early stage of regulatory engagement are categorized under E3.3, reflecting insufficient information to establish socio-economic viability. In some cases, projects that are abandoned, historic, or opposed by local communities, where the EIA process has yielded negative results, may be classified under E3.2 or E3.3, depending on whether technical assessments are being pursued.

- **F axis, the technical feasibility:** The decision tree for the F axis addresses the technical maturity and feasibility of the project, progressing from operational projects to those in early exploration. A key criterion for classification is whether capital funds have been committed and if development implementation has begun. If this is the case, the project may be categorized under F1.1 or F1.3, indicating that technical feasibility has been demonstrated and implementation is underway or imminent. If capital has not yet been committed but detailed feasibility or pre-feasibility studies have been completed, the project may be categorized as F1.3, reflecting readiness for development pending administrative processes. Where preliminary studies suggest the project is technically viable but additional data acquisition is required (e.g., extended drilling, sampling, or engineering studies), the appropriate category would be F2.2, indicating moderate technical feasibility but subject to delay. Conversely, if studies are ongoing with no significant data gaps, the project may be placed in F2.1. Moreover, projects that are not actively being developed and lack plans for further technical assessment are categorized under F2.3, which reflects a temporary halt in project advancement due to limited perceived potential. For early-stage projects based on regional geological studies or surface exploration, where drilling or sampling has yet to begin, the classification enters the F3 categories, with the sub-category depending on the quality and scope of geological investigation. F3.2 is used when surface-level indicators suggest promising resource potential, while F3.3 applies to even earlier stages where mineralization is only inferred from broad geological models.

- **G axis, degree of confidence:** The G axis decision tree enables classification based on the level of geological confidence and certainty regarding resource quantity and quality. Projects where permitted reserves are actively being extracted fall into G1, denoting a high degree of confidence supported by detailed exploration, sampling, and testing. This typically includes continuous core drilling, geochemical analyses, and geostatistical modeling that confirm geological continuity. When parts of the reserves are still under development or undergoing extraction and further geological evaluation is needed, the project is assigned G2, indicating moderate confidence. This is typical of projects where estimation is based on interpolated data between known points of observation but without sufficient density to fully confirm continuity. Furthermore, projects in early exploration where substantial geological work is still required are generally categorized under G3, reflecting low confidence. These cases usually involve inferred resources based on sparse data, such as surface mapping or limited trench sampling. For areas where exploration has not yet begun or is based solely on indirect indicators such as geophysical anomalies or regional geochemistry, classification under G4 is appropriate.

The implementation Italian UNFC decision-trees also demonstrates how such tools could be extended to form part of a National UNFC Guidance Document, similar to initiatives undertaken in France and the United Kingdom (BRGM, 2023; Bide et al., 2022). Such guidance could further institutionalize the application of UNFC principles within the Italian mining and geological framework, ensuring a harmonized approach across national data providers and projects.

The full Italian decision-trees and a more in-depth elaboration are found under **Appendix E**. It provides an overview of the national mining law, the structure and logic of each decision-tree for the E, F, and G axes, and explanatory notes detailing the reasoning behind each decision branch. **Appendix E** also includes two case study examples, illustrating the application of the Italian decision-trees to real mineral projects. These examples demonstrate the practical use of the tools in assessing project viability, feasibility, and geological confidence, and serve as a preliminary validation of their applicability for broader national use.

6.4 UNFC National Guidance

As part of the present work, a UNFC National Guidance Template has been developed, in collaboration with UNECE, to support EU Member States in aligning their resource classification and reporting systems with UNFC. Although this template is not yet tailored specifically to the Italian context, its adaptation based on the decision-trees developed in the previous section, can form the basis for an Italian National UNFC Guidance Document, to be officially recognized and adopted by the competent national authorities (UNECE, 2024).

The main objective of this proposed document is to provide a structured and harmonized approach for the application of UNFC at the national level. It is intended to assist EU Member States, particularly those without mandatory reporting or classification systems, in aligning their frameworks and data management practices with UNFC. Establishing a coherent methodology for classification promotes consistency, transparency, and reliability in resource data management across Europe. This template has been designed in line with existing UNFC National Guidance documents, such as from Czech Republic, Poland, Austria, and Hungary. Ultimately, the guidance aims to support the creation of a common European classification language that enhances data interoperability, supports the goals of CRMA, and strengthens evidence-based decision-making in resource governance.

Mapping national resource classification systems to UNFC represents a crucial step toward achieving standardized and interoperable resource management. Within the EU, national systems vary considerably, ranging from GKZ-based systems and country-specific schemes to international reporting standards or, in some cases, the absence of any formal system. The proposed guidance therefore outlines a high-level approach for mapping national definitions, categories, and criteria to the UNFC structure, enabling comparability and integration between national and international frameworks.

The full UNFC National Guidance Template is appended to this dissertation under **Appendix F**. It provides the conceptual and procedural foundation for developing a country-specific guidance document for Italy and for other EU Member States seeking to align their national systems with UNFC.

Chapter 7

Building a UNFC-based Italian Raw Materials Inventory

7.1 The Role of Inventories in Sustainable Resource Management

Sustainable resource management is fundamental to securing long-term, reliable access to the raw materials required for modern societies. Ensuring the availability of minerals and metals, particularly those essential for the green and digital transitions, begins with the development of accurate, transparent, and harmonized national inventories. These inventories form the backbone of evidence-based policymaking, enabling governments and industry actors to understand what resources exist, under which conditions they may be developed, and how they fit within broader sustainability priorities (Sabra and Solar, 2023).

As emphasized in literature, responsible resource management must consider the full value chain, from exploration and extraction to processing, use, recycling, and eventual recovery (UNECE, 2020). Every stage is shaped by the availability of trusted information. UNFC directly addresses this need by embedding environmental-socio-economic viability, technical feasibility, and confidence in resource estimates into a single, multidimensional classification system. Because UNFC is project-based and applicable across all resource types and stages of maturity, it offers a harmonized and transparent foundation for national inventories. UNFC's capacity to bridge different reporting and classification systems makes it especially relevant for countries that either lack a national mineral reporting standard or rely on heterogeneous, legacy systems. Providing consistent definitions and decision rules enables comparability across commodities, jurisdictions, and project types. A UNFC-aligned national inventory therefore supports a wide range of national functions: policy formulation, land-use planning, investment prioritization, strategic stock assessment, resource security monitoring, and long-term sustainability planning. In doing so, it also facilitates harmonized reporting at European level, contributing to regional integration in the context of CRMA.

The importance of UNFC-based inventories and their potential role in strengthening national raw materials governance are examined in detail in the paper "The Potential Role of the United Nations Framework Classification for Resources in National Raw Materials Inventories", found under **Appendix G** (Sabra and Solar, 2023). The paper explores the conceptual basis for UNFC-aligned inventories, demonstrates how UNFC can bring coherence and transparency to national datasets, and outlines how such inventories can support sustainable resource management at both national and regional levels.

7.2 Aggregated Italian UNFC Inventory

The development of a UNFC-based raw materials inventory for Italy represents one of the central outcomes of this thesis. It synthesizes the results generated across earlier chapters, application of UNFC to statutory projects, historical datasets, geological extrapolations, decision-tree–supported classifications, and national guidance considerations, into a coherent, systematic inventory structure. This effort builds upon and extends the work presented in Sabra G. et al., Applying the United Nations Framework Classification for Resources for a National Raw Materials Inventory in Italy (2025), providing a consolidated national overview of primary raw materials potential using the UNFC as the interpretative and classification framework. The resulting inventory compiles raw materials data from three principal acquisition pathways: (i) active and statutory projects with published production or exploration data, (ii) historical datasets and academic sources, and (iii) extrapolated geological occurrences derived from publicly available mapping outputs. Each commodity included in the inventory is assigned a superscript indicating its source: "a" for project- and production-based data, "b" for historical datasets, and "c" for geological occurrences. Estimates are expressed in metric tonnes and classified according to their environmental-socio-economic viability (E), technical feasibility (F), and degree of geological confidence (G). To support visual interpretation, each cell in the compiled inventory table is shaded based on its UNFC category, allowing readers to recognize, at a glance, how commodities progress from higher-confidence classifications in the upper-left of each section to lower-confidence categories in the bottom-right (Table 23). The full dataset, including the project list, sources consulted, classification records, and the complete template sheets, is provided as supplementary material to this thesis.

Table 23: UNFC-based Italian raw materials inventory (Sabra G., et al., 2025)

Commodity	E			F				G				Quantity (t)	UNFC class
	1	2	3	1	2	3	4	1	2	3	4		
Antimony [b]												20,000	333
Arsenic [a]												3,200	221
Arsenic [a]												132	223
Ball Clay [a]												560	111
Bauxite [a]												769,500	111
Bauxite [b]												2,250,000	333
Bauxite [b]												1,250,000	332
Baryte [b]												3,500,000	333
Baryte [b]												3,500,000	344
Bentonite [a]												32	111
Bentonite [b]												150,000	344
Boron [a]												1,500,000	221
Boron [a]												36,800,000	223
Common Clay [a]												2,000	112
Cobalt [a]												1,020,497	224
Copper [a]												15,400	111
Copper [a]												14,000	221
Copper [a]												316	223
Copper [c]												2,045,465	334
Gold [a]												5,732,715	221
Gold [a]												799,982	222
Gold [a]												892,323	223
Gypsum [a]												160	111
Feldspar [a]												2,200	112
Feldspar [b]												1,000,000	332
Feldspar [b]												5,000,000	344
Fluospar												2,200,000	112
Fluospar [b]												35,000,000	333
Kaolin [b]												1,000,000	332
Kaolin [b]												10,000	344
Lead [a]												98,000	222
Lead [a]												39,000	223
Lead [b]												4,000,000	332
Lead [b]												100,000	344
Lithium [a]												39,000	222
Lithium [a]												352,000	223
Nickel [a]												680,162	224
Potassium [a]												17,500,000	222
Potassium [a]												84,000,000	223
Potash [b]												500,000,000	332
Rock Salt [a]												3,017	111
Rock Salt [b]												100,000,000	332
Rock Salt [b]												3,000,000	344
Sand and Gravel [a]												78,000	111
Silver [a]												563,000	221
Silver [a]												6,399,889	222
Silver [a]												2,999,356	223
Silver [c]												67,953,367	344
Sulphur [b]												5,000,000	332
Sulphur [b]												800,000	333
Talc [a]												385	111
Talc [b]												10,000,000	333
Talc [b]												100,000	344
Titanium [a]												9,000,000	323
Zinc [a]												181,000	112
Zinc [a]												375,000	222
Zinc [a]												153,000	223
Zinc [b]												2,506	224
Zinc [b]												3,400,000	333
Zinc [c]												1,946,000	344

Italy's CRM inventory integrates heterogeneous datasets from multiple national and international sources (Table 24). These include industry reporting platforms (e.g., S&P Global), publicly available institutional resources (e.g., ISPRA archives, Minerals4EU, USGS publications), and spatially organized occurrence datasets (e.g., ISPRA resource maps, EDGI outputs). The diversity of sources mirrors the fragmented, uneven raw materials data landscape across Europe and reinforces the need for a unified, UNFC-based national inventory. Given data inconsistencies and the variable quality of historical and regional datasets, many entries were assigned to lower-confidence classes, most commonly G3 or G4, reflecting limited geological certainty or the absence of deposit-specific information. Differentiation between F3 and F4 was determined based on whether identifiable deposit-level information was available (F3) or whether only regional, non-delineated occurrences existed (F4). While these lower-confidence classifications are not ideal, they nonetheless represent an essential first step in establishing a national baseline inventory and place the heterogeneous data into a single, coherent interpretative structure. Where higher-confidence datasets existed, particularly CRIRSCO-aligned exploration results or confirmed production figures, they were placed exclusively within higher-category cells in accordance with UNFC's mutual exclusivity principle. Further elaboration on the methodology and full results may be found in the appended paper Sabra G. et al. (2025).

Table 24: UNFC-based CRMs inventory for Italy, with figure in metric tonnes (Sabra G., et al., 2025)

UNFC Classification	Viable Projects		Potentially Viable Projects				Non-Viable Projects	Prospective Projects		
	111	*112*	*221*	*222*	*223*	*224*	*323*	*333*	*334*	344
Antimony								20,000		
Arsenic			3,200		132					
Bauxite	769,500							2,250,000	1,250,000	
Baryte								3,500,000	3,500,000	
Boron			1,500,000		36,800,000					
Cobalt						1,020,497				
Copper	15,400		14,000		316	2,045,465				
Feldspar		2,200						1,000,000		5,000,000
Fluorspar		2,200,000						35,000,000		
Lithium				39,000	352,000					
Nickel						680,162				
Titanium							9,000,000			

Ultimately, this dissertation demonstrates that constructing a UNFC-based CRM inventory supports the implementation of CRMA. Such an inventory improves transparency, supports risk monitoring, guides national investment strategies, and enhances comparability with other EU Member States. Integrating environmental-socio-economic, technical, and geological criteria, into the inventory allows it to become a dynamic governance tool capable of supporting strategic planning, circularity initiatives, and long-term supply security.

The classification workflow developed under this research, and applied to the Italian dataset, aims at showing how UNFC can be made operational for mapping, monitoring, and reporting national CRM potential. Classifying CRMs at each stage of the value chain, provides a panoramic understanding of Italy's raw materials potential through the resulting inventory, beginning with early-stage occurrences and extending to near-production and active projects. Early-phase occurrences, such as those emerging from ISPRA's NEP and the extractive wastes in the GeMMA database, are to be classified under UNFC to reveal their developmental conditions and relative importance. While most will fall under prospective categories, they establish a baseline for identifying promising exploration targets and guiding future investments. Their UNFC classification provides meaning and granularity to otherwise static occurrences, transforming them into trackable assets whose maturity can evolve over time. The methodology also applies to incorporate active or near-production CRM projects, including those recognized as Strategic Projects under CRMA. It is to be noted that recycling projects and secondary raw materials were not incorporated into the resulting national inventory. However, further developments should include the potential from secondary raw materials, especially in Italy where all the recognized Strategic Projects from the first cut-off are recycling projects. UNFC offers a structured approach to monitoring these projects from the baseline classification at recognition through annual reporting cycles. Linking UNFC categories with production volumes, market conditions, and risk indicators, the classification code can serve as an early-warning tool for foresight and criticality assessment.

The workflow supports monitoring across the entire lifecycle:

- Prospective resources from exploration and occurrences,
- Pre-development and development projects,
- Producing or near-producing operations,
- Strategic Projects, with UNFC acting as a baseline,
- Secondary raw materials, including extractive waste with potential CRM recovery.

In all cases, UNFC converts dissimilar datasets into structured knowledge, enabling a coherent stock assessment that aligns with CRMA requirements for strategic planning, stockpiling, and national reporting.

The construction of a UNFC-based national inventory has revealed several methodological and operational challenges, many of which reflect broader European circumstances. Italy's raw materials datasets are highly fragmented, and this heterogeneity is compounded by disparate reporting standards, inconsistent analytical methods, incomplete grade information, and variable spatiotemporal coverage. The inventory requires meticulous and frequent maintenance and update. ISPRA is well positioned to collect raw materials data across the country, including the outcome of the NEP, production data from industry, and resource and reserve estimates from statutory and public reporting. Therefore, institutional capacity stands as a cornerstone to overcome challenges of maintaining and updating the inventory. From a technical point, one of the principal challenges concerns ore grades and quality within aggregated national volumes. Ore grades cannot be meaningfully aggregated across raw materials at national scale because they represent project-specific concentrations. What can be aggregated are tonnages assigned to similar confidence classes, such as the corresponding categories on the G axis. Accordingly, given that the resulting Italian inventory comprises only primary raw materials, the G axis categories refer to the confidence associated with the estimated quantities in-situ or available for potential extraction. For this reason, the national inventory aggregates tonnages according to geological confidence and classification status. Grade data, where available, are retained at deposit and project levels in the supplementary material and incorporated into the UNFC classification, but not into the total volume estimates. As such, the reported tonnages should not be interpreted as indicative volumes rather than precise recoverable quantities. Furthermore, a significant proportion of the compiled estimates originate from legacy datasets, historical records, and broad regional surveys. These often lacked detailed geological validation, resulting in a predominance of lower-confidence categories (e.g., E3; F3; G3/G4). For more granularity, future iterations should consider subdividing the G4 category (G4.1, G4.2, G4.3) to improve granularity for early-stage exploration classifications, following the methodology outlined in the NEP-R document. All in all, it is likely that the inventory underestimates Italy's total resource potential, as confidential datasets held by companies or public authorities were not accessible for this study. For context, out of the 21 active projects listed in ISPRA's CRMs dashboard, 7 presented no information. Moreover, Italy's NEP is expected to reveal additional prospects, requiring future updates to the inventory. The study also does not tap into the potential from secondary raw materials projects. Another important note involves cases where multiple G axis categories could apply, but this dissertation adopted a simplification: using a single representative category per estimate, prioritizing the most abundant with the highest confidence degree. While this deviates from the full flexibility of the UNFC methodology, it ensures clarity and avoids artificially inflating confidence levels through mixed assignments. Finally, the observed trend, where higher-confidence categories correspond with smaller reported volumes and vice versa, reinforces the need for caution when interpreting aggregated totals. Higher geological certainty emerges only where significant exploration investment has been made. Thus, the baseline inventory presented in this thesis provides a foundation, not a conclusion, a first structured step toward a comprehensive national raw materials knowledge system. The continuous cycles of reporting in accordance with CRMA will enrich the value of the inventory across the whole CRMs value chain.

Chapter 8

Conclusion

This dissertation set out to address a structural challenge at the intersection of mineral economics, sustainability science, and resource management, answering the question of how resource classification can evolve from a mere and static reporting tool into a dynamic knowledge infrastructure, capable of supporting sustainable resource management. Anchored in UNFC, this work aims to contribute to the understanding of how UNFC can support EU Member States in transforming fragmented raw materials data into structured knowledge and actionable intelligence for the classification, monitoring, and sustainable management of CRM projects. In doing so, the dissertation approached the classification of raw materials as a systematic and interdisciplinary matter, rather than a pure economic concern. The scope therefore stands on advancing UNFC from a classification tool to a connecting scientific node for multiple domains that are often treated separately in the literature, more specifically as an interface between geology and policy, between uncertainty and decision-making, and between sustainability principles and project-level realities. Using Italy as a primary case study, the research produced methodologies for applying UNFC across the full supply chain, from exploration and extraction through processing, recycling, and extractive waste, while ensuring that the relevance of the findings is not limited to a single country.

The presented methodologies are shaped by sustainable resource management, criticality assessment and CRMs, regional raw materials regulations, national mining legislations, data governance, and importantly the green and digital transition. Within this broader framing, CRMA was interpreted as an accelerator and a catalyst to this research. To support CRMA, the aim was to facilitate its implementation by underlining a demand for harmonized, coherent, and consistent classification tool that integrates sustainability aspects at EU levels, across all Member States. To elaborate, the research more specifically attempted to answer the question of how can an EU Member State effectively monitor, manage, and communicate its CRMs potential in accordance with CRMA. Through the UNFC provisions enunciated in CRMA, the methodologies covered Strategic Projects, NEPs, extractive wastes, and active CRMs extraction, processing, and recycling projects. Ultimately, the coverage of the whole supply chain supported the development of a national raw materials inventory, based on various data sources and types.

The primary contribution is the development and testing of structured and harmonized methodologies for applying UNFC across the full raw materials supply chain. UNFC is applicable to exploration, extraction, processing, and recycling projects, yet its operationalization at national or regional level remains relatively new. This dissertation advances applied knowledge by designing and applying UNFC-based templates, decision trees, and application workflows tailored to different project types, maturity stages, and purposes. The methodologies showed effective application of UNFC to early-stage exploration results, producing and near-production projects, extractive waste, and Strategic Projects. While the dissertation initially focused on primary raw materials, the methodology was extended to include anthropogenic resources, namely for recycling Strategic Projects, extractive waste, and for the monitoring of advanced recycling CRM projects, as per the obligations of CRMA. Given the complex nature of recycling projects, the classification looked mostly into recycling capacities and feedstock supply security, rather than a comprehensive assessment of the process flow and finished product estimates.

A second key contribution concerns the translation of fragmented raw materials data into coherent, policy-relevant information. Although the absence and limitation of geological information is a prominent issue, one of the central scientific problems addressed in this dissertation is the inability to aggregate, compare, and interpret existing data in a way that supports strategic analysis. Developing and implementing a UNFC-based national raw materials inventory is therefore showcased in this research with dispersed and different datasets. This methodology is corroborated through the development of a UNFC-based Italian raw materials inventory. The Italian case study illustrated that UNFC-based inventories are not merely descriptive and technical exercise, but analytical tools that meaningfully contribute to national and regional raw materials management practices. In terms of CRMA, UNFC-based inventories can serve as an indicator of progress, bottlenecks, and policy patterns related to CRMs projects. This finding has broader relevance for mineral economics and resource policy research, where data comparability and transparency remain persistent challenges.

A third central contribution relates to the dynamic application of UNFC as a monitoring instrument, capable of following the project's development. Traditional raw materials classifications offer static snapshots, obscuring the temporal dimension of project development and risk evolution. This dissertation advances the literature by proposing UNFC as a time-sensitive framework to track changes in project status as new geological information, technical maturity, regulatory constraints, or environmental-socio-economic conditions emerge. In parallel to the development of monitoring models, the research proposes a preliminary methodology to connect UNFC and the analysis of supply potential and associated risks from designated Strategic Projects. However, it necessary to recognize that this aspect remains only partially developed and represents a major field for future work. In particular, the integration of UNFC within criticality assessments, viability scenario modelling, and stress testing remains an area where significant improvement and data are still required. Importantly, this would reframe raw material classification as a process rather than an outcome, reflecting more accurately the realities of project lead times and uncertain transition pathways.

Across all chapters, Italy was used as a test field to provide tangible grounding for the research contributions. The application of UNFC to Italian raw materials projects displayed both the strengths and limitations of existing data infrastructures in the field of raw materials. Importantly, the findings illustrate that the value of UNFC does not lie in producing optimistic assessments of raw material availability, but in clarifying uncertainty, constraints, and development pathways. A key outcome of the dissertation is the development of a first-of-its-kind Italian Raw Materials Inventory based on UNFC. Drawing on the methodologies developed throughout the dissertation, the UNFC-based Italian raw materials inventory demonstrated how data from different sources, namely national mining databases, statutory records, mineral occurrences, and historical estimates, can be harmonized within a single UNFC-based structure. The UNFC-based inventory revealed the structure of Italy's resource governance capacity, not merely its geological endowment. The majority of low-confidence classifications (G3/G4) in the Italian inventory does not primarily reflect poor geological potential, rather the absence of modern systematic exploration, the decentralization of data governance, and restricted access to company-held information. This insight is as valuable for policy as any positive resource estimate. Ultimately, the coverage of the whole supply chain, including from secondary raw materials, would support the development of a comprehensive and uniform national raw materials inventory, from various data sources and types. If inventories from all Member States incorporate UNFC in a similar manner, these could be therefore aggregated into a singular EU-level raw material inventory, rendering the base for raw materials intelligence at EU scales more effective. In the case of the Italian raw materials inventory, it provided not only a snapshot of the CRMs potential, but also a dynamic tool for strategic planning, policy evaluation, and EU reporting. UNFC functions most powerfully not as a static inventory tool but as a dynamic monitoring instrument. When applied consistently over time, UNFC classifications become indicators of governance performance, permitting efficiency, and investment climate, not merely technical descriptors of project maturity. The results also showed the effectiveness of the developed UNFC decision-trees aligned with Italian mining legislation. To facilitate consistent application and integration into the inventory, the research also proposed a national UNFC guidance template.

While this dissertation argues for the usefulness of UNFC, it also identifies substantial conceptual and operational limitations in practice. UNFC is not a complete solution to resource management challenges. Rather, it constitutes only one component of the broader discipline of sustainable resource management. The effectiveness of UNFC depends fundamentally on institutional capacity, data governance structures, transparency of reporting, and the consistency with which the framework is interpreted and applied across jurisdictions. Four critical limitations emerged from the methodologies applied for the Italian case and in support of CRMA. First, the Italian inventory is not a comprehensive resource assessment, as data confidentiality and regulatory fragmentation constrained access to approximately one-third of listed CRM projects. Second, the validation of the supply risk framework remains qualitative, since quantitative calibration against observed project outcomes requires longitudinal data that is not yet available. Third, the application of UNFC to extractive waste in Italy is methodologically preliminary as the approach adapts GTK best practices to a national context without project-specific data, which will only be available once Italy's GeMMA database is complete. Fourth, the secondary raw materials potential in Italy is not integrated into the national inventory.

These limitations are posed by challenges stemming from fragmented and incomplete datasets, poor data quality, incomplete documentation, inconsistent reporting standards, lack of crucial geologic data, weak accessibility of company-held information, and inconsistent harmony, and in return, interpretation of UNFC and its application across jurisdictions. In many cases, the absence of reliable project information constrains the ability to assign robust UNFC categories. Consequently, harmonized aggregation at national and European scales risks producing classifications that appear comparable formally, while reflecting fundamentally different assumptions, data quality levels, and methodological approaches. This challenge becomes particularly acute in countries where geological surveys or competent authorities do not have direct access to confidential company data and must instead rely on historical estimates, public disclosures, or probabilistic assessments. As such, a gap in UNFC commonly recurs, that is to confuse classification with future assumptions (Hokka et al., 2021). Projects are often assigned E- and F-axis categories based on expectations about future viability and feasibility, or perceived economic attractiveness, rather than on evidence and information carried by the existing project. Similar risks emerge in the classification of Strategic Projects under CRMA. In practice, this results in projects being classified as viable projects, or speculative assessments being assigned confidence levels inconsistent with the available project data. Such practices weaken comparability between countries and undermine the reliability that UNFC is intended to provide. This issue is also particularly relevant for NEPs. The dissertation shows that most exploration targets and occurrences identified naturally fall into broad prospective classes with relatively low geological confidence. Consequently, the application of UNFC to NEP results may appear insufficiently granular if interpreted as a detailed resource assessment tool rather than as a standardized method for communicating exploration maturity and uncertainty. In this sense, UNFC does not necessarily provide a highly granular classification for ranking early-stage occurrences.

Another major challenge concerns the interpretation and weighting of E axis controlling factors. UNFC provides limited operational guidance regarding how competing environmental, social, and economic factors should be balanced in practice. Questions remain regarding whether classification should follow a “lowest-ranking factor prevails” logic or a broader balanced-judgement approach. This dissertation argues that the appropriate interpretation depends on the user of the classification. For regulatory and governmental purposes, particularly within CRMA implementation, a conservative “lower-rank prevails” approach is more appropriate to ensure that permitting, legal, or environmental barriers are fully reflected. Conversely, for investment communication or project-financing purposes, a balanced judgement is a better capture of the overall maturity of a project. Nevertheless, the absence of standardized weighting methodologies introduces variability in classification outcomes between evaluators and jurisdictions. At the same time, the E axis remains one of the least mature and least standardized dimensions of UNFC. Methodologies for evaluating social acceptance, public opposition, community engagement, or social license to operate remain unclear in UNFC. In practice, social considerations are frequently referenced qualitatively but rarely supported through transparent, measurable, and reproducible indicators. As a result, project economics, permitting status, or market considerations may inadvertently dominate E axis classification, while broader societal dimensions remain weakly represented. Existing research on this topic remains limited, although studies exploring protest-event analysis and social-risk indicators suggest possible future directions for methodological development (Eerola, 2023). The dissertation therefore concludes that further research is needed to operationalize social and environmental indicators within UNFC.

The research also highlights significant structural challenges associated with confidentiality of company data. In many Member States, including Italy, geological surveys and public authorities have only partial access to current resource and reserve information. Where operators are not legally required to report disclose tonnage, grade, recovery, or reserve/resource classifications (beyond public reporting obligations in certain cases), UNFC-based national inventories remain difficult to validate. Where only indirect data are available, UNFC assigns lower-confidence classes, rendering the classification less reliable and indicative for decision making. At the same time, it is noteworthy to mention that public institutions may be reluctant to estimate or classify projects independently of operator disclosure due to legal liability and reputational concerns associated with potentially misleading interpretations and confidentiality. Long-term effectiveness of UNFC-based national inventories therefore depends on the establishment of robust statutory reporting obligations, protected-access databases, and institutional mechanisms enabling confidential but standardized resource reporting to competent national authorities. Relevant authorities would need to progressively establish standardized national reporting procedures, harmonized metadata requirements, digital interoperability between regional and national databases, and clear protocols for integrating exploration, extractive waste, production, and recycling data.

On a broader note, this research opens four directions for further research. First, further testing of the UNFC methodologies across independent practitioners is needed to establish stronger quality control and comparability across jurisdictions, as the foundational requirement for EU-level aggregation. Comparative studies across Member States would help identify best practices and refine implementation pathways. Second, quantitative integration of UNFC within supply chain scenario modelling and EU-level criticality assessments would extend the framework to support more realistic supply-security assessments. Third, the interaction between UNFC, ESG reporting, and sustainable finance frameworks presents a promising research frontier, particularly as capital markets increasingly demand transparent, sustainability-aligned resource information. For that matter, stronger definitions are needed for the E axis classification, particularly for social acceptance and engagement, as operational indicators. Fourth, extension of the Italian inventory to secondary raw materials, particularly through integration of the GeMMA extractive waste database and the URBES platform, would transform it from a primary-resource baseline to a full circular-economy resource potential system, consistent with CRMA's overarching policy objectives.

The successful implementation of CRMA depends as much on understanding CRMs information as on regulatory and financial instruments. Accelerated permitting, strategic projects, and investment mechanisms can only deliver resilience and sustainability if they are underpinned by consistent, transparent, and policy-fit information on raw materials and projects. In this context, this dissertation demonstrates that sustainable and secure raw materials supply is fundamentally a governance challenge, not merely a geological one. Positioning UNFC at the heart of CRMA provides a coherent, practical, and forward-looking framework that aligns sustainable resource management practices with European strategic objectives. The research conducted here shows that this language can be made operational at national level, even under conditions of fragmented data and decentralized governance. Its credibility as a policy instrument will depend on the consistency and rigor with which it is applied as CRMA implementation advances. The findings show that UNFC is not only fit for purpose, but can be essential for translating ambition into implementation.

As the EU navigates an increasingly complex global resource landscape, frameworks that integrate technical, economic, environmental, and social dimensions will be indispensable. The dissertation supports this effort by offering both conceptual foundations and practical methodologies, ones that place the EU on a more resilient and sustainable path for resource management.

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Appendix A – UNFC – CRMA Strategic Projects Monitoring Model

Workable Model for Monitoring based on UNFC, for Designated Strategic Projects

Project Information

Project Information						
Project ID						
Project Name						
Project Promoter / Company						
Country						
Project Type						
Main Strategic Raw Material		**Other Strategic Raw Materials**			**Other Material**	
Project lifetime (y)						
Estimated Starting Date of Production						

Verified UNFC Classification (2025)	Code	Class	Sub-class
E axis			
F axis			
G axis			

For Extraction	2025	2026	1st Update Date	2nd Update Date	3rd Update Date	2030
Estimated annual production of extracted raw material (t)						
Raw material content in weight (t)						

For Processing / Recycling	2025	2026	1st Update Date	2nd Update Date	3rd Update Date	2030
Material Input						
Annual material feed input (t)						
Raw Material content of annual material feed input (t)						
Material Output						
Annual production (t)						
SRM content in weight (t)						

Operational Monitoring

Operational Monitoring

Environmental-Socio-Economic Viability	2026			1st Update Date			2nd Update Date		
	Status	UNFC	Note	Status	UNFC	Note	Status	UNFC	Note
Legislative Framework									
Raw Materials Policy at National Level		#N/A			#N/A			#N/A	
Regulatory Approval Process		#N/A			#N/A			#N/A	
E axis									
Permitting Status									
Extraction / Mining		#N/A			#N/A			#N/A	
EIA		#N/A			#N/A			#N/A	
Operational / Industrial		#N/A			#N/A			#N/A	
Water Use		#N/A			#N/A			#N/A	
Waste Management		#N/A			#N/A			#N/A	
Construction / Land use		#N/A			#N/A			#N/A	
Health & Safety		#N/A			#N/A			#N/A	
Others		#N/A			#N/A			#N/A	
E axis									
Economic Viability									
Development Stage		#N/A			#N/A			#N/A	
NPV		#N/A			#N/A			#N/A	
IRR		#N/A			#N/A			#N/A	
Off-takes Agreement		#N/A			#N/A			#N/A	
Risk Mitigation		#N/A			#N/A			#N/A	
E axis									
Social Acceptance									
Public Consultations		#N/A			#N/A			#N/A	
Public Opposition		#N/A			#N/A			#N/A	
Jobs Creation		#N/A			#N/A			#N/A	
Skills Development		#N/A			#N/A			#N/A	
Indigenous Engagement		#N/A			#N/A			#N/A	
E axis									
Environmental Commitments									
Air Emissions		#N/A			#N/A			#N/A	
Water Use / Protection		#N/A			#N/A			#N/A	
Soil Use		#N/A			#N/A			#N/A	
Biodiversity Impacts		#N/A			#N/A			#N/A	
Waste / Tailings		#N/A			#N/A			#N/A	
Hazardous Substances		#N/A			#N/A			#N/A	
Noise / Vibrations		#N/A			#N/A			#N/A	
Energy Use		#N/A			#N/A			#N/A	
E axis									
Governance Practices									
Transparent operations		#N/A			#N/A			#N/A	
E axis		#N/A			#N/A			#N/A	
Final E axis Category / Sub-category									

Technical Feasibility	Status	UNFC	Note	Status	UNFC	Note	Status	UNFC	Note
Development Stage		#N/A			#N/A			#N/A	
Activities Status		#N/A			#N/A			#N/A	
TRL (Processing/Recycling)		#N/A			#N/A			#N/A	
Infrastructure Readiness		#N/A			#N/A			#N/A	
Financing Secured									
Final F axis Category / Sub-category									
Degree of Confidence	**Status**	**UNFC**	**Note**	**Status**	**UNFC**	**Note**	**Status**	**UNFC**	**Note**
For extraction projects									
CRIRSCO-compliance									
Resources									
Reserves									
G axis									
For Processing / Recycling									
Supply Security		#N/A			#N/A			#N/A	
G axis		#N/A			#N/A			#N/A	
Final G axis Category									

UNFC Classification	2025	2026	1st Update Date	2nd Update Date	3rd Update Date	4th Update Date	5th Update Date	6th Update Date	7th Update Date
Code									
Class									
Sub-Class									

Financing and Bankability

Financing and Bankability		1st Date of Update			2nd Date of Update			3rd Date of Update		
		Status	Note		Status	Note		Status	Note	
Project Development Stage										
Completion % of Current Stage		%			%			%		
Foreseen Total CAPEX (€M)		(€M)			(€M)			(€M)		
Foreseen Total OPEX (€ M/year)		(€M/year)			(€M/year)			(€M/year)		
Stage-Specific CAPEX (€ M)		(€M)			(€M)			(€M)		
Financing Secured (€ M)		(€M)			(€M)			(€M)		
Funding Gap (€ M)		(€M)			(€M)			(€M)		
Investment Type	Equity		(€M)			(€M)			(€M)	
	Debt / Loans		(€M)			(€M)			(€M)	
	Public Grant / Subsidy		(€M)			(€M)			(€M)	
	Blended		(€M)			(€M)			(€M)	
	Other		(€M)			(€M)			(€M)	

Use Case – Monitoring an Extraction Project using the UNFC-CRMA Monitoring Template

Project Information

Project ID	Project_Extraction_2024					
Project Name	X					
Project Promoter / Company	X					
Country	Third Country					
Project Type	Extraction					
Main Strategic Raw Material	Lithium - battery grade		**Other Strategic Raw Materials**	Boron - metallurgy grade	**Other Material**	-
Project lifetime (y)	70					
Estimated Starting Date of Production	1/1/2028					

Verified UNFC Classification (2025)	E2; F2.2; G2	Pot. Viable	On Hold
E axis	E2		
F axis	F2.2		
G axis	G2		

For Extraction	2025	2026	1st Update Date	2nd Update Date	3rd Update Date	2030
Estimated annual production of extracted raw material (t)	805000	805000	1000000			
Raw material content in weight (t)	21735	21735	27000			

For Processing / Recycling	2025	2026	1st Update Date	2nd Update Date	3rd Update Date	2030
Material Input						
Annual material feed input (t)						
Raw Material content of annual material feed input (t)						
Material Output						
Annual production (t)						
SRM content in weight (t)						

Operational Monitoring

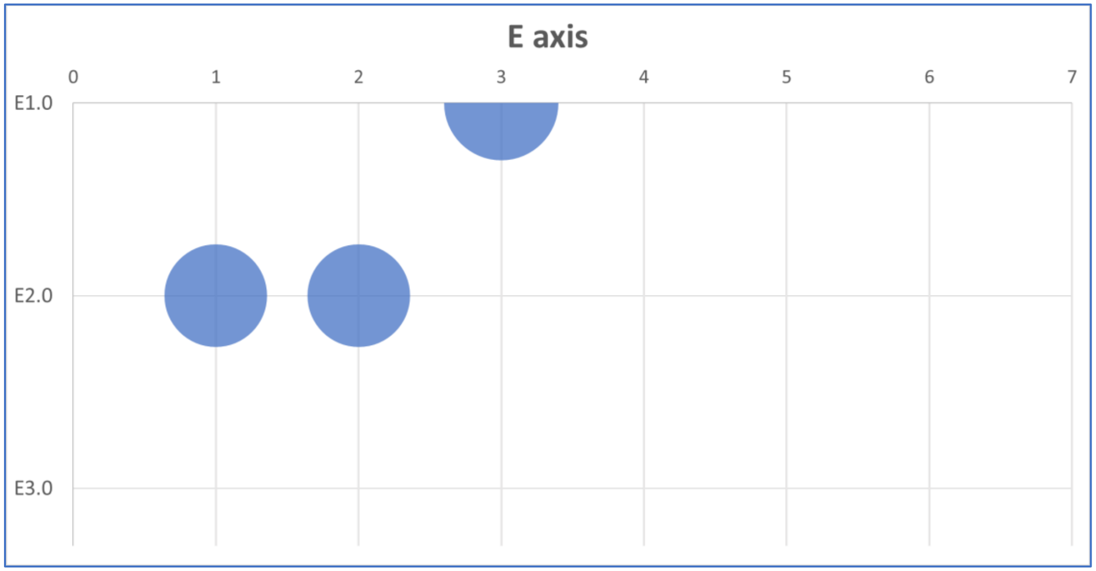
Environmental-Socio-Economic Viability	2026			1st Update Date			2nd Update Date		
	Status	UNFC	Note	Status	UNFC	Note	Status	UNFC	Note
Legislative Framework									
Raw Materials Policy at National Level	Neutral	E2	No particular legislative su	Neutral	E2			#N/A	
Regulatory Approval Process	Unknown	E3.2	Depends on the case	Unknown	E3.2			#N/A	
E axis		E2			E2				
Permitting Status									
Extraction / Mining	Applied	E1.2	Expected by Jan 2027	Acquired	E1.1			#N/A	
EIA	Acquired	E1.1	Approved in 2025	Acquired	E1.1			#N/A	
Operational / Industrial	To be applied	E2	Contingent on Extraction P	Acquired	E1.1			#N/A	
Water Use	To be applied	E2	Contingent on Extraction P	Applied	E1.2			#N/A	
Waste Management	To be applied	E2	Contingent on Extraction P	Applied	E1.2			#N/A	
Construction / Land use	To be applied	E2	Contingent on Extraction P	Applied	E1.2			#N/A	
Health & Safety	To be applied	E2	Contingent on Extraction P	Applied	E1.2			#N/A	
Others	Acquired	E1.1	X Permit aquired in 2025	Acquired	E1.1			#N/A	
E axis		E2			E1.1				
Economic Viability									
Development Stage	PFS	E2	PFS completed in 2025	FS	E1			#N/A	
NPV	Strongly Positive	E1	X % based on 3rd party pro	Strongly Positive	E1			#N/A	
IRR	Strongly Positive	E1	X % based on 3rd party pro	Strongly Positive	E1			#N/A	
Off-takes Agreement	Partial off-takes signed	E2	Negotiations are ongoing y	Partial off-takes signed	E2			#N/A	
Risk Mitigation	Partial measures in place	E2	Well documented contigen	Partial measures in place	E2			#N/A	
E axis		E2			E1				
Social Acceptance									
Public Consultations	Initiated but limited in scop	E2	Non inclusive consultation:	Initiated but limited in scop	E2			#N/A	
Public Opposition	Strong/Apparent	E3		Strong/Apparent	E3			#N/A	
Jobs Creation	Significant	E1	The project plans to emplo	Significant	E1			#N/A	
Skills Development	Planned	E2		Active training/upskilling	E1			#N/A	
Indigenous Engagement		#N/A		N/A				#N/A	
E axis		E2			E1				
Environmental Commitments									
Air Emissions	Fully Compliant	E1		Fully Compliant	E1			#N/A	
Water Use / Protection	Strong Commitments	E2		Fully Compliant	E1			#N/A	
Soil Use	Weak Commitments	E3		Strong Commitments	E2			#N/A	
Biodiversity Impacts	Strong Commitments	E2		Strong Commitments	E2			#N/A	
Waste / Tailings	Strong Commitments	E2		Fully Compliant	E1			#N/A	
Hazardous Substances	Weak Commitments	E3		Strong Commitments	E2			#N/A	
Noise / Vibrations	Strong Commitments	E2		Fully Compliant	E1			#N/A	
Energy Use	Strong Commitments	E2		Fully Compliant	E1			#N/A	
E axis		E2			E1				
Governance Practices									
Transparent operations	Strong Commitments	E2		Adherance to International	E1			#N/A	
E axis		E2			E1			#N/A	
Final E axis Category / Sub-category		**E2**			**E1**				

Technical Feasibility	Status	UNFC	Note	Status	UNFC	Note	Status	UNFC	Note
Development Stage	PFS	F2.1		FS	F1.3			#N/A	
Activities Status	On Hold	F2.2		Ongoing				#N/A	
TRL (Processing/Recycling)	N/A			N/A				#N/A	
Infrastructure Readiness	Partially Available	F2		Partially Available	F2			#N/A	
Financing Secured	Secured (>70%)	F1.2		Secured (>70%)	F1.2				
Final F axis Category / Sub-category	**F2.2**			**F1.2**					

Degree of Confidence	Status	UNFC	Note	Status	UNFC	Note	Status	UNFC	Note
For extraction projects									
CRIRSCO-compliance	Yes			Yes					
Resources	Indicated	G2	85 Mt at 1.76% Li2O	Measured	G1	65 Mt at 0.86% Li2O			
Reserves	N/A								
G axis	G2			G1					
For Processing / Recycling									
Supply Security		#N/A			#N/A			#N/A	
G axis	#N/A			#N/A			#N/A		
Final G axis Category	**G2**			**G1**					

UNFC Classification	2025	2026	1st Update Date	2nd Update Date	3rd Update Date	4th Update Date	5th Update Date	6th Update Date	7th Update Date
Code	E2, F2.2, G2	E2, F2.2, G2	E1, F1.2, G1						
Class	Potentially Viable	Potentially Viable	Viable						
Sub-Class	Development On Hold	Development On Hold	Approved for Developement						

Financing and Bankability		1st Date of Update			2nd Date of Update			3rd Date of Update		
		Status	Note		Status	Note		Status	Note	
Project Development Stage		FS	Yet to be initiated, contingent on permits		FS			FS		
Completion % of Current Stage		0%	Starting in mid 2027		75%			%		
Foreseen Total CAPEX (€M)		1100 (€M)			(€M)			(€M)		
Foreseen Total OPEX (€ M/year)		150 (€M/year)			(€M/year)			(€M/year)		
Stage-Specific CAPEX (€ M)		20 (€M)	To complete FS		(€M)			(€M)		
Financing Secured (€ M)		20 (€M)			(€M)			(€M)		
Funding Gap (€ M)		0 (€M)			(€M)			(€M)		
Investment Type	Equity	Secured	900 (€M)		Secured	(€M)			(€M)	
	Debt / Loans		(€M)			(€M)			(€M)	
	Public Grant / Subsidy		(€M)			(€M)			(€M)	
	Blended		(€M)			(€M)			(€M)	
	Other		(€M)			(€M)			(€M)	


E axis
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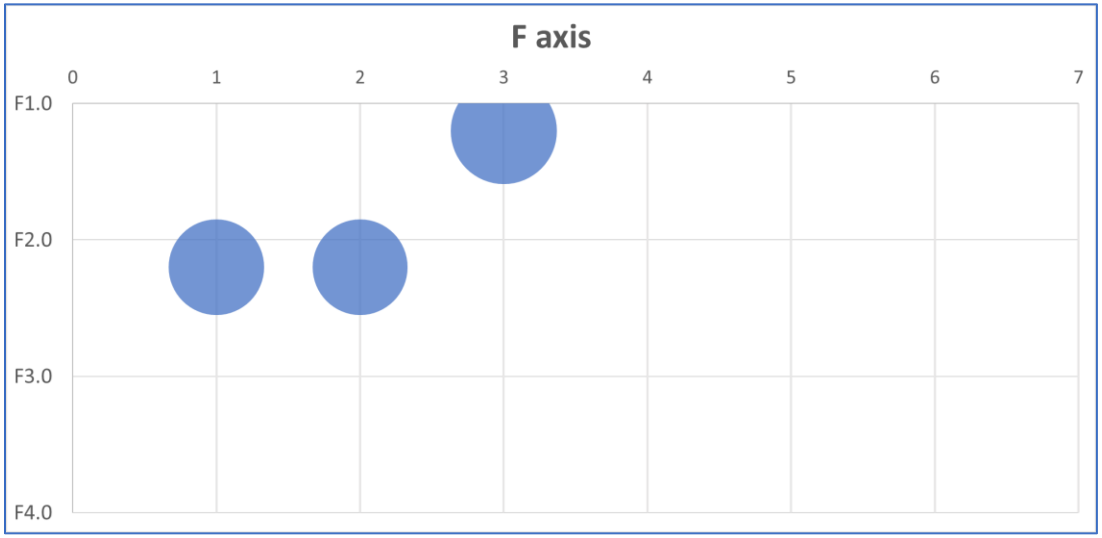
E3.0


F axis
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F1.0
F2.0
F3.0
F4.0

Appendix B - United Nations Framework Classification for Resources Case Study: Titanium deposit, the Piampaludo exploration project in Italy

United Nations | ECE/ENERGY/GE.3/2023/7

Economic and Social Council

Distr.: General
20 April 2023

English only

Economic Commission for Europe

Committee on Sustainable Energy

Expert Group on Resource Management

Fourteenth session
Geneva, 25-28 April 2023
Item 7(a) of the provisional agenda
Development and Implementation Road Map for the United Nations Framework for Resources: The next five years: Minerals

United Nations Framework for Resources Case Study: Titanium deposit, the Piampaludo exploration project in Italy

Prepared by Ghadi Sabra, Politecnico di Torino,* and Consultant, United Nations Economic Commission for Europe

Summary

This case study demonstrates the application of the United Nations Framework Classification for Resources (UNFC) to a titanium exploration project (Piampaludo) in Liguria, Italy. It is an attempt to introduce UNFC to Italy. The Piampaludo exploration project is reported to be one of the largest deposits of titanium in Europe with the potential for significant economic importance, yet its development is constrained by environmental and social considerations. UNFC is a classification tool that provides end users with an assessment of a resource project to allow informed decision making as part of sustainable resource management. The case study demonstrates the classification process for the Piampaludo exploration project, highlighting the social and environmental constraints according to the transparency needed for UNFC, using only data available to the public. Therefore, the information presented in this case study results in a classification sufficient for local and national mineral inventories. For that purpose, this report emerges as an educational example of the use of UNFC with only publicly available data and not on accessing detailed exploration information that would be available to Compagnia Europea per il Titanio, the current owners of the Piampaludo exploration project.

In light of the limited data availability, it is important to note that this case study is not a resource analysis that provides comprehensive and complete insights. The data collected for the classification was limited and restricted, and therefore, the analysis presented is not exhaustive. This case study is a "light" study without the detailed data of sufficient quality and quantity required for the “true classification of the project”. With these caveats and limitations, the study presents a correct classification based on the available data and presents the resultant downgrading of the estimate confidence in comparison to a “true classification”. If additional information does become available, the conclusions drawn from this study will need to be revised but even with the limited information, the exercise provides valuable insights into the resources for decision-making purposes.

* Under the PNRR GeoSciences IR project.

Contents

I. Introduction

1. The world understands the necessity to make progress towards attaining the 2030 Agenda for Sustainable Development. Evidence for this need stems from global trends that indicate a shift towards difficult living conditions if no actions are taken with regard to economic growth, social wellbeing, and environmental protection. In addition, it is understood that it is desirable to leave a prosperous planet with better living standards for our future generations. Achieving this goal is dependent on the responsible use of minerals and energy and the participation of extractive industries, in particular the mining industry. Minerals are integral for the sustainable development and industrial progress. In contrast, mining and its inherent activities are often viewed as inconsistent with the goals of sustainable development. Therefore, the mineral extraction needs to embody a sustainable management approach in all mining activities, from exploration and extraction to processing and recycling, that is built on a classification system that expresses the environmental-socio-economic systems, technical aspects, and the level of knowledge in the product estimates; the United Nations Framework Classification for Resources (UNFC).

2. UNFC is a global, robust, and exhaustive classification system with a structured framework of principles, rules, and guidelines. UNFC is developed for a wide range of resource and energy projects including minerals, petroleum, renewables, underground storage, and anthropogenic resources. This tool provides information on project maturity pertaining to policy formulation, resource management functions, business process, and capital allocation [1]. UNFC is established on three fundamental pillars for every resource and energy projects: the environmental, social, and economic viability (E axis), the technical feasibility (F axis), and the degree of confidence in the estimate of resource quantity (G axis). The integration of these axes makes UNFC a useful communication tool to express complex concepts to stakeholders in a clear and unambiguous fashion.

3. According to the European Union (EU)-funded project Mineral Intelligence for Europe (Mintell4EU), Italy has a significant number of mineral occurrences and deposits, which include several containing Critical Raw Materials (CRMs) (Figure I) [2]. The Geologic Survey of Italy (ISPRA) has identified more than 3,000 mining sites that have been constructed on Italian territory since 1870 [3]. However, Italy has neither a formal national nor regional classification or reporting policy for primary and secondary mineral resources to direct the mining industry. The lack of a national, regional mineral reporting system in Italy has contributed to the reduction of mining activities in the country over the last decade. There is no comprehensive and sustainable information for interested stakeholders on mineral potential for new prospection of mineral resources or even reactivation of historic mines.

4. With the addition of the current challenge of enhancing the security of CRMs supply in the EU and the support of energy transition, there is a need in Italy to map its potential mineral resources. Securing mineral resources starts with the correct mapping of supply and demand with sustainable considerations. Minerals require coherent definition and classification at national, regional, and global scales. This can be achieved through the application of UNFC, as is underlined as an action module in the EU financed project: Piano Nazione di Represa e Resilienza (PNRR) [4].

5. This report presents a case study on the application of UNFC to a titanium exploration project (Piampaludo) in Liguria, Italy. This case study is an attempt to apply UNFC to a unique deposit in Italy and determine the projects status using the classification tool. The challenge of the Piampaludo exploration project is that it is one of the most significant deposits of Titanium in Europe with potential economic importance, and yet it is constrained by environmental and social considerations. The classification of this project was inspired by the UNFC Guidance Europe document for minerals and anthropogenic resources in Europe [5]. This report highlights the classification of an exploration project according to UNFC using only data available to the public. Information from the company in charge of the project, Compagnia Europea per il Titanio (CET), were not disclosed due to the social sensitivity of the matter, and company confidentiality. Therefore, all information used for the classification of the Piampaludo titanium exploration project are strictly from public data: from scientific research studies, journals, news, and court cases. It should be noted that higher confidence in a UNFC classification requires more detailed exploration activities provided

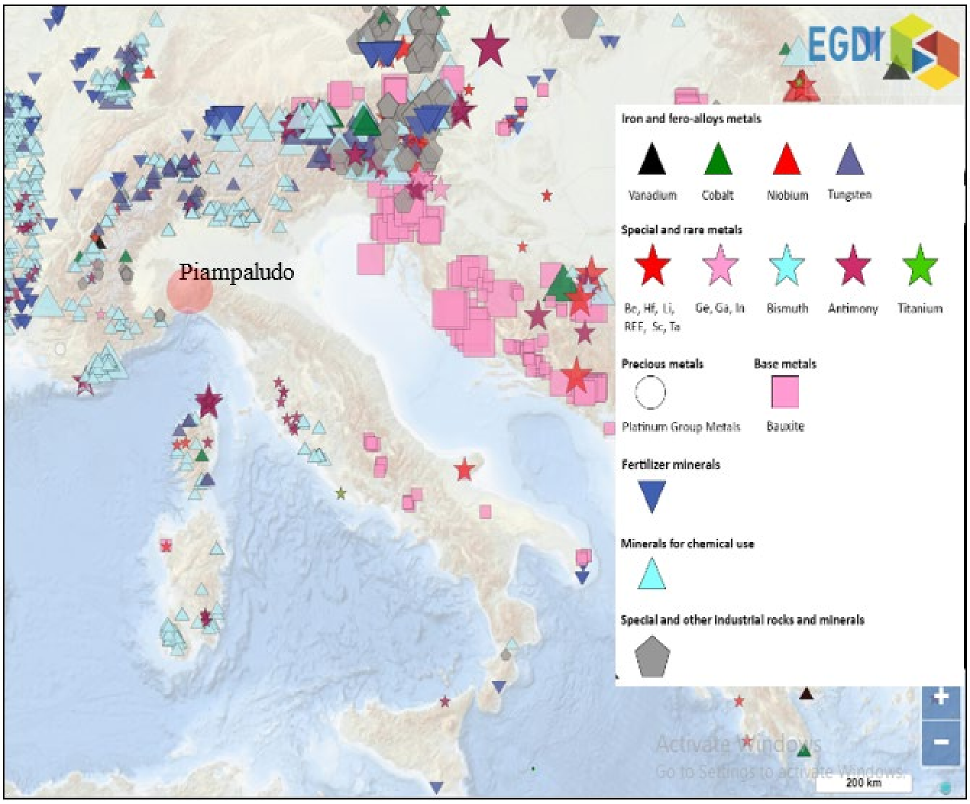
by the CET, which is inaccessible for this case study. However, the information used in this case study results in a classification sufficient for the mineral inventory of the Liguria region. For that purpose, this report is an educational example of the use of UNFC with only publicly available data, and not on accessing detailed exploration information that would be available to CET. The assessment of the Piampaludo project using the available social and environmental information is further elaborated in this document. End users can take this classification and request additional information according to their needs.

6. The classification of the Piampaludo Titanium exploration project using UNFC can also be used to demonstrate the evolution of a project's viability over time. Mining should be planned with respect to land and environmental policy and regulatory frameworks. Therefore, the changes in the classification observed in this report emphasize the changing environmental-socio-economic aspects of each decision through time and their resultant impacts on the UNFC classification.

7. The Piampaludo exploration project is located in the Beigua natural regional park, which is Italy's largest protected park. The Beigua Park is intended to conserve the geologic history by safeguarding the natural heritage showcased in the park. The goals of protecting the environmental resources by managing social and economic development are based on the Italian law on protected areas (L. 394/91). The Beigua Park has also been incorporated into Europe's Natura 2000 network, due to the presence of exceptional and rare bird species [6]. The social and environmental impacts linked with the Beigua Park and the Natura 2000 network are major impediments facing the Piampaludo project. These impediments and their implications are explained later in this document.

8. The Piampaludo exploration project is a rich metamorphic-type titanium deposit, which are very attractive to the EU market as indicated by its inclusion in the list as a CRM in 2020 [7]. The titanium of Piampaludo is found as high-grade concentrations of rutile, a titanium dioxide mineral (TiO_2), hosted in large tonnages of the metamorphic ore rock eclogite. The ore grade and tonnage have been corroborated by several series of testing throughout the years, at laboratory scale and in the field. Most of the studies and tests on the Piampaludo ore were carried out by the "*Società Mineraria Italiana*" (Italian Mining Company) and "*Mineraria e Metallurgica di Pertusola*", on eclogite samples extracted from up to a maximum depth of 115 meters by boreholes. Drill hole sampling and in situ samples collection led to an analytical understanding of the mineralogical, petrographical, and chemical characteristics of the ore [17]. Preliminary development of the Piampaludo site was conducted by the previous mine owners "*Mineraria Italiana Srl*" in 1975, and by the current owners CET. The developments included surface trenching, adits, and a shaft. Additionally, academic researchers have carried out geophysical and geochemical studies, and geologic mapping based on core and surface sampling [12]. The technical and geologic information used for this classification are therefore, based on these tests.

Figure I
Critical Raw Materials occurrences in Italy [2]



Note: Based on the European Geological Data Infrastructure (EGDI) database that aims at mapping all mineral deposits in EU. The Titanium occurrence of this case study do not appear on the map, which exemplifies the lack of mineral reporting in Italy.

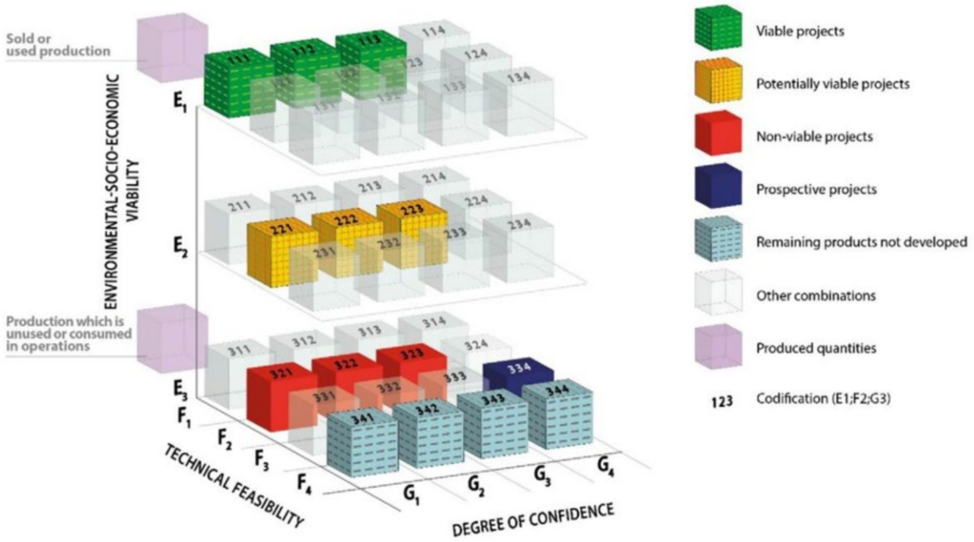
II. The United Nations Framework Classification for Resources

9. UNFC is a global, robust, and project-based classification system built on a structured framework of principles, rules, and guidelines. It is designed to provide the necessary project information relating to policy formulation, resource management functions, corporate business process, and financial capital allocation.

10. The classification of a project in UNFC is based on three fundamental criteria: the environmental-socio-economic viability (E axis), the technical feasibility (F axis), and degree of confidence in the estimate of resource quantity (G axis). These criteria are illustrated in the diagram on the axes (Figure II). Each criterion is assessed and classified individually, until assigned a class. In return, each class for each criterion is subdivided into subclasses, according to the project's maturity. The combination of the three axes creates the Categories and Sub-Categories, which are the building blocks of the classification system.

11. Each Class has a unique description defined by the selection of the relevant combination of the three criteria of a particular Category or Sub-Category. Although the various combinations of E, F, and G Categories and/or Sub-Categories have no explicit constraints, some are more remarkable than the others.

Figure II
UNFC Classification System



12. In this case study, the UNFC concept and specifications for its application adopted pertain to mineral resources. The relevant terms, principles, and definitions are found in the UNFC Minerals Specifications document [8].

13. The classification of Piampaludo using UNFC begins with an investigation of all publicly available information on the deposit including previous studies and tests done in the region on field and in laboratories to understand the geology. Ideally the best information for the classification would be based on the estimates of a qualified person regarding ore grades, quantities (tonnage), and continuity/distribution, with the appropriate quality control and quality assurance methods. These estimates would be supplemented with field sampling and surveying, surface and subsurface, carried by the current project owners, as well as independent researchers. Unfortunately, this information is not available from CET due to the sensitive nature of the site and its resources. This information would provide for better accuracy in the estimates of Piampaludo's titanium ore quantities, the G axis. Instead the document must rely on compilations and reports in the academic literature to provide the information needed for the G axis. In contrast the environmental-socio-economic maturity can be accurately assessed on the basis of the project's current status in terms of permits granted and court decisions. Piampaludo's technical feasibility is evaluated according to the previous developments held on site during earlier exploration.

III. The Piampaludo Exploration Project

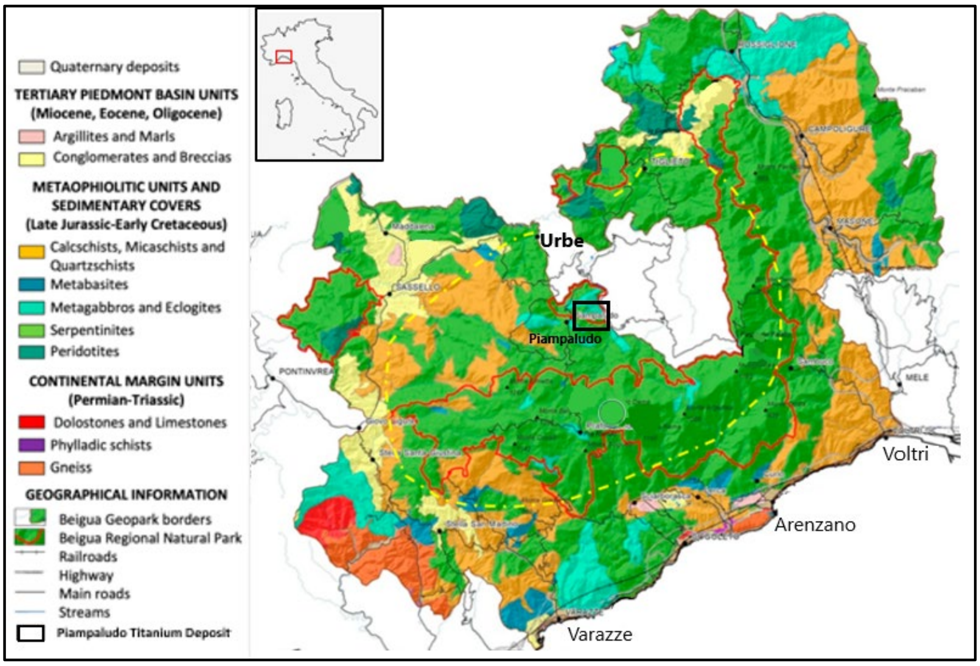
Figure III
Location of the Piampaludo titanium deposit

Note: The image on the left shows the extension of the Piampaludo titanium with respect to the Natural Park, and the image on the right shows the deposit with respect to Monte Tariné and Monte Antenna.

14. The Piampaludo titanium deposit is located in north-east Italy, in between the Urbe and Sassello provinces, in Liguria. The titanium deposit is found between the mountains of Monte Tariné (930m) and Monte Antenna (670m) at approximately 850 metres above sea level [9].

A. Geology of Piampaludo

Figure IV
Geological map of Piampaludo [9] with the park limits outlined in red



15. The extension of Monte Tariné, where the deposit is found, belongs to the Voltri Massif within its south-eastern marginal unit in the Ligurian Alps, referred to as the Voltri-Rossiglione Unit. To be more specific, the Voltri massif is found on the Piedmont-Liguria border (Figure V).

16. The Voltri Massif is a large ophiolitic massif located in the Alpine-Apennine chain, the western Alps. The units of the Voltri Massif underwent metamorphism during the Alpine convergence [22].

17. It is represented by a polyphase deformed and metamorphosed ophiolotic formations with metasedimentary interlayers and slivers of sub-continental lithospheric mantle. The Voltri Massif is subdivided into five distinct units, often referred to as Voltri Group: four of them are composed of meta-ophiolites corresponding to serpentinite, metabasites, metagabbro, calcshist, and minor mica and quartz-schist, and an overlying unit of mantle rocks consisting of lherzolite and harzburgite peridotites, associated with minor dunites and pyroxenites (Table 1) [10]. The Voltri group displays features from the subduction of the Piedmont-Ligurian oceanic lithosphere, in the Alps-Apennine portion of the Tethys, during the Mesozoic era [11]. The oceanic basin underwent intra-oceanic subduction, followed by collision during the early Cretaceous with the European continental crust, which led to emplacement of the Voltri group along the Alpine zone [12].

Figure V

Regional geology: Ligurian – Piemontese geologic units [10]

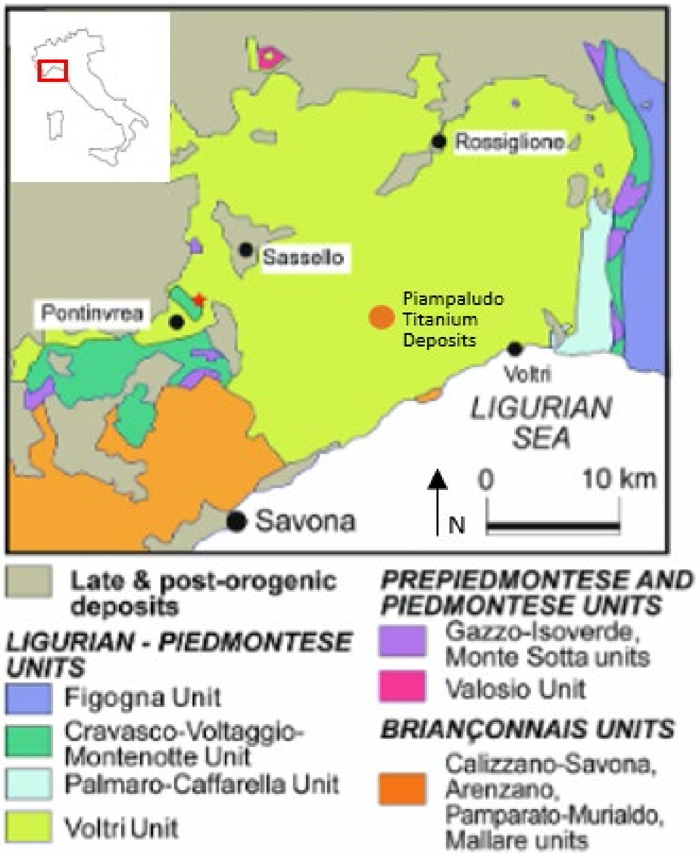


Table 1

Stratigraphy of the Voltri Group

Formation	*Location*	*Geology*	*Structure*
Monte Tobbio Peridotites	Northeastern part of Voltri group	Serpentinized peridotite + lherzolite + harzburgitic bodies + dunite lenses + bands of pyroxenite	Remnant mantle texture, mainly tectonic foliations
Bric del Dente Serpentinites	Dominant lithology of the Voltri group	Serpentinite + serpentine-schist + antigorite, magnetite + chlorite + olivine + diopside + tremolite + ankerite + Ti-clinohumite	Relic texture of the original peridotite. Multiple folds with shear bands
Colma Metagabbros	Southern part of the Voltri group	Leucocratic metagabbro + garnet + Cr-mica + omphacite + glaucophane + albite + tremolite + Mg-chlorite + epidote + traces of white mica + titanite + talc + oxydes	Relic eclogitic paragenesis
Voltri-Rossiglione Metabasites	Southeastern part of the Voltri group	Ca-amphibole + chlorite + albite + epidote + minor Fe-Ti oxides + titanite + talc + biotite + calcite + white mica. Local Na-amphibole + rutile + garnet	Layered or foliated textures of melanocratic and leucocratic facies. Original textures erased by metamorphism and deformation
Turchino Calcschists	Western part of the Voltri group	Micaschist + quartz-micaschist + carbonate schist with quartz + white mica + calcite + chlorite + biotite + pyrite. Local garnet + chloritoid + mica	Re-equilibrated green-schist facies conditions. Different deformational events across all outcrops

18. The stratigraphy containing the titanium deposit of Piampaludo, is part of the Voltri-Rossiglione unit of the Voltri massif. The Voltri-Rossiglione unit was metamorphosed at peak conditions of pressure ranging from 18 to 22 kbar and temperature between about 500-600℃, typical of the eclogite facies. Garnet, omphacite, rutile, Na-amphibole, phengite, clinozoisite were formed in Fe-rich metagabbro during this metamorphism.

19. The titanium ore consists of the rutile concentrated in eclogitic rock masses. The eclogites of Piampaludo are primarily composed of garnet, Ca-, Na-, Fe-, and Al-silicates, rutile, as well as concentrations of pyroxene and glaucophane [13]. The eclogites of the area are erosion resistant with very hard and compact properties [14].

20. According to the mineralogical and chemical analyses of Piampaludo eclogite samples, collected from boreholes at a depth of 41.5 meters, the rutile is in masses several millimetres across, and locally in aggregates in the order of centimeters. Electron microprobe analysis and X-ray diffractometer tests performed on samples demonstrate the titanium content of the aggregates (Tables 2 and 3) [17]. Individual rutile crystals range from 30-40 µm within these aggregates, with a clear metallic luster and vary in color from brown to yellow. Rutile is restricted to the aggregate concentrations, but can form an average of 65% of the aggregates. In some cases, the rutile dimensions tend to be 0.5-3 mm across and display an orientation parallel to the foliation [16].

21. The titanium dioxide concentrations within the eclogites are denoted to have a grade of about 6% TiO_2, with localized enrichments up to twice that. It is also indicated that the total rutile weight in the rock mass is 9 Mt [14][15]. Additional, reports based on field tests and research projects indicate that the rutile concentrations extend over 400 Mt at depths below 500 meters [15]. The orebody is characterized as massive, but highly fractured, with a low schistosity. Geophysical data determined that the orebody dips 20˚ South, as a largely concordant lens [16]. The characteristics of the orebody were determined by preliminary developments carried out by "*Mineraria Italiana Srl*" and "*Compagnia Europea per il Titanio"*, who were both once granted mining concession post 1976. CET managed to carry out surface trenching, adits, and a shaft based on studies from drill holes, geophysics, geochemistry, and geological mapping and presumably have a much greater understanding of the deposit. However, for this case study, the characteristics reported in publicly accessible information are summarized in Table 3.

22. About 30 to 40% of the deposit consists of garnet concentrations (Figure VI) [17]. Results of the X-ray diffractometer analysis performed on the Piampaludo eclogitic ore indicate that the available garnet is frequently iron-rich (more than 66%) and manganese-poor (less than 15%) [17]. Garnet, as a by-product of the rutile, can be used to improve the economic viability of the Piampaludo project, since Fe-garnet, known as Almandine, is considered to be an attractive gemstone in the jewelry industry, or a good abrasive for sandpaper.

Figure VI
Microscopic view of the Piampaludo eclogites (ca. x20) [17]

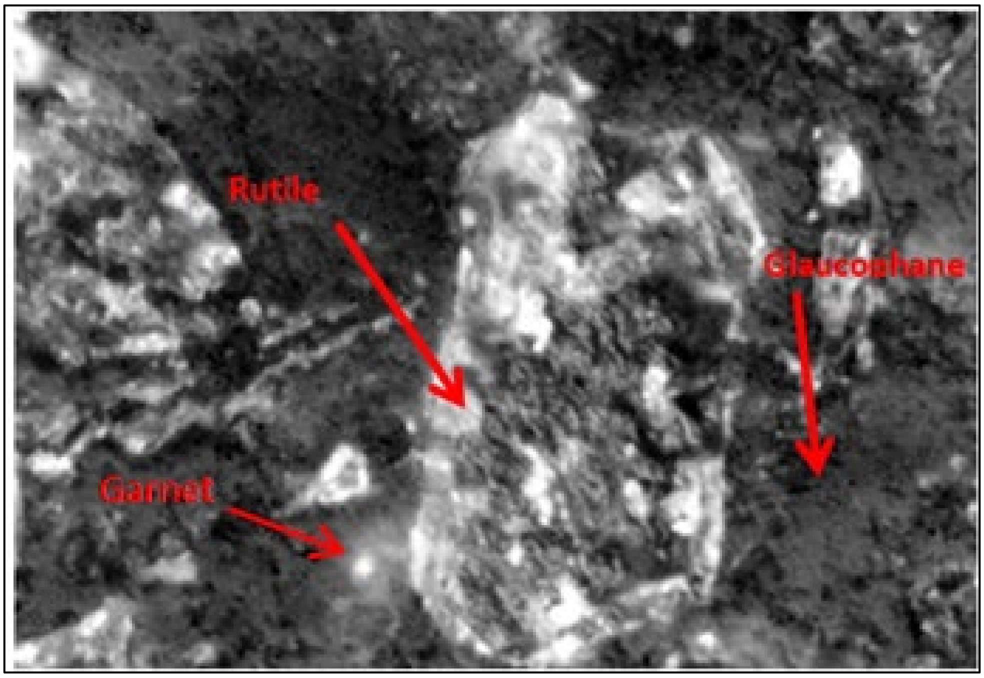


Table 2
Chemical analysis of eclogites from Piampaludo [17]

% Oxides	1	2	3	4	5	6	x	ב
SiO_2	54.48	51.75	52.82	53.89	51.96	53.25	53.03	1.07
TiO_2	0.92	0.88	0.12	0.68	0.76	0.44	0.63	0.30
Al_2O_3	8.51	4.79	11.37	10.64	10.23	11.25	9.46	2.51
FeO	9.19	15.77	10.66	9.47	11.66	10.11	11.14	2.43
MnO	0.04	-	-	0.28	0.21	0.12	0.16	0.10
MgO	6.58	6.60	6.29	5.78	5.34	6.10	6.11	0.49
CaO	10.64	13.12	7.63	8.34	8.62	9.41	9.63	2.00
Na_2O	9.74	5.91	9.98	10.27	11.31	9.18	9.40	1.85
K_2O	0.08	0.07	0.16	0.09	0.09	0.12	0.10	0.03
Total	**100.18**	**98.89**	**99.03**	**99.44**	**100.18**	**99.98**	**99.62**	**0.58**

Table 3
Chemical analysis of rutile in eclogites from Piampaludo [17]

% Oxides	1	2	3	4	5	6	x	ב
SiO_2	0.10	0.18	0.19	0.13	0.18	0.21	0.16	0.04
TiO_2	98.35	98.05	98.51	98.19	98.34	97.80	98.21	0.25
Al_2O_3	0.13	0.11	0.17	0.37	0.10	0.18	0.18	0.10
FeO	0.41	0.22	0.32	0.48	0.41	0.26	0.35	0.10
V_2O_3	-	-	-	0.54	-	0.06	0.07	0.03
MgO	0.05	0.10	0.11	0.04	-	0.06	0.07	0.03
CaO	0..06	0.12	0.08	-	0.11	0.07	0.09	0.03
Na_2O	0.12	0.23	0.17	0.17	-	0.13	0.16	0.04
Total	**99.22**	**99.01**	**99.55**	**99.92**	**99.77**	**99.13**	**99.47**	**0.37**

Table 4
Piampaludo titanium orebody characteristics

Location	Piampaludo, Liguria, Italy
Regional Geology	Voltri Massif
Formation	Voltri-Rossiglione Metabasties
Age	Jurassic to Cretaceous
Overburden	Oligocene clastic sediments
Geologic Setting	Ophiolites and metasediments
Rock type	Eclogites
Physical Features	Massive, very compact, hard rocks
Ore mineral	Rutile (TiO2)
Ore occurrence	Aggregates ~ 0.5-3mm
Ore tonnage	9Mt
Ore grade	~ 6%
Orebody morphology	Large concordant lens
Orebody orientation	20˚Dip to the South
Associated minerals	Garnet, Glaucophane, Titanite, Ilmenite, Serpentine, Talc, Magnetite, Actinolite

B. CET Mining Plan

23. The majority of the exploration and geo-technical development of the property was completed by CET. CET earned the mining concession for the Piampaludo project in 1985. The permit had been transferred to CET from "*Mineraria Italiana Srl*", who earned the initial concession to mine the Piampaludo Titanium in 1976, from the Ministry of Industry of Italy. CET is a very small company with a share capital of only 10,400 euros, without historic mining experience and know-how in the sector, represented and hosted by an accounting firm in Cuneo, Italy.

24. CET conducted preliminary feasibility studies during the permitted period, leading to the development of a comprehensive mining plan. The prefeasibility study was supported by surface preliminary developments, such as adits, trenches, and a shaft. Additionally, CET, completed drilling with coring and collected samples from a maximum depth of 115m, performed during a sampling survey carried out by "*Società Mineraria Italiana*", supported the technical and geologic investigations for the development of a preliminary mining plan. However, it is necessary to note that no information regarding the drilling spacing and density was disclosed by CET [17].

25. The geology of Piampaludo was mapped during the investigation phase. Both geophysical and chemical analyses were applied concurrent with CET's preliminary development, which served to accumulate a considerable dataset of information. An initial mineralogical examination of the eclogitic ore revealed notable assemblages of rutile associated with minor Mg-Fe garnets, and other minerals. The rutile was found to be as pure as 99 wt % TiO_2. The initial developments conducted by CET included the construction of a pilot shaft [16].

26. A comprehensive mining plan was developed by CET for the recovery of rutile, with garnet as a secondary product. The plan included detailed information on production, mine lifecycle, transportation, market, and waste management (Table 2). According to CET's mining plan available online, the mining activity would be in open pit with a lifespan of 90 years and a production rate of 10,000 t/d of ore, equating to 163, 240 t/y of rutile produced, down to a depth of up to 500 m [16]. Mining wastes composed largely of garnet were foreseen to be conveyed 3 km by gravity flow tunnels towards the coast of Liguria, at a maximum flowrate of 9,400 t/d [16].

Table 5
CET mining plan proposal for the Piampaludo project

CET Proposed Mining Plan as part of the Piampaludo Prospect Project	
Type of Mining	Surface
Mining Method	Open Pit
Mining Technique	Drill & Blast
Surface Area	90 Hectares
Maximum Pit Slope	60 °
Operating Days per Year	265
Operating Shifts per Day	2 shifts of 8 hours each
Production	10,000 t/d
Production Unit Cost	1.37 $/t ore[a]
Waste Rock	48.4 %
Ore Mining Features	
Ore Hardness	Hard Rocks (Eclogites)
Length	~ 1,800 m
Width	500 m
Thickness	300 m
Wall-Rock Alteration	None
Ore Control	Fracturing
Latest Ore Record	1991

[a] Subject to conversion into today's market price.

C. Social and environmental contingencies facing Piampaludo

27. While the Piampaludo project appears to be economic, it has not been exploited since its discovery. Currently, the titanium ore is located in a Natural Preserve region, which has caused the project to be hindered by social and environmental challenges.

28. All mining operations relating to the Piampaludo project, including exploration, ceased when titanium occurrence was included in the Beigua Natural Park, in 1995.

29. The Beigua Natural Park is the largest protected park in Italy [18]. Various features in the park have warranted the protected status, and has an outstanding geologic heritage, from outcrop features to the preserved fossils. The Beigua GeoPark is mandated to conserve the geology and to safeguard the natural heritage. The mission aims to protect environmental resources by managing social and economic development, according to the Italian law on protected areas "*Legge quadro sulle aree protette*" (L. 394/91).

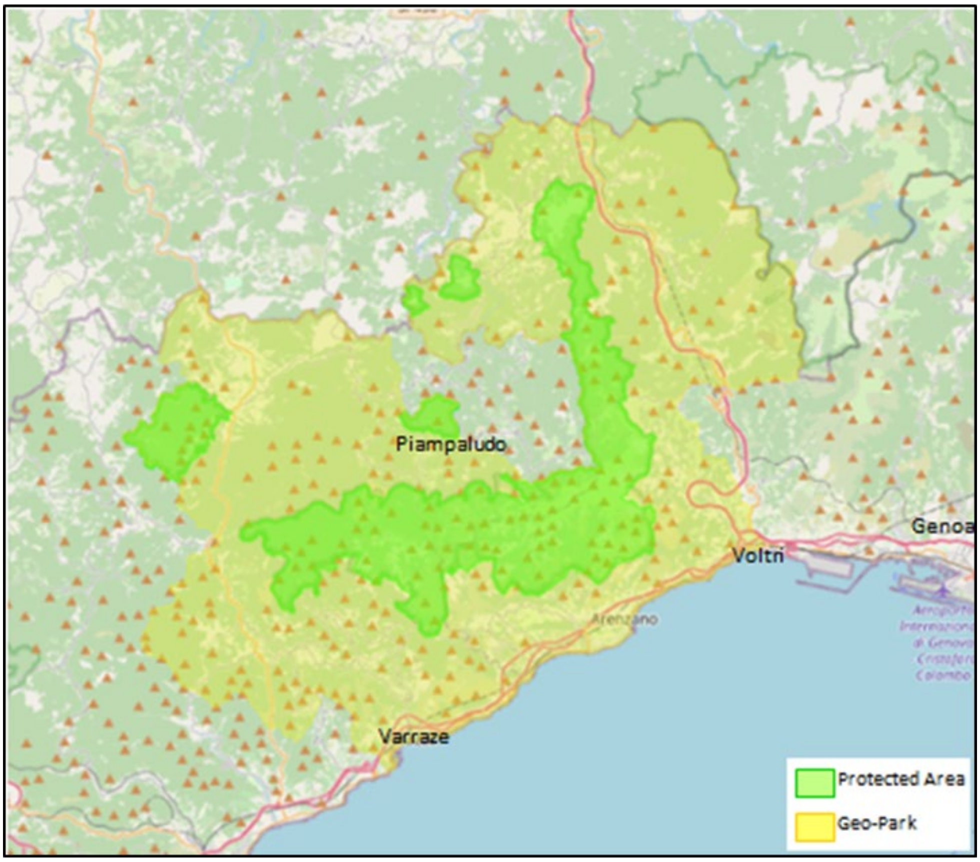
30. The Beigua Geopark has been included in the Europe's Natura 2000 network, to protect rare bird species hosted in the park [18]. The Beigua Natural Park includes a wide range of fauna and flora, with 26 different types of ecosystems. There are considerable wetlands at the park that exhibit significant environmental settings for many organisms of natural value. Both, geo- and bio- diversity observed at the Beigua Natural Park are focal points for social and environmental concerns to preserve these natural settings. These are supported by the touristic and historic values of the Park, with geotourism museums and Roman archaeological artefacts.

31. Politically, the Ligurian region supports the social and environmental protection of the area, with additional support from neighbouring municipalities and environmental activists. These groups are opposed to any mining operations within the borders of the Beigua Park the Natura 2000 borders of the region (Figure VII).

32. As a consequence, the efforts to protect the area have forced operations in Piampaludo to cease. Several legal actions have been initiated by stakeholders opposing mining companies interested in this deposit [19].

33. According to the European Commission (EC), mineral exploration is permissible in Natura 2000 sites, under the condition that the resiliency of ecosystems and the integrity of the entire site are not severely disturbed. The conditions required to build a mine could be met by comprehensive short- and long- term strategic planning for the operation, requiring the inclusion and consent of stakeholders to avoid future issues. This would allow the operation to remain consistent with sustainable development principles and policies [20].

Figure VII
The Beigua Geo-Park [21]



IV. UNFC Classification of the Piampaludo Project

A. G3+G4 classification on the G Axis, the Degree of Confidence

34. The titanium ore in Piampaludo has been a subject of interest for many researchers, scholars, and mining companies for years. CET considers that sufficient studies and tests have been completed to support the regional geology, as well as the titanium volume and recovery, supported by the thorough analyses done over the years [12] [17]. In addition to the tests conducted for scientific purposes, the site was a subject of prospecting tests to supplement the detailed exploration evaluations. However, no information on the testing results and reporting have been publicly disclosed. It is important to note that these estimates are on studies conducted between 1979 and 1998, leaving most of the scientific geological information inaccessible to the public, yet the technical data on the Piampaludo titanium ore are not.

35. According to UNFC-2019, product quantities of prospecting projects are classified as G4. The Piampaludo titanium ore quantities from the publicly available data are assessed with confident estimates from laboratory analyses and field observations and developments, which allowed the estimations to be at moderate to low levels of confidence. Another factor that supports this statement is the continuous pursuit for mining by CET, over the years. With that said, the titanium ore has moderate probability to equate the estimated quantities.

36. According to the results of the X-ray diffractometer analysis performed on the Piampaludo eclogites, garnet is strongly present, mainly as iron-rich garnet [17]. In addition, various sources available online state that garnet could be a viable by-product of the rutile extraction [19]. However, given the inferred quantities, the garnets are presumed to present less economic importance compared to those of the titanium. The garnet quantities are estimated with less certainty because of the fewer available information, rendering the confidence in the estimates to low degrees. It is necessary to mention, for the accuracy and

reliability of the assessment, that these estimates are based on data lastly updated in 1991, which makes them historic results and should be valued with lower certainty today.

37. Thus, for the purpose of assessment quality, a conservative approach was followed to classify the Piampaludo project as G3+G4 on the degree of confidence, the G axis.

B. E3.2 classification on the E Axis, the Environmental-Socio-Economic Viability

38. The Piampaludo Project currently has exploration permit, which was granted to CET by the Regional Council of Liguria in 2021. Table 6 demonstrates the paucity of information available to classify this project and the main social and environmental impediments tied to it. Table 7 presents the chronological events related to the Piampaludo exploration project from discovery to now.

39. The Piampaludo Project began with a 20-year mining concession and was approved for Mineraria Italiana Srl to recover titanium in 1976. The concession was transferred to the current owners CET in 1985. Since 1991, CET has been requesting for an extension of 20 years for the mining license from the Ministry of Industry in Italy, yet the social and environmental concerns have delayed the procedure. The Piampaludo area was protected by various regulations. Concurrently the Ligurian Regional Law “n.12/95” structured and supported protective functions over the land included in the Beigua Park, and an area that included approximately 50% of the Piampaludo ore field. For over 35 years, the land has been an environmentally protected area for its nature and ecosystem and exploration has been prevented [17].

40. Legal disputes continued in the fall of 2014 when CET applied for a new exploration permit for the Piampaludo titanium, garnet and associated minerals. In 2021, the project was approved for exploration rights on the half of the resource area (around 229 ha in surface area) which is not included within the Beigua Park domain, under act n. 1211 of 02/26/2021. CET maintains complete exclusivity for exploration in this area. Additionally, this permit allows CET to develop preliminary studies and tests on the designated half, with the intention of evaluating the areal and surface distribution, and to confirm and re-evaluate the rutile concentrations.

41. An exploration permit was granted until 31/12/2023 [19]. CET’s planned investigation and studies do not intend to alter the natural state of the field, as was highlighted in the court appeal. The exploration strategy is to use approaches with minimal negative environmental impacts and landscape disturbance; Sampling shall be carried out on foot, as well as the geological and structural surveys and mapping, using the existing trails [19]. CET is likely to undertake EIA and SEA to identify and mitigate environmental concerns, and to solidify their case for future recovery.

42. From the economic side, Piampaludo’s titanium deposit certainly exhibits great economical potential, given the measured ore-grade and tonnage. The Piampaludo Project has been estimated to generate approximately 500 M€ in royalties for the region of Liguria, with the deposit valued between 400 and 600 B€. In 2021, the price of rutile per ton was worth a bit over 2000 euros [18]. With this price, and the given rutile grades at Piampaludo, the deposit is estimated to be valued at minimum 120 B€ [18]. Although titanium deposits with these grades and tonnages could be cost-effective, conventional mining is not expected to be accepted from the environmental and societal point of view, therefore other methods need to be considered with the appropriate environmental measures, which makes the operations more costly.

43. At present, the development of the project is not assured to be environmentally-socially-economically viable based on the limited available information. Given both the continuous opposition facing the project and the recent permit given to CET, it is too early to determine the environmental-socio-economic viability of the project. Accordingly, in order to be more conservative with the classification and respecting the lowest rank prevails rule, the project is classified as E3.2 on the E axis.

Table 6
Piampaludo project social and environmental impediments

Environmental factors	
Project located in a restricted area	- Natural protected area - Beigua Natural Geo-park and Natura2000
Flora and fauna to be protected	26 different ecosystems -Fauna • Buzzard (*Buteo buteo*) • Biancone (*French Circaetus*) • Falco pecchiaiolo (*Pernis apivorus*) • Ferro di cavallo maggiore (*Rhinolophus ferrumequinum*) • Bechstein's bat (*Myotis bechsteinii*) -Flora • Elleborine palustre (*Epipactis palustris*)
Available critical ecological land-use planning	Maybe, but not publicly disclosed
Critical land use	Not available
Social variables	
Presence of indigenous communities	No
Within indigenous region	No
Social land ownership	Not available
Presence of marginalization as per the marginalization index	No
Project interference with an economic activity	Tourism at the park
Water concern	Not available
Legal variables	
Legal status of the project	CET currently holds exploration grant on 229 hectares of land
Available environmental approvals and permits	No EIA nor any environmental permits are yet presented
Social assessments presented - Social Impact Assessment?	Social Impact Assessment not carried out, yet local and neighbouring communities are strongly against the project

Table 7
Permitting timeline of the Piampaludo project with respect to the E axis

Period	*Event*	*E axis Category*
1976	Mineraria Italiana Srl granted mining concession	E1.3
1985	Mining concession transferred to CET	E1.3
1991	CET request 20 years concession renewal from the Ministry of Industry, no answer to date	E2
1995	Area included in the Beigua Park any mining or related activity was interrupted	E3.3
2014	Court objects to CET's request to obtain new mining research permit	E3.3
2015	Court objects to CET's appeal for the annulment of the inadmissibility of the application relating to the mining research activity	E3.3
2015	Court rejects CET's request to activate the procedure for the EIA for geological surveys	E3.3
2020	Court rejects CET's plea to challenge court's decision, entrusting the recourse to Violation and/or False Application of Law	E3.3
2021	Regional Council of Liguria confers in favor of CET, granting the research permit on the mainland of solid minerals (Titanium, garnet and associated minerals) for 3 years	E3.2

C. F2.2 Classification on the F Aaxis, the Technical Feasibility

44. The technical feasibility for the Piampaludo project can be deduced from the preliminary plan proposed by CET (Table 2), with the support of tests done for research purposes [14][17][18]. These studies represent a starting point that can be used by CET, given their newly acquired exploration right. Granted that the Piampaludo project is still an exploration project, the prefeasibility planning indicates potential development, yet it provides insufficient information on the probability for progression in developments while upholding a clear resource definition, therefore, further data acquisition is needed to evaluate the feasibility of development.

45. At present, activities for the advancement in technical development at Piampaludo are still pending due to the ongoing environmental and social impediments tied to the project. This reluctance to initiate activities may result in significant delays for development. The technical feasibility for this project is yet at preliminary stages, despite the promising indications. More detailed data are needed to confirm the feasibility of future developments.

46. To this point, CET's preliminary developments include a shaft and adits. According to CET these developments have provided sufficient data on the titanium ore to confirm that it should be considered a promising prospect. Given the prospective economic benefits of the ore, one can comprehend the stakeholder's willingness to increase investment to ensure that the Piampaludo project has more potential.

47. CET proposes relatively high production rates in their mining plan (approximately 163,000 t/y), with a mine life of 90 years. To accomplish this rate, it is clear that the most viable excavation method suitable for the Piampaludo project would be open-pit mining. However, with Piampaludo's current circumstances, this mining method would not comply with the site's laws.

48. Thus, the Piampaludo Titanium project has been given a conservative classification for the technical feasibility, F2.2 on the F axis.

V. Conclusion and Challenges

49. According to the United States Geological Survey (USGS), Piampaludo's titanium deposit, located in Liguria, Italy, is one of the largest eclogite-hosted deposits in Europe, and of possible significant economic importance in the near future (Figure VIII) [23]. The project demonstrates the potential for a substantial and long-lived production. Based on the estimated ore grades and tonnage of the Piampaludo titanium deposit, it has the ability to eliminate the titanium supply risks in Italy and across Europe (Table 5) [23].

50. However, social and environmental concerns have forced the Piampaludo project into a hiatus and not progress. The opposing associations, municipality, and neighbouring communities have a fundamental opposition to mining in Piampaludo, based on the elevated risks associated with disturbing the natural landscapes and ecosystems of the park.

51. The Piampaludo project was classified according to UNFC to highlight the contingencies linked to it. This report demonstrates the application of UNFC to an exploration project using public information. UNFC addressed all issues related to the Piampaludo titanium deposit. UNFC is a resource classification tool that gives stakeholders information on the project's maturity.

52. The Piampaludo classification as an E3.2F2.2G3+G4 project according to UNFC provides an evaluation of titanium quantities and the project maturity status based on the available public information. With reference to UNFC-2019, the given classification category renders the Piampaludo project under the "Non-Viable Projects" class, and the "Development Unclarified" sub-class (Figure IX). The assessed sustainable aspects tied to the Piampaludo project are determined with respect to the permits granted by the Ligurian municipality to CET.

53. The information provided in this document infer that garnet could be produced as a potential by-product to titanium from the Piampaludo project. In line with the UNFC, by-products are to be classified separately, meaning that other considerations should be taken into account in terms of value addition, processing methods, and environmental impact. However, the Piampaludo titanium project is currently classified as non-viable, making the classification of garnet as a by-product irrelevant. In the event where titanium production becomes viable, then garnet is required to be classified separately using UNFC.

54. UNFC is a principles-based system, meaning that the end user is required to incorporate these principles even in the circumstances of less than ideal information. A more fulsome UNFC classification process would require more complete information from the industry's exploration activities, which have not been not made public for this classification. However, despite these limitations, the information used in this case study can define a classification sufficient for the mineral inventory of the Liguria region. This case study of the classification of the Piampaludo Project using UNFC is also intended as educational material for the application of UNFC.

Figure VIII
European titanium mineral deposits [23]

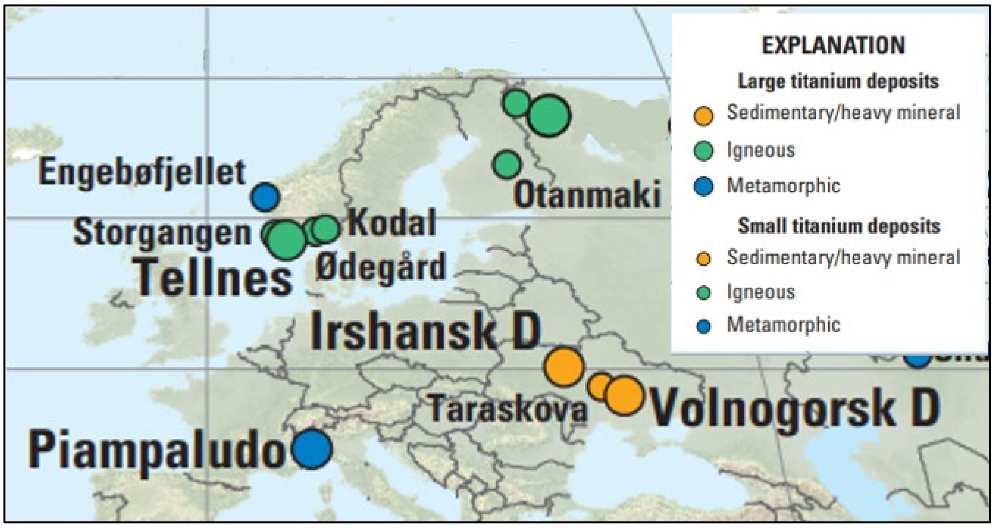
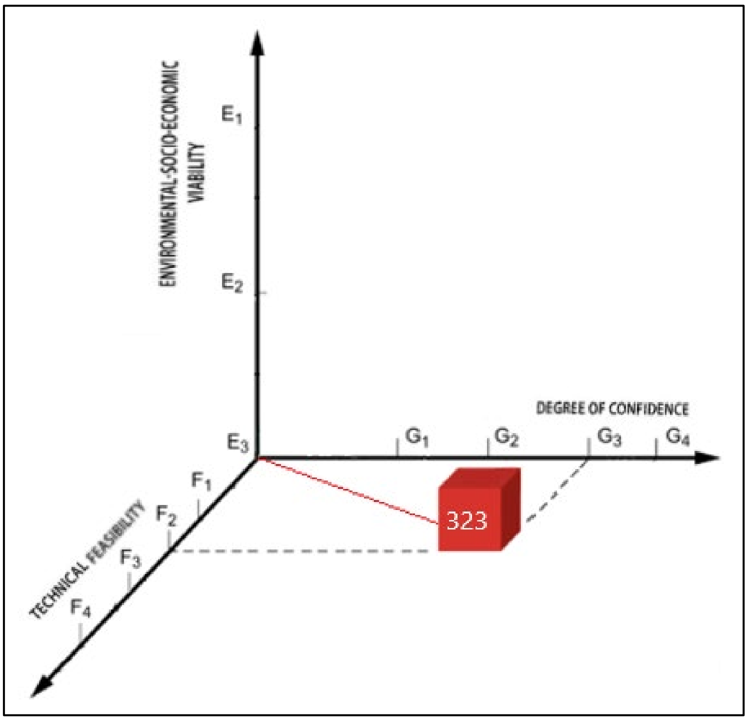


Table 8
Titanium mineral resources of Europe for ilmenite and rutile [23]

Country	*Deposit type*	*Deposit class*	*Contained TiO_2 by primary ore mineral (million Mt)*	
			Rutile	*Ilmenite/ titanomagnite*
Italy[a]	Rutile in eclogite	Metamorphic	9	-
Norway	Gabbro/anorthosite	Igneous	-	238
Norway	Rutile in metamorphic/ metasomatic rocks	Metamorphic	61	-
Ukraine	Heavy-mineral sands	Sedimentary	0.5	~14

[a] Pertaining solely to Piampaludo titanium deposit.

Figure IX
3D representation of the UNFC classification for the Piampaludo Project



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Appendix C - Applying the United Nations Framework Classification for Resources for a National Raw Materials Inventory in Italy

Mineral Economics
https://doi.org/10.1007/s13563-025-00552-4

ORIGINAL PAPER

Applying the United Nations Framework Classification for Resources for a national raw materials inventory in Italy

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Received: 23 July 2025 / Accepted: 16 September 2025

Abstract

The increasing demand for critical raw materials (CRMs) driven by the green and digital transitions calls for the implementation of a robust resource management framework across Europe. Similarly to other EU Member States, Italy faces challenges in managing the inventory of its mineral resources, stemming mainly from in-homogeneous and discontinued data collection, in the absence of a specific classification and reporting system adopted at national level. The implementation of a coherent and centralized data collection and classification system could help improve the currently fragmented regional reporting practices, in turn supporting Italy to contribute to the objectives of the EU Critical Raw Materials Act (CRMA). Resource classification is important to resource management, serving as one of the foundations for collecting, analyzing, and communicating data on resources, presenting data into information for decision-making and policy formulation. The United Nations Framework Classifications for Resources (UNFC) offers a standardized approach that bridges current gaps in classification, and reporting practices. This paper pursues the objectives of assessing the applicability of UNFC in Italy using publicly available data. Besides demonstrating the applicability of UNFC in Italy, the findings support a shift towards standardized, policy-relevant resource classification for a sustainable and transparent resource management system, by classifying the raw materials projects in UNFC, and furthermore the development of a UNFC-based Italian national raw materials inventory.

Keywords Resource classification · UNFC · Critical raw materials · Raw materials inventories

Introduction

The European Union (EU) is navigating an era of unprecedented challenges. The quest to deliver on the objectives set by the Green Deal and the Digital Transition, as well as the Paris Agreement and the United Nations 2030 Agenda for Sustainable Development, fundamentally depends on a sustainable and secured supply of raw materials, especially Critical Raw Materials (CRMs). CRMs are the building blocks for strategic sectors, such as green technologies, digital infrastructure, defense applications (European Commission 2024). This transition to a low-carbon economy is projected to increase the demand for CRMs (IEA 2025), though the scale of growth for a range of raw materials remains highly uncertain and varies across different scenarios (Naegler, et al. 2025). However, known reserves and resources of these materials represent only a small fraction of the quantities projected to be needed in the coming decades (IEA 2021). Meeting this demand will rely heavily on intensified exploration and research, which in turn require substantial investments, cutting-edge geoscientific capabilities, and robust industry-academia collaboration. The discovery of new ore deposits, particularly those with complex geology and processing challenges, will depend on coordinated research efforts that integrate advanced mineral systems understanding with the development of more

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Published online: 23 October 2025

efficient and environmentally sound extraction technologies (Marlatt 2020).

As demand for CRMs grows, the EU's ability to ensure long-term supply security hinges not only on diversification of importing countries and international partnerships but also on improving domestic capacity, both based on sustainable resource management practices. At the heart of such practices lies an important enabler: *resource classification*. Sustainable resource management requires consistent, coherent, and transparent information on the availability, recoverability, and viability of natural resources (UNECE 2020). It is through classification that raw material data become actionable information, potentially guiding decision-making across exploration, investment, permitting, and policy development. The role of classification is particularly pronounced in Europe, where multiple national systems and international codes exist. EU Member States rely on a variety of systems, including codes from the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) (e.g., JORC, PERC, NI 43–101), the United Nations Framework Classification for Resources (UNFC), legacy systems such as the Russian GKZ classification, and classification systems that are unique and only used within a certain jurisdiction (e.g., Austria or Czech Republic). This multiplicity complicates the interoperability of raw materials data across jurisdictions and hampers efforts to build a unified EU-wide resource intelligence base (Bide 2018). Since the EU Critical Raw Materials Act (CRMA) came into force in 2024, the need to harmonize national inventories and align them with European strategic goals has become increasingly urgent (European Commission 2024).

Italy, one of the largest manufacturing economies in the EU, with several CRMs-reliant industrial sectors e.g., automotive), is in the process of aligning with resource management practices. Its raw material governance landscape is fragmented, as the mining legislations mainly exist at regional levels (Grandi 2019). Moreover, classification and reporting systems vary across regions and provinces, data is often confidential or inaccessible, and there is no national-level framework for consistent classification or public reporting of mineral projects. These are the main bottlenecks to be tackled in order to boost Italy's capacity to assess domestic supply opportunities and meaningfully contribute to the EU's raw materials agenda.

The speed at which demand is accelerating may exceed the mining sector's ability to respond under conventional market conditions. This could necessitate interim policies such as the development of less economically attractive deposits under national or private-public ownership models, to ensure security of supply during this transitional period. Therefore, it is beneficial for authorities to establish a raw materials inventory of sources and products, with reliable and relevant information for decision-makers, to better evaluate such priorities (UNECE 2022). Italy's raw material potential must therefore be approached with a long-term strategy, anchored not only in geology, but also in governance and sustainability. As illustrated in Fig. 1, nonfuel minerals, CRMs for instance, contribute a large portion to the Italian economy, and is assumed to grow even larger in the upcoming years.

This paper aims to demonstrate the adoption of UNFC in Italy and show that such an adoption is both feasible and practical to manage. UNFC offers the possibility of integrating environmental-socio-economic viability (E axis), technical feasibility (F axis), and geological confidence (G axis) into classification, thereby addressing sustainability and policy concerns that are not solely on purely market- or commodity-driven systems (UNECE 2020; Wittenberg et al. 2024).

The specific objectives of this paper are:

1. Analyze the current state of raw materials classification, data availability, and collation of primary raw materials information in Italy, while highlighting challenges in terms of consistency, transparency, and policy integration;
2. Test the applicability of a UNFC in Italy on primary raw materials with data from different sources, harvested from (i) industry reporting, (ii) historic data, and (iii) extrapolated geological occurrences deduced from publicly available data and research and academic reports. The collected data ultimately contributed to a preliminary UNFC-based Italian raw materials inventory built from available sources.

The results are then used to discuss CRMs management in the context of CRMA, particularly by highlighting the importance of classifying and communicating domestic raw materials data in a consistent and policy-relevant manner. The paper aims to lay the groundwork and test how a harmonized national inventory of raw materials can contribute to the EU's collective strategic autonomy, sustainability, and resilience goals. Moreover, this study lies in its pioneering application of UNFC within the Italian context.

Critical raw materials policy landscape in Europe and Italy

UNFC in the EU critical raw materials act

CRMA is the EU's regulation to enhance EU's CRMs value chains and reduce dependencies on imports, especially from single third countries. Recent global crises

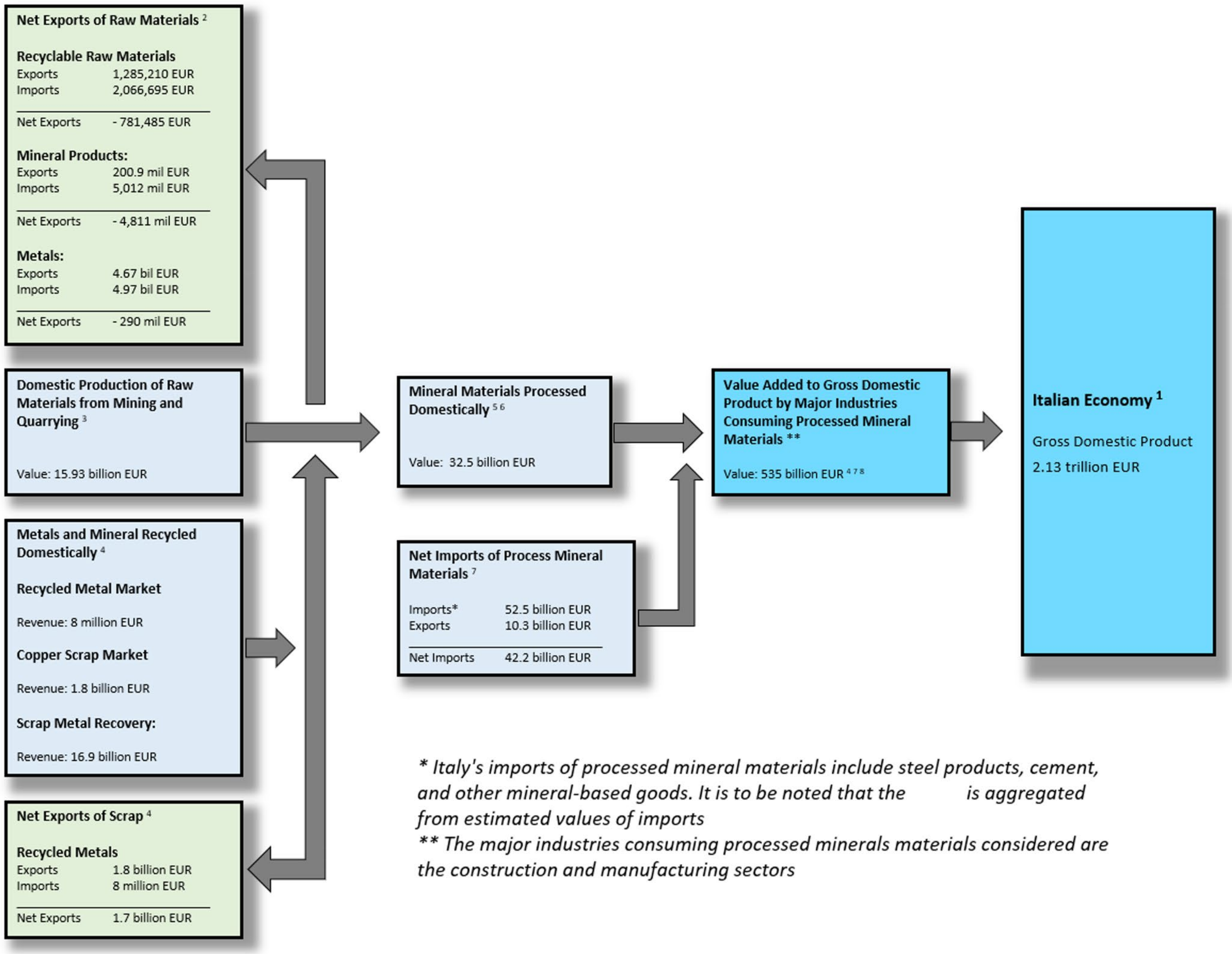

Fig. 1 The role of nonfuel minerals in the Italian economy, estimated values in 2023. 1USGS (2021) Methodology adopted and revised from the U.S. Geological Survey and U.S. Department of Commerce, Mineral commodity summaries 2021: U.S. Geological Survey, Figure 1. p.4, https://doi.org/10.3133/mcs2021. Reuters. (2024). Italy revises down 2023 GDP growth, budget deficit, debt. 2. Reuters. https://www.reuters.com/markets/europe/italy-revises-down-2023-gdp-growth-budget-deficit-debt-2024-09-23/. 3. Italian National Institute of Statistics (ISTAT) (2025). Mining and quarrying sector data. Esploradati. https://esploradati.istat.it/databrowser/#/en/dw/categories/IT1,Z0920ENV,1.0/DCCV_CAVE_MIN/IT1,9_951_DF_DCCV_CAVE_MIN_2,1.0. 4. Trading Economics (2025). Italy exports of non-metallic mineral processed products. https://tradingeconomics.com/italy/exports-of-non-metallic-mineral-processed-products. 5. GMK Center (2024). Italy imported 7.2 million tons of steel from third countries in 2023. https://gmk.center/en/news/italy-imported-7-2-million-tons-of-steel-from-third-countries-in-2023/. 6. Marmomacchine International (2024). Nel 2023 lieve flessione per l'export italiano di pietre naturali [Slight decline in Italian natural stone exports in 2023]. https://www.marmomacchineinternational.com/en/nel-2023-lieve-flessione-per-lexport-italiano-di-pietre-naturali/. 7. Statista (2025). Imports and exports of stone and mineral construction materials in Italy. https://www.statista.com/statistics/1417949/imports-and-exports-of-stone-and-mineral-construction-materials-italy/. 8 . Eurostat. (2025). Structural business statistics overview – Mining and quarrying. https://ec.europa.eu/eurostat/databrowser/view/sbs_sc_ovw/default/table?lang=en

have underscored Europe's vulnerability and the need for joint, timely action to protect the single market, support competitiveness, and secure the materials essential for achieving climate and digital transitions (European Union 2025). CRMA seeks to ensure the EU has strong, resilient, and sustainable CRM value chains by enhancing domestic capacities across extraction, processing, and recycling, diversifying sources of supply, and improving monitoring of risks and disruptions. To further these goals, CRMA sets specific benchmarks for Strategic Raw Materials (a subset of CRMs): at least 10% of annual EU consumption should come from domestic extraction, 40% from domestic processing, and 25% from recycling, with no more than 65% of any CRM supplied by a single third country. Alongside the Net Zero Industry Act, CRMA is also a pillar of the EU's Green Deal Industrial Plan (European Commission 2024).

A distinctive feature of CRMA is the integration of UNFC as the tool for resource classification and reporting across the EU and beyond (in the case of Strategic Projects). UNFC offers a unified language for Member States to report in, while evaluating the sustainability, technical feasibility, and geological aspects of projects across the CRM value chain. UNFC is referenced under four articles in CRMA. First, it is mandated for use by Member States to report the results of their National Exploration Programmes (NEPs). Second, UNFC is to be applied for risk monitoring and stress testing on producing CRMs projects in EU. Third, UNFC is required for the classification of extractive waste from closed facilities, when applicable. Lastly, project promoters applying for Strategic Projects are required to classify their projects using UNFC. Moreover, the first call for Strategic Projects under CRMA received 157 projects in EU and in third countries, all classified in UNFC (European Commission 2025). UNFC supported in the technical assessment phase of these Strategic Projects proposals, in evaluating economic viability, technical feasibility, environmental and social aspects, and project readiness (European Commission 2024).

On the other hand, UNFC also supports the monitoring of project development over time. To this end, it supports CRMA objectives by making it possible to compare projects across different stages (from exploration to recycling), to assess sustainability, and to translate diverse reporting systems into a common format, without imposing additional burdens on users (Grohol 2024).

Collection of raw materials data in Italy

In the EU and elsewhere, a persistent obstacle to effective resource management is the issue of data confidentiality and inaccessibility. Reliable and consistent data acquisition is a fundamental element for national authorities to monitor and support sustainable resource management. Statutory reporting of raw materials, including resource and reserve estimations, exploration activities, and production, is an essential step to minimize geological information losses and to prevent non-active license holdings that delay development (European Commission 2024; Grandi 2019). Additionally, publicly listed companies are required to disclose exploration and production data to investors under international stock exchange rules (if listed). More recently, the increased emphasis on ESG (Environmental, Social and Governance) performance and sustainable finance has intensified demands for greater transparency in raw materials reporting. This aligns with societal expectations for shared value, social responsibility, and environmental stewardship between governments, local communities, and private sector actors in the extractive industries. Furthermore, global capital allocators increasingly demand ESG-aligned disclosure, influencing the availability of finance for exploration and mining projects (World Bank 2021).

Within Italy, the landscape of raw materials data collection and reporting is marked by institutional decentralization and regulatory heterogeneity. Responsibilities for primary raw materials management lie primarily with regional governments, reflecting the devolution of administrative functions set out in the Republic President's Decree of 24 July 1977, n.616 (articles 61 and 62) and the Legislative Decree of 31 March 1998, n.112 (articles 33–35). Under these provisions, regional authorities are entrusted with the governance of mineral and thermal waters, as well as quarries and peatlands. Moreover, regions may delegate specific responsibilities for exploration, evaluation, and development to provinces and municipalities, resulting in a patchwork of local governance arrangements. Raw materials data, especially for industrial and metallic minerals, is collected annually at the regional level through varying methodologies defined by local legislative frameworks. The data is stored and managed using diverse formats depending on the region (Parker 2015). Notably, the raw materials databases are not INSPIRE-compliant and rarely available in multilingual formats (Grandi 2019). Although the Instituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA), to which the geological survey of Italy is part of, maintains statistical datasets, such as the *Environmental Data Yearbook*, and a historical database of extraction activities from 1860 to 2007, national-level harmonization remains a significant challenge. The *Mining Map of Italy* (1:1,000,000 scale), produced in 1973, and more recent regional maps (e.g., Tuscany, Sardinia) provide valuable spatial data, but a consistent, up-to-date national mining cadaster is lacking (Servizio Geologico d'Italia 1973; ISPRA 2012). It is to be noted that, in light of the CRMA provisions on upscaling national exploration activities, ISPRA is implementing the new National Exploration Programme (Piano Esplorazione Nazionale), which aims to harvest and add up of further data on CRMs in Italy (ISPRA 2025). Complementary economic and financial data is gathered by ISTAT (Italian National Institute of Statistics) (Parker 2015).

Currently, there is no unified national standard or internationally recognized classification system used systematically across Italian regions for resource and reserve reporting. As such, raw materials information in Italy remains fragmented, with varied terminology, inconsistent collection intervals, and non-harmonized formats (Grandi 2019). Exploration companies are legally required to report resource and reserve data to the respective regional authorities, and most regions have implemented Regional Plans for Extractive Activities (PRAE), which aim to manage the full extraction lifecycle, from site identification through extraction to post-closure remediation, while balancing natural resource use and environmental protection. However, the PRAE implementation and legislative underpinning differ significantly between regions (Grandi 2019). On another note, ISPRA, in collaboration with ISTAT and under the guidance of the Ministry of Industry and Made in Italy (MIMIT), is working on a national harmonized census of mining activities (Fumanti 2023). The objective is to standardize data collection from quarries and mines based on international reporting codes such as the UNFC or CRIRSCO-aligned standards (Grandi 2019). This initiative acknowledges the urgent need to integrate national raw materials data into broader European and international classification and reporting systems, especially in light of CRMA (European Commission 2024). The roles and responsibilities related to raw materials data collection and management in Italy are summarized in Fig. 2.

Implementation measures for CRMA in Italy

In response to CRMA and EU Regulation 2024/1252, Italy has taken a legislative step by adopting Decree-Law No. 84 (D.L. 84/2024) of 25 June 2024. This urgent legislative measure seeks to strengthen national capacities for ensuring the secure and sustainable supply of CRMs of strategic interest, while aligning Italy's domestic framework with European objectives.

The decree, composed of 17 articles, includes a comprehensive national strategy across the CRM value chain, from exploration and extraction to processing, investment, export control, and governance. In essence, D.L. 84/2024 would serve as a blueprint for Italy's national CRM strategy, bridging the policy gap between EU expectations and national capacities. The provisions on CRMs of strategic interest and their relevant implications, as well as whether they pertain to UNFC are summarized in the Table 1 (Senato della Repubblica 2024).

Methodology

UNFC application

Resource classification is defined as a structured process for assigning potentially recoverable resources to appropriate categories based on their environmental, social, economic viability and technical feasibility. It involves a sequence of steps starting with information collection, quality assurance, evaluation, classification, and lastly reporting. These steps are aimed at supporting resource development under conditions of uncertainty (Speirs et al. 2015; McKelvey 1972). While a perfect classification system would offer error-free assessments, the inherent geological complexity and

ISRPA / ISTAT	Arranging Harmonized mining census across Italy based on international standard codes, in collaboration with MIMIT
Ministry of Industry and Made in Italy (MIMIT)	Supports regional policies for raw materials exploitation; collaboration on defining minerals in line with EU policies
Exploration Companies	Reports resource and reserve data for regional territories, required by statutory obligation
ISTAT	Gathers economic, financial, and statistical mining data; collaborates with ISPRA for national harmonized mining activity census
Geological Survey of Italy (ISPRA)	Collects statistical data on mining and quarrying activities; maintains data on industrial and metallic mineral extraction; collaborates with ISTAT for mining census using international codes
National Government	Jurisdiction on mining exploration, industrial and metallic minerals, national mining policy, and strategic minerals identification
Local Authorities	Occasionally involved in exploration, evaluation, development, production of raw materials by designation from regions
Regional Authorities	Collects raw material data; administers minerals, thermal waters, quarries, and peat bogs. Manages solid minerals extraction. Implements regional plan for extractive activities

Fig. 2 Roles and responsibilities in Italian primary raw materials data collection and management

Table 1 Summary of measures introduced by Decree-Law No. 84 of 25 June 2024

Article	Decision/Strategy	Points of Contact	Action Plan	Relevance to CRMA	UNFC relevant
Art. 8 – Production Royalties	Introduces a production royalty (5–7%) for strategic mining concessions. Funds go to the state (offshore projects) or state & region (onshore projects).	Ministry of Economy and Finance, Ministry of Environment and Energy Security, Ministry of Industry and Made in Italy	Implement via a decree in coordination with the Unified Conference. Allocate funds to the National Made in Italy Fund for strategic raw materials investment.	Support to strategic projects funding (*CRMA* Sect. 2*)*	Unrelated
Art. 9 – Mineral Recovery from Waste	Extends existing mining regulations to allow extraction from closed/abandoned waste storage sites.	Ministry of Environment and Energy Security, Ministry of Industry and Made in Italy	Define eligibility criteria for waste extraction projects. Grant extraction permits under the extended mining law framework.	Promote secondary CRMs supply (*CRMA*, *Article 27)*	Yes
Art. 10 – National Exploration Program	Assigns ISPRA (Italian Geological Survey) responsibility for drafting the National Exploration Program.	ISPRA, Ministry of Industry and Made in Italy, Ministry of Environment and Energy Security	Establish a formal agreement between ISPRA and relevant ministries. Develop and implement the exploration program.	Expanding CRMs knowledge (*CRMA*, *Article 19*)	Yes
Art. 11 – Strategic Value Chains Monitoring	Requires monitoring of strategic value chains and national needs. Establishes a National Register of Strategic Companies & Value Chains.	Ministry of Industry and Made in Italy	Set up the registry and conduct stress tests to assess vulnerabilities in supply chains.	Supply chain resilience (*CRMA*, *Article 20)*	Yes
Art. 12 – Fast-Track Disputes on Strategic Projects	Applies fast-track legal procedures for disputes over strategic project approvals.	Ministry of Justice, Ministry of Industry and Made in Italy	Align procedures with those used for PNRR-funded projects to accelerate legal resolution.	Accelerating permitting (*CRMA*, *Article 11*)	Unrelated
Art. 13 – Support for Critical Raw Materials Processing & Extraction	Expands the National Made in Italy Fund to include extraction & processing projects. Allows INVIMIT S.p.A. to create investment funds for strategic companies' infrastructure.	Ministry of Industry and Made in Italy, INVIMIT S.p.A.	Amend fund regulations. Identify eligible projects and investment opportunities.	Fostering domestic production (*CRMA* Sect. 2)	Unrelated
Art. 14 – Export Controls on Critical Raw Materials	Strengthens export notification requirements for critical raw materials, including scrap metals. Establishes a monitoring committee.	Ministry of Industry and Made in Italy, Ministry of Foreign Affairs	Update regulations to include EU tariff codes. Monitor and evaluate market impacts.	Export Monitoring (*CRMA*, *Article 36*)	Unrelated
Art. 15 – Coordination of Sectoral Policies	Adjusts the role of the Interministerial Committee for Ecological Transition (CITE).	CITE, Ministry of Industry and Made in Italy	Align CITE's functions with new industrial policies.	Coordination and Governance (*CRMA*, *Chap. 6*)	Unrelated
Art. 16 – Strategic Companies Oversight	Modifies rules on transactions involving strategic companies.	Ministry of Industry and Made in Italy	Implement regulatory adjustments for foreign and domestic investments.	Security of Supply (*CRMA*, Sect. 2)	Unrelated
Art. 17 – Decree Implementation	Establishes decree enforcement timeline.	Government of Italy	Publish and execute the decree following parliamentary approval.	Implementation and enactment (*CRMA*, *Article 49*)	Unrelated
Motivation & Urgency	Ensures secure supply of critical raw materials and strengthens supply chains. Recognizes strategic projects as being of high public interest.	Government of Italy, Parliament	Fast-track legislative approval. Align policies with EU strategies.	National compliance with CRMA	Unrelated
Legislative Competence	Confirms state authority over competition and environmental protection. Notes regional role in mining sector.	Constitutional Court, Ministry of Industry and Made in Italy, Regional Authorities	Ensure compliance with national and EU laws. Address potential regional concerns.	National compliance with CRMA	Unrelated

variable data availability render classification a probabilistic and often imperfect, but an indispensable tool for effective decision-making (UNECE 2020). Uncertainty in resource classification stems from various matters to which knowledge may be inadequate (Speirs et al. 2015).

UNFC is a classification tool, applicable to raw material projects, based on three criteria, each represented by an axis:

- E axis (Environmental-Socio-Economic Viability): Underlines the project's alignment with environmental

impacts, social prosperity and acceptance, economic viability, and related regulations.
- F axis (Technical Feasibility): Evaluates the technical maturity and feasibility of the project.
- G axis (Geological Knowledge): Indicates the level of confidence in product estimates.

As displayed in Fig. 3, the classification of projects in UNFC is plotted on a three-dimensional scheme using a numerical coding system, that determine a *Class* (e.g., Viable, Potentially viable, Non-viable, Prospective) and *Sub-class* (e.g., On Production). Each axis is categorized from 1 to 3 (or 4 for the F and G axes), with 1 being the highest level of viability, feasibility, and confidence, and 3 (or 4) the lowest. The entire system is thus further defined with Categories and Sub-categories for each of the axes for a granular and comprehensive framework.

Table 2 illustrates a 2D plot of the UNFC cube, where most common Classes and Sub-classes are defined by the corresponding Categories and Sub-categories. As per the methodology proposed for this preliminary UNFC-based raw materials inventory for Italy, the classification of raw materials projects halted at category level, for simplification purposes and to minimize subjectivity. This means that projects were classified as Viable, Potentially Viable, Non-Viable, or Prospective Projects. Further granularity from Sub-classes and Sub-categories should be included in future updates. The definitions for each Category and Sub-category are well explained in the UNFC (2019) generic document (UNECE 2020). The viability of a project is generally determined by the E, F, and G (rarely, when it's G3 or G4) axes. However, in this study, a balanced judgement approach was taken for the viability, dominated by the E axis i.e., E1 for Viable, E2 for Potentially Viable, and E3 for Non-Viable and Prospective Projects.

In many cases, the obstacles to advancing mineral projects are not geological, but social, environmental, or economic. UNFC accounts for these dimensions through its E axis, the environmental-socio-economic viability. The E axis limitations are becoming particularly prevalent across the EU, where local acceptance, regulatory complexity, land use conflicts, and biodiversity concerns directly shape the viability of raw materials projects. At the same time, addressing the mounting supply pressures, particularly for CRMs, requires a forward-looking approach. It is therefore vital that EU Member States, including Italy, assess whether public funding should be more proactively directed toward exploration and geoscientific research. Studies consistently show that private sector exploration expenditures in Europe are insufficient relative to the projected demand (European Commission 2020).

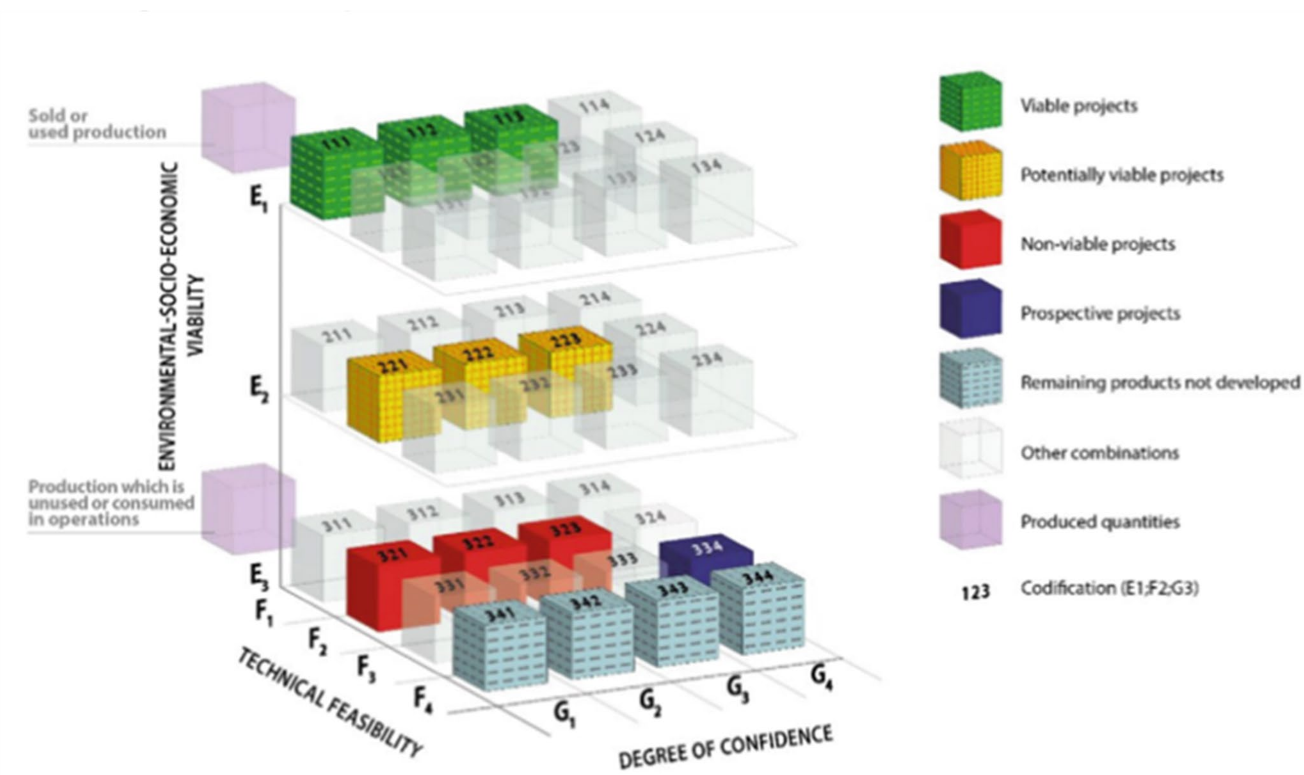

Fig. 3 A three-dimensional diagram illustrating the E, F, and G axes of UNFC, with the corresponding categories and example classes (UNECE 2020)

Table 2 The relationship between UNFC classes and Sub-classes defined by their corresponding categories and Sub-categories (UNECE 2020)

Total Products	Class		Sub-class	Categories		
				E	F	G
	Known Sources	Viable Projects	On Production	1	1.1	1, 2, 3
			Approved for Development	1	1.2	1, 2, 3
			Justified for Development	1	1.3	1, 2, 3
		Potentially Viable Projects	Development Pending	2	2.1	1, 2, 3
			Development on Hold	2	2.2	1, 2, 3
		Non-Viable Projects	Development Unclarified	3.2	2.2	1, 2, 3
			Development Not Viable	3.3	2.3	1, 2, 3
	Potential Sources	Prospective Projects	No sub-classes defined	3.2	3	4

Application of UNFC to the Italian raw materials inventory

This initial contribution for a UNFC-based Italian raw materials inventory is built on various data types and sources, was conducted independently, and is therefore intended as a methodological demonstration. Ideally, cooperation with governmental authorities and the extractive industry is warranted for supplying and validating the data inserted in the inventory. Each type of data considered a unique method of acquisition and classification, since the collation of raw materials in Italy is widely scattered and challenging (as seen in Fig. 2). The data included in the inventory are supplied from:

(i) formal reports submitted to authorities and/or public company reports on production, including raw materials projects with statutory claims (either for exploration or extraction);
(ii) historical data previously reported and/or thoroughly studied for research purposes; and.
(iii) data extrapolated from known geological occurrences and deduced from public information and/or academic reports.

Authorized raw materials projects and production data

Firstly, one way to understand and monitor Italy's raw materials potential is through the analysis of mining concessions, exploration permits granted or under review, concessions currently in force, and active production projects. Figure 4, showcasing records on exploration and mining permits as compiled by ISPRA, provided an important foundation for this understanding (Fumanti 2023). In parallel, international datasets such as the S&P Global Metals and Mining Database offered complementary insights into exploration trends and Italy's relative position in terms of resource attractiveness and project pipeline. These datasets were used in combination to build the current preliminary UNFC-based raw materials inventory (S&P Capital IQ 2025). The projects listed in Fig. 4 have been classified in accordance with their technical study phase, which in return is an indication of the permitting status. Projects yet at research phase have been assigned E3 and F3, since the environmental-socio-economic viability is at an early stage to be evaluated, and the technical feasibility at research levels. Separately, projects at exploration and pre-feasibility have been classified under the E2 and F2 categories, since they are permitted, furthering the technical feasibility, and possibly progressing towards viability.

Subsequently, data on raw materials production represented one of the most direct indicators of a country's raw material output and, by extension, its resource security, industrial demand, and economic positioning in CRMs markets. For Italy, production data were compiled from various sources such as the United States Geological Survey (USGS) Minerals Yearbook (2023), Raw Materials Information System (RMIS) and ISTAT's data portal. These datasets offered the insights included in the inventory on quantities and types of raw materials extracted domestically (USGS 2023a; USGS 2023b; RMIS 2025; ISTAT 2025). The data collected on production pertain solely to extraction projects. Ideally, a comprehensive national raw materials inventory should also include data from processing and recycling projects.

Within the UNFC framework, projects with exploration or mining titles and production data, especially when sourced from the extractive industry, are among the most straightforward to classify due to the pre-existence of established technical and commercial standards, such as those of the CRIRSCO template. When available, the CRIRSCO-reported data were added to the inventory by means of translation to UNFC, through the use of the CRIRSCO-UNFC bridging document (UNECE 2025). While it is allowed to aggregate numbers on the G axis of UNFC (as to reflect a range of uncertainty), such data were reported as aggregated figures within the preliminary inventory. For this study, the industry-reported data have been assigned to UNFC categories 1 or 2 on the G axis, with E1; F1 categories, corroborated by the fulfillment of regulatory requirements in Italy. This entails compliance with Italian mining and environmental legislations, including the Presidential

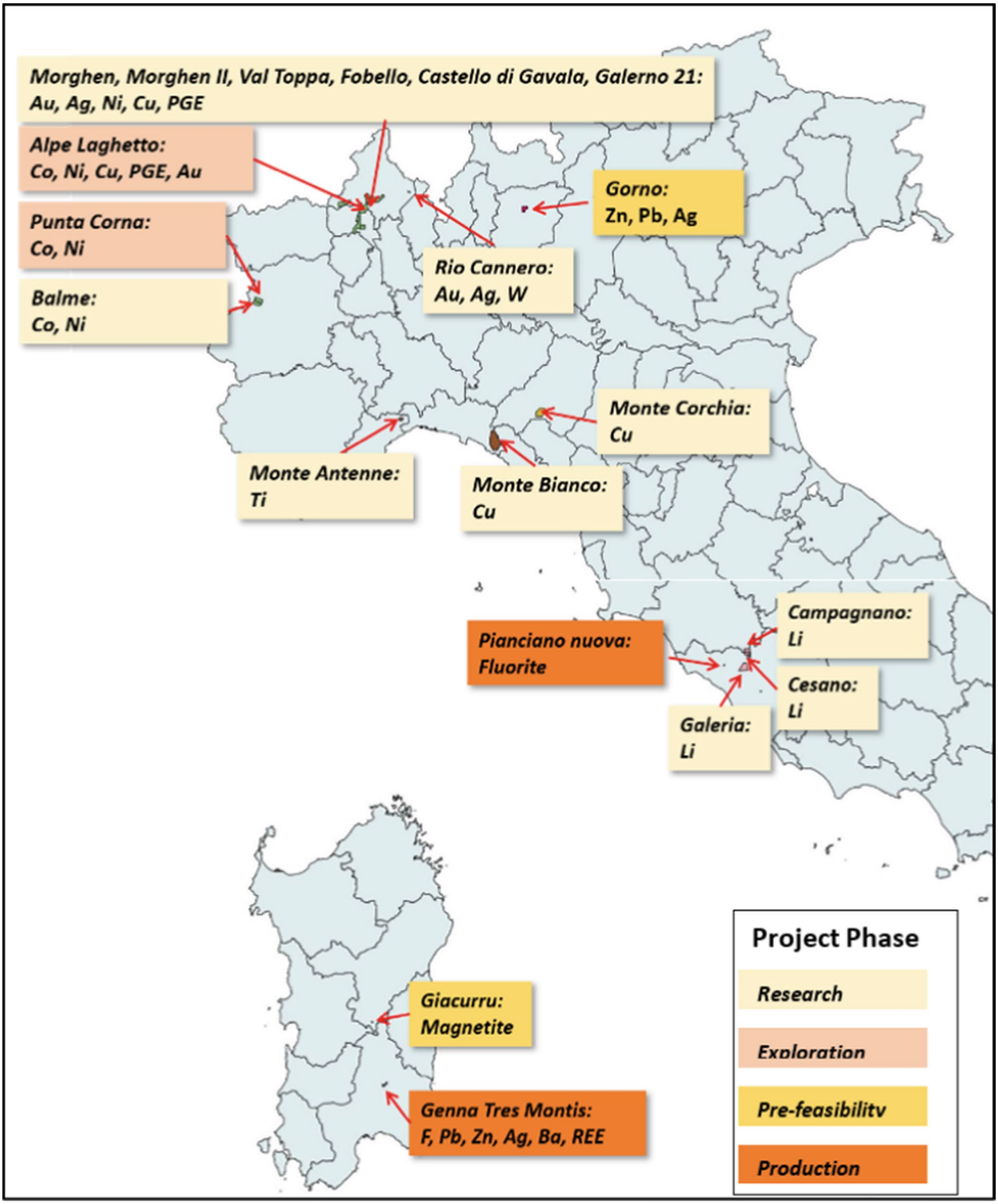

Fig. 4 Mining titles for metal ores and other CRMs, with project progress status (Fumanti 2023) – (F = Fluorspar)

Decree 128/59 (rules for mining and quarrying), Legislative Decree 152/06 (legislative framework applicable to all matters concerning environmental protection), the Law of 23 December 2000 no. 388, Art. 114 (necessitates a special plan for remediation and environmental recovery of mines), Legislative Decree no. 624/1996 (health and safety of workers), and Legislative Decree no. 117/08 (transposing Directive 2006/21/EC and important for the management of extractive waste). Collectively, compliance with these regulations supports classification under E1, reflecting strong environmental-socio-economic viability (UNECE 2022).

As an elaboration on the method of classification of data from such projects, the Gorno project (located in northern Italy, see Fig. 4) is used to make the point. Gorno is currently in an advanced exploration phase and has undergone extensive drilling and geological assessment since 2015 (Altamin Limited 2023). A publicly available JORC-compliant mineral resource estimate identifies 7.79 million tonnes of *Indicated* and *Inferred resources*, grading 6.8% Zn, 1.8% Pb, and 32 g/t Ag, as a result of the scoping study conducted in 2021 (S&P Capital IQ 2025). In line with the CRIRSCO–UNFC bridging document (UNECE 2025), these *Indicated* and *Inferred resources* were respectively classified as E2; F2; G2 and E2; F2; G3. For a direct application of UNFC to Gorno, the project complies with regulatory processes, as current activities are conducted under a granted exploration license, valid until July 2025, in addition to progression in feasibility-development and compliance with international techno-economic studies (Altamin Limited 2023). These support an E2 and F2 classification, similarly to from the bridging method.

Historical data and legacy records

Historic data on raw materials may provide insights into potential future supplies, but they are largely in-homogeneous. Therefore, UNFC is applied to historical data firstly to classify them in a harmonized manner, and secondly to understand their viability and maturity status, and subsequently their potential for recovery. Historical data were derived from the Minerals4EU (2019) project and repository held by ISPRA, regional mining authorities, and academic institutions (EGDI 2025)). These data include information on past exploration results, resource and reserve estimates (including non-compliant with industry standards or poorly documented in most cases), and deposits that are currently uneconomic. Despite their dated nature, historic estimates were included in the inventory due to their strategic importance, as they offer a broader understanding of the national raw materials base and highlight areas where future exploration may be warranted, particularly under evolving market or technological conditions (Bide et al. 2022).

Classifying historic data under UNFC is complex due to uncertainty across all three axes. In this study, these data have been classified, in most cases, under the categories E3; F3; G3, to reflect the low confidence in environmental-socio-economic viability, technical feasibility, and product quantity/quality. For these data, E3 has been predominantly assigned, since sustainability performance cannot be determined at present times due to insufficient information, or no reasonable prospects exist. Regarding the technical feasibility, F3 has been assigned due to obsolete or limited available data to determine the technical maturity, and F4 where no development has been identified. In some cases, G2 has been applied when volumes and quantities were estimated as well documented reserves, as a result of previous exploration activities i.e., where drilling and/or advanced geological investigations were conducted. As such, historical resource and reserve estimates compliant with industry standards have been assigned higher confidence categories of the G axis, in correspondence with the bridging mechanism (if existing, and if not, lower categories have been assigned). G4 has been used in instances of insufficient and indirect geological evidence. Although these data are classified as "Non-Viable" under current conditions, they remain strategically important for long-term planning. Their inclusion provides a broader perspective on the national raw materials base and may guide future exploration under changing economic, policy, or technological conditions.

For instance, as recorded by the Minerals4EU repository, a lead reserve of 4 million tonnes (2013) has been assigned a E3; F3; G2 classification, to reflect moderate geological confidence (EGDI 2025). Additionally, feldspar resource estimate of 5 million tonnes (2013), poorly documented and lacking technical validation, has been assigned E3; F4; G4. Similarly, a fluorspar resource of 35 million tonnes (2019), based on historic resource estimates without alignment to reporting standards, has been classified as E3; F3; G3. The difference in the G axis classifications between these historic estimates lies in the availability and quality of documented geological evidence, as well as the extent of investigation carried out to support the estimation (i.e., G2 if well documented reserve, G3 if well documented resource, and G4 if poorly documented resource).

Extrapolated data from geological occurrences

The attempt to build this preliminary Italian raw materials inventory also incorporates raw materials data derived from geological occurrences across the country. This approach was necessary because of the existing information gaps on raw materials and the scattered data collection streams in Italy (as demonstrated in Fig. 2). Limitations arose on this particular data source, namely from occurrences that are not publicly reported, either due to confidentiality matters or the absence of legal reporting obligations from private companies. Data on geologic occurrences were sourced from a variety of publicly available materials, mainly inferred from geological mapping, geological survey reports, academic research publications, regional assessments, and government publications. It is to be noted that in this attempt, the extrapolation of such data has been carried out at regional, and in some cases, at national levels. However, Fig. 5, developed by the Italian geological survey, represents a good starting point for harnessing information on CRMs occurrences in Italy (Fumanti 2023). Incorporating such data in this study relied on published and public information on occurrences type, mineralized zones, and associated volumes or grades. Where available, these data were cross-checked with historical records and mineralogical studies to increase reliability i.e., mainly qualitatively. Quantitative estimates for these occurrences, such as in-situ tonnages, grade ranges, and spatial distribution, were reviewed. Although this method did not involve a full geospatial analysis using GIS, as used in other countries like the United Kingdom (Bide et al. 2022), it adopted a similar logic of inference by interpreting geological mapping, large-scale models, and documented occurrences to approximate potential volumes. Ideally, this exercise should be conducted on the scale of individual occurrences.

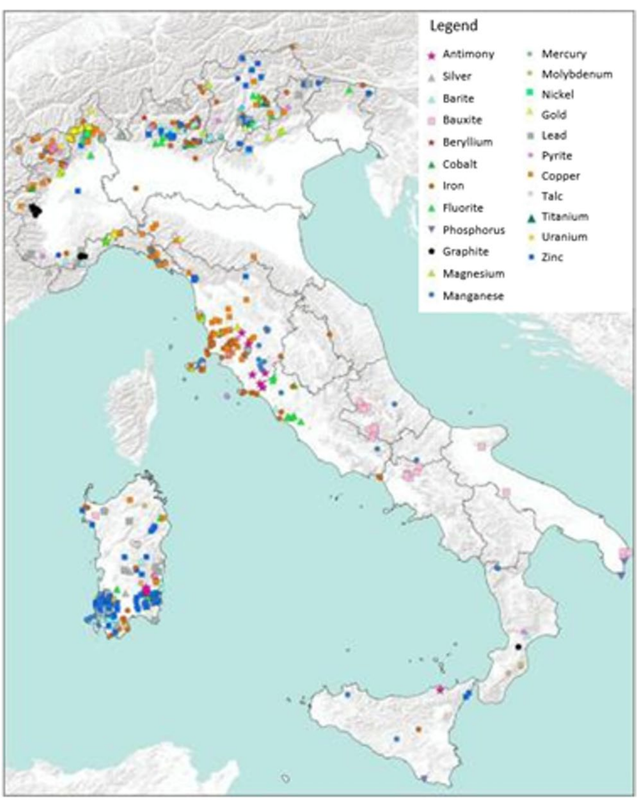

Fig. 5 Occurrences of CRMs and other metal minerals (Fumanti 2023)

Applying UNFC to these data reflects the low confidence and lack of credible sources across the E, F, and G axes. Thus, these data have been classified under E3; F3; G4 or E3; F4; G4 categories. Since these occurrences have no plausible indications on the environmental-socio-economic viability in regards to future conditions, they have been classified as E3. Regarding the technical feasibility, a distinction has been made between 'F3' and 'F4' based on the presence and maturity of the occurrence development. For regional or occurrence-based studies with no deposit-specific information, F4 classification has been assigned. On the other hand, the distinction between G3 and G4 depended on whether estimations were carried primarily on direct (G3) or indirect (G4) evidence. The low categorization indicates the raw nature of these data, which are either at initial stage or not the subject of systematic exploration or feasibility studies. It is to be noted that the use of such data in the inventory is intended to showcase the potential of raw materials in Italy, including those occurrences that have not yet been fully characterized or developed. Future iterations of the inventory should aim to improve the confidence of this data type through systematic national-scale surveys, deposit-specific assessments, and resource and reserve estimation.

Results of a preliminary UNFC-based Italian raw materials inventory

Our contribution for this first-of-its-kind attempt of an Italian national raw material inventory is provided in Fig. 6. It presents the classification of Italian raw material commodities, gathered from the aforementioned data sources and acquisition methodologies (Sect. 3), according to UNFC. The data source used for each commodity is indicated by the superscripts: "a" from projects and production data, "b" from historical data, and "c" from occurrences. The inventory is mainly populated by data from reported mining projects and production ("a"), followed by legacy records ("b"). By contrast, extrapolated geological occurrences ("c") are only sparsely represented, as they lack robust information on quantities and quality. Quantities for each commodity, expressed in metric tonnes, are estimated and classified across the corresponding E, F, and G axes. The full dataset for the development of the inventory, the projects and their sources, collation and classification is available as supplementary information. The development of this inventory is inspired by the UK minerals inventory in UNFC (Bide et al. 2022). Similarly, each cell has been shaded based on its assigned UNFC category for each axis, as a visual summary of the UNFC axes in a two-dimensional layout. This approach illustrates, for each commodity, a progression from higher to lower confidence levels, moving diagonally

Fig. 6 Preliminary UNFC-based Italian raw materials inventory

Commodity	E			F				G				Quantity (t)	UNFC class
	1	2	3	1	2	3	4	1	2	3	4		
Antimony [b]			■			■				■		20,000	333
Arsenic [a]		■			■			■				3,200	221
Arsenic [a]		■			■					■		132	223
Ball Clay [a]	■			■				■				560	111
Bauxite [a]	■			■				■				769,500	111
Bauxite [b]			■			■				■		2,250,000	333
Bauxite [b]			■			■			■			1,250,000	332
Baryte [b]			■			■				■		3,500,000	333
Baryte [b]			■				■				■	3,500,000	344
Bentonite [a]	■			■				■				32	111
Bentonite [b]			■				■				■	150,000	344
Boron [a]		■			■			■				1,500,000	221
Boron [a]		■			■					■		36,800,000	223
Common Clay [a]	■			■					■			2,000	112
Cobalt [a]		■			■						■	1,020,497	224
Copper [a]	■			■				■				15,400	111
Copper [a]		■			■			■				14,000	221
Copper [a]		■			■					■		316	223
Copper [c]			■			■					■	2,045,465	334
Gold [a]		■			■			■				5,732,715	221
Gold [a]		■			■				■			799,982	222
Gold [a]		■			■					■		892,323	223
Gypsum [a]	■			■				■				160	111
Feldspar [a]	■			■					■			2,200	112
Feldspar [b]			■			■			■			1,000,000	332
Feldspar [b]			■				■				■	5,000,000	344
Fluospar	■			■					■			2,200,000	112
Fluospar [b]			■			■				■		35,000,000	333
Kaolin [b]			■			■			■			1,000,000	332
Kaolin [b]			■				■				■	10,000	344
Lead [a]		■			■				■			98,000	222
Lead [a]		■			■					■		39,000	223
Lead [b]			■			■			■			4,000,000	332
Lead [b]			■				■				■	100,000	344
Lithium [a]		■			■				■			39,000	222
Lithium [a]		■			■					■		352,000	223
Nickel [a]		■			■						■	680,162	224
Potassium [a]		■			■				■			17,500,000	222
Potassium [a]		■			■					■		84,000,000	223
Potash [b]			■			■			■			500,000,000	332
Rock Salt [a]	■			■				■				3,017	111
Rock Salt [b]			■			■			■			100,000,000	332
Rock Salt [b]			■				■				■	3,000,000	344
Sand and Gravel [a]	■			■				■				78,000	111
Silver [a]		■			■			■				563,000	221
Silver [a]		■			■				■			6,399,889	222
Silver [a]		■			■					■		2,999,356	223
Silver [c]			■				■				■	67,953,367	344
Sulphur [b]			■			■			■			5,000,000	332
Sulphur [b]			■			■				■		800,000	333
Talc [a]	■			■				■				385	111
Talc [b]			■			■				■		10,000,000	333
Talc [b]			■				■				■	100,000	344
Titanium [a]			■		■					■		9,000,000	323
Zinc [a]	■			■					■			181,000	112
Zinc [a]		■			■				■	■		375,000	222
Zinc [a]		■			■					■		153,000	223
Zinc [b]		■				■					■	2,506	224
Zinc [b]			■			■				■		3,400,000	333
Zinc [c]			■				■				■	1,946,000	344

from the top left to the bottom right of each section. Given the data limitations, this inventory aims, to the extent possible, to be as thorough as possible. The figures presented for many commodities do not capture the full extent of what may exist underground. Additional, yet-to-be-discovered deposits likely exist, but quantifying them would require further exploration efforts (Bide et al. 2022).

As a further elaboration from Fig. 6; Table 3 is an excerpt focused exclusively on CRM-related data. These have been classified into Viable Projects (111 and 112), Potentially

Table 3 UNFC-based CRMs inventory for Italy

UNFC Classification	Viable Projects		Potentially Viable Projects				Non-Viable Projects	Prospective Projects		
	111	112	221	222	223	224	323	333	334	344
Antimony								20,000		
Arsenic			3,200		132					
Bauxite	769,500							2,250,000	1,250,000	
Baryte								3,500,000	3,500,000	
Boron			1,500,000		36,800,000					
Cobalt						1,020,497				
Copper	15,400		14,000		316	2,045,465				
Feldspar		2,200						1,000,000		5,000,000
Fluorspar		2,200,000						35,000,000		
Lithium				39,000	352,000					
Nickel						680,162				
Titanium							9,000,000			
Zinc		181,000		375,000	153,000	2,506		3,400,000		1,946,000

Viable Projects (221 to 224), Non-Viable Projects (323), and Prospective Projects (333, 334, and 344). All figures are reported in metric tonnes. The distribution of CRMs across these categories reveals three notable trends. First, a substantial portion of the classified quantities lies within the "Potentially Viable" class, reflecting either technical immaturity or the need for improved environmental-socio-economic viability before development. Quantities classified under "224" pertain to unreliable estimates, deduced and roughly calculated from preliminary public sources and informal data despite being registered projects, and as such, are included only for the purpose of this inventory. Second, a smaller share of CRMs has been classified under the "Viable" category, indicating mature projects ready for or already undergoing production. It is noteworthy to mention that only Titanium has been classified under the "Non-Viable" (red) category, reported from a UNFC case study applied on the Piampaludo Titanium Exploration Project (UNECE 2023). Third, prospective projects remain abundant, and represent future potential. The quantities presented in Table 3 have been aggregated from the multiple sources, and compiled per commodity. This aggregation represents the sum of the same UNFC categories for each commodity to provide a consolidated national-level estimate per classification level.

Discussion

EU Member States are employing diverse national systems to classify and report raw material data, which leads to inconsistencies that hinder comparability and harmonized policymaking at EU scales. Over recent years, initiatives such as the ORAMA project (Optimizing Quality of Information in Raw Materials Data Collection across Europe) have demonstrated UNFC's capacity to harmonize this fragmented landscape, with a consistent classification that integrates geological, technical, and environmental-socio-economic dimensions (Bide 2018). Additionally, the European Commission has acknowledged UNFC's potential to serve as this raw materials harmonization tool, particularly in CRMA. UNFC's multidimensional structure provides a transparent, scalable, and integrative framework to support decision-making at various stages of the resource development lifecycle, from early-stage exploration to production. When applied to national inventories, UNFC transforms the concept of raw materials aggregation beyond mere geological quantification. It embeds feasibility assessments, market conditions, permitting status, and environmental and social aspects, thus allowing policymakers to make informed decisions grounded in sustainability and long-term value. Furthermore, UNFC's applicability to both primary raw materials and secondary raw materials is especially relevant for the EU, where increased attention is being given to secondary raw materials. In this context, UNFC serves as a classification tool, capable to support public authorities in policy-making, reporting, and monitoring, while also enabling companies to plan, evaluate, and communicate projects more strategically and sustainably.

The exercise presented in this paper has tested the applicability of UNFC to a national raw materials inventory for Italy and has revealed a number of methodological and operational challenges, many of which can be found elsewhere in Europe. The proposed Italian CRMs inventory aggregates a heterogeneous dataset encompassing exploration projects, active production data, historical records, academic sources, and publicly available databases. It should be noted that, while ore grade is a critical factor in determining true recoverable resources, the aggregation presented in the CRMs inventory (Table 3) does not differentiate by grade. This is primarily due to the heterogeneity and limited availability of consistent grade data across different sources. In many cases, grades were either unreported or based on non-comparable analytical methods. As a result, aggregating quantities with different grades would overcomplicate the inventory and risk misrepresenting the purpose of this paper. Therefore, the CRMs inventory serves as generalized indicative volume estimates rather than precise recoverable resources. Where available, grade information is retained and considered in the classification process (available in supplementary information) but it is not reflected in the total aggregated quantities presented in Table 3. The diversity of sources reflects the fragmented nature of existing data infrastructures and underscores the need for a centralized, harmonized classification approach. Although the transformation of such varied inputs into a coherent and consistent UNFC-based inventory is inherently complex, the proposed methodology adopts a systematic approach for the different sources, quality of data, and levels of confidence to handle such complexity.

In the Italian case, a significant proportion of estimates originated from legacy datasets and regionally aggregated studies. As such, many records were assigned to lower-confidence categories (e.g., E3; F3; G3 or G4). It is recommended for future iterations to sub-divide the G4 categories (G4.1, G4.2, G4.3) to add more granularity unto early stage exploration classifications. Given that the data used are only from publicly available sources, it is to be noted that the presented inventory most likely underestimates the country's total subsurface potential, since restricted data kept at company or governmental level were not accessed. Besides, the upcoming Italian national exploration programme could reveal new potential. As a simplification, this study adopts a single G axis category to represent each estimate, favoring the most dominant and reliable classification rather than combining multiple G axis categories, as permitted under full UNFC methodology. The baseline inventory represents a step in building a structured and expandable raw materials knowledge system, that serves as an important policy tool for governments. The trend observed where higher confidence correlates with smaller volumes reinforces the need for caution in interpreting aggregated totals. Users must remain aware that actual extractable volumes are substantially lower than the total geological endowment (Bide 2022). This observation further strengthens the case for data validation, deposit-specific assessments, and systematic national-scale exploration campaigns to improve future inventory iterations.

At the EU scale, the integration of UNFC into Italy's national CRM inventory can contribute to the objectives of CRMA. UNFC allows for comparable data from EU Member States, which enables more accurate criticality assessments, stress-testing exercises, and policy interventions across the value chain. Implementing a UNFC-based national raw materials inventory, decision-makers can better understand where to focus attention, which policy instruments are needed, where capital should be allocated, and how to integrate environmental and social safeguards into development strategies. This supports a holistic and evidence-based method to advance mineral supply security without compromising Italy's broader commitments to environmental sustainability, economic growth, and social well-being. The proposed Italian CRMs inventory, when continuously updated, can serve as a dynamic tool for tracking progress in the raw materials sector, identifying national supply bottlenecks, and aligning national efforts with EU strategic objectives under CRMA. This kind of understanding is particularly relevant in the context of reducing Italy's dependence on external suppliers, for high-risk and economically important CRMs (Agenzia Nova 2024). Importantly, the ability to distinguish between Viable, Potentially Viable, and Prospective projects through UNFC enhances the effectiveness of CRMA requirements for reporting. Projects falling within the Potentially Viable class are particularly relevant, as they often require targeted support, financial or permitting, to progress toward production. Meanwhile, Prospective Projects can guide future exploration and policy attention. Even projects assigned to Non-Viable categories should not be disregarded; such records offer long-term strategic value, particularly when combined with technological progress and innovation, and circular economy solutions. Furthermore, UNFC elevates raw materials inventories into instruments of governance by embedding ESG considerations into resource evaluation. This also aligns with CRMA's emphasis on responsible sourcing, environmental performance, and public acceptance.

It is interesting to note that, despite its advantages, the adoption of UNFC has so far been limited. This can be attributed to the continued use of well-established national and industry-specific reporting systems (e.g., CRIRSCO codes), as well as the need for UNFC capacity building and technical expertise. However, new policy drivers such as CRMA and the African Mineral and Energy Resources Classification and Management System (AMREC) are providing momentum for broader uptake.

Conclusion

This study presents a structured attempt to incorporate UNFC on a proposed model of national raw materials inventory for Italy. The implementation of UNFC provides a multidimensional perspective supporting a robust, transparent, and harmonized classification that not only accounts for geological potential but also incorporates environmental, social, and economic dimensions. Reliable and continually updated datasets will be essential for feeding into the UNFC-based national raw materials inventory. This preliminary inventory is also an opportunity to expand to secondary raw materials, incorporating the potential sourced from anthropogenic resources, either from mining waste or end-of-life.

The presented Italian case illustrates both the challenges and opportunities of integrating UNFC into national resource inventory that can be used for sustainable management practices. The outcome of the proposed inventory demonstrates that Italy has untapped raw materials potential that could be strategically developed to enhance supply security. Additionally, systemic barriers such as limited exploration investment, fragmented data, and socio-environmental constraints must be acknowledged and addressed through proactive planning and governance.

The development of a UNFC-based primary and secondary raw materials inventory for Italy can represent more than just a technical exercise, it can be a meaningful contribution in view of information based national resource management practices. While challenges related to data quality, classification consistency, and resource estimation persist, the methodology proposed in this paper offers a replicable and scalable approach to building information-based, raw materials governance systems. Continued collaboration with the Italian Geological Survey and relevant ministries will be essential to enhance this proposed inventory.

This study draws specific implications for different stakeholders. For the national government, a UNFC-based inventory serves as a strategic tool for long-term planning and policy formulation, as well as to address risks on supply security. For industry, UNFC enables more consistent project reporting, access to green investment, and bridge the communication with authorities and civil society, with a classification based on environmental, social, and economic dimensions. For the EU, this case demonstrates the feasibility of developing a UNFC-based inventory that can feed into EU-wide platforms (e.g., EGDI, RMIS), contributing to cross-country comparability across EU Member States, and strengthening Europe's collective capacity to secure CRMs in a sustainable manner.

Future work should prioritize three key directions: (i) expansion of the inventory to include secondary (anthropogenic) raw materials; (ii) development of standardized protocols for data acquisition, validation, and classification across regions and commodities; and (iii) integration of UNFC-based inventories with national decision-support systems and EU-wide platforms.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s13563-025-00552-4.

Acknowledgements This work has benefited from the support and collaboration of GeoSciences IR, the Geological Survey of Slovenia, and Ms. Charlotte Griffiths from UNECE for the valuable guidance and encouragement.

Author contributions Conceptualization: G.S., S.S., G.A.B.; Methodology: G.S., S.S., G.A.B.; Formal analysis and investigation: G.S.; Writing - original draft preparation: G.S.; Writing - review and editing: G.S., S.S., G.A.B.; Funding acquisition: G.A.B., S.S.; Resources: G.A.B., S.S.;Supervision: G.A.B, S.S.

Funding Open access funding provided by Politecnico di Torino within the CRUI-CARE Agreement. This work was supported by European Union - Next GenerationEU - Mission 4 “Education and Research” - Component 2 “From Research to Business” - Investment 3.1 “Fund for the realization of an integrated system of research and innovation infrastructures” - Project IR0000037 - GeoSciences IR - CUP I53C22000800006.

Data availability Data is provided within the supplementary information file.

Declarations

Competing interests The authors declare no competing interests.

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Appendix D – Data for developing the UNFC-based Italian Raw Materials Inventory

Data for developing the UNFC-based Italian Raw Materials Inventory

Contents

Supplementary Information

The Italian national raw materials inventory based on UNFC was built based on the templates and data sources presented here, alongside the described methodologies for application to each dataset. It was developed as a result of gathering raw materials projects information from 3 main datasets, which are those highlighted in the dissertation (a: Authorized raw materials projects and production data; b: Historical data and legacy records; c: Extrapolated data from geological occurrences). The compilation of these datasets and tables were carried out following the template for the application of UNFC to Italian projects, for the purpose of the proposed national raw materials inventory. The template is applicable to authorized projects in Italy. Their classification is corroborated in this appendix.

Template for the application of UNFC to projects for the Italian Raw Materials Inventory

Project Name	
Project Location	
Project Type	
Development Phase	
Commodity(ies)	
Date of Classification	

E axis Classification - Environmental-Socio-Economic Viability	**Category and Sub-category:**
	Justification: *If available: Legal, Economic, Environmental, Social, Governance, etc.*
F axis Classification - Technical Feasibility	**Category and Sub-category:**
	Justification: *If available: Project development phase, Activity status, Technology, Infrastructure, etc.*
G axis Classification – Degree of Confidence	**Category:**
	Justification: *Indicate the data source, documentation of resource/reserve estimation (if available), and degree of geological investigation*
	UNFC Code:

UNFC Classification of the Project	**UNFC Class and Sub-class:**	
	Justification:	
Sources and additional information		

The Gorno Project

Project Name	Gorno (Appian Natural Rsrc Fund II LP, Altamin Ltd. (Vedra Metals Srl))
Project Location	Oltre il Cole, Lombardy Region, Italy
Project Type	Exploration
Development Phase	Scoping Study
Commodity(ies)	Zn, Pb, Ag
Date of Classification	30/06/2024

E axis Classification - Environmental-Socio-Economic Viability	**Category and Sub-category:** E2
	Justification: Gorno operates under a permit (valid until July 2025) and is progressing toward a mining license through full regulatory compliance with Italian law. A Scoping Study confirms strong economic potential (\$211M Post-Tax NPV, 50% IRR, 2.5-year payback). The project features an underground design with minimal surface impact, full tailings backfill, and limestone reuse in the circular economy. Active engagement with local communities and job creation. Governance is grounded in responsible mining and sustainable social and environmental practices.
F axis Classification - Technical Feasibility	**Category and Sub-category:** F2.1
	Justification: At scoping study, progressing with exploration, well-connected by transport and industrial infrastructure. Historical production and recent test-work confirm simple metallurgy and processing, supporting the development of a long-term supply of clean, high-grade zinc and lead concentrates. Plans to implement smart mining and processing technologies to enhance efficiency, reduce environmental impact, and ensure safety. Advanced exploration and remote sensing techniques are being used to optimize resource identification and extraction
	Category: G2 for indicated resources and G3 for inferred

G axis Classification – Degree of Confidence	**Justification:** This project pertains to the authorized raw materials projects data type. Gorno is underlain by a rich Alpine Mississippi Valley Type (MVT) style geological formation that hosts significant primary mineralisation that includes zinc sulphides such as sphalerite, as well as associated lead and, silver. Extensive exploration drilling and geological studies since 2015 has confirmed a JORC-compliant Mineral Resource estimate, with the corresponding G axis categories: • Indicated Resources: 375 kt @ 6.6% Zn, 98kt @ 1.7% Pb, and 33g/t Ag -> G2 • Inferred Resources: 153 kt @ 7.2% Zn, 39kt @ 1.8% Pb, and 31g/t Ag -> G3
UNFC Classification of the Project	**UNFC Code:** E2; F2.1; G2+G3
	UNFC Class and Sub-class: Potentially Viable, Development Pending
	Justification: Based on the justifications provided for each category separately, the project is potentially viable.
Sources and additional information	1. https://www.altamin.com.au/gorno 2.https://www.mimit.gov.it/images/stories/documenti/allegati/Presentazione_dott_Marcello_De_Angelis_Energia_Minerals_e_Altamin_10-11-2022.pdf 3. https://www.capitaliq.spglobal.com/web/login?target=dashboard

Silius Mine

Project Name	Silius (MINERARIA GERREI SRL (LLC))
Project Location	Silius, about 50 km from Cagliari
Project Type	Extraction
Development Phase	Mining Concession
Commodity(ies)	Fluospar
Date of Classification	06/05/2024

E axis Classification - Environmental-Socio-Economic Viability	**Category and Sub-category:** E1.1
	Justification: Fully permitted, mining concession and all necessary approvals, including EIA, and is currently in the construction phase with production expected in 2025. Financially, the project is fully funded with €44 million secured. Compliance with local environmental regulations, monitoring air quality, noise, vibrations, soil, water, and energy use. The project is well-accepted by the community, creating up to 100 jobs. Governance is based on full compliance with national and international standards and regulations.
	Category and Sub-category: F1.2

F axis Classification - Technical Feasibility	**Justification:** The project is in the construction development phase, with mine infrastructure and a beneficiation plant nearing completion. Supported by strong infrastructure. Facilities will be located near the shaft at 630 meters altitude to optimize operations. Energy-efficient buildings will be built on the existing logistics yard, designed for rooftop solar panels. The site layout includes a main flotation facility, a water treatment and sludge management unit, and adaptable storage sheds. Excavation is minimal, with no expected groundwater impact, and surplus material will be reused.
G axis Classification – Degree of Confidence	**Category:** G2
	Justification: This project pertains to producing/near production projects data type. The Project indicates 2.2 million tonnes of certified fluorspar. Mineraria Gerrei projects an estimated annual production of 70 thousand tonnes of 97.5% fluorspar, and an additional 6,800 tonnes of galena from the site. However, these figures are only declared by the operator. They are not supported by well documented resource/reserve estimation, neither compliant with international standards.
UNFC Classification of the Project	**UNFC Code:** E1.1; F1.2; G2
	UNFC Class and Sub-class: Viable, Approved for Development
	Justification: Based on the justifications provided for each category separately, the project is viable.
Sources and additional information	1. "Mondillo N. et al., Evaluation of the amount of rare earth elements -REE in the Silius fluorite vein system (SE Sardinia, Italy)" 2. https://portal.sardegnasira.it/-/concessione-mineraria-per-la-riattivazione-della-miniera-genna-tres-montis-comune-di-s-basilio-e-silius-v-3 3. https://www.minerariagerrei.com/it/

Lazio

Project Name	Energia Minerals Srl
Project Location	Lazio Region
Project Type	Extraction
Development Phase	Reserves Development
Commodity(ies)	Lithium, Boron, Potassium
Date of Classification	13/11/2025

	Category and Sub-category: E2

<table>
<tr><td rowspan="1">E axis Classification - Environmental-Socio-Economic Viability</td><td>Justification:
Permitted, socio-environmental assessments ongoing. Not yet fully approved for production but shows clear economic and strategic potential. Use of geothermal brines and direct lithium extraction technologies indicates a reduced surface footprint compared to conventional mining, with potential co-production of energy and minerals. Compliance with local environmental regulations, monitoring air quality, noise, vibrations, soil, water, and energy use. The project is set to create up to 100 jobs. Governance is based on full compliance with national and international standards and regulations.</td></tr>
<tr><td rowspan="2">F axis Classification - Technical Feasibility</td><td>Category and Sub-category: F2.1</td></tr>
<tr><td>Justification:
The project is in the reserves development stage and is supported by extensive subsurface data derived from geothermal exploration and testing. Technical feasibility is demonstrated through defined extraction concepts for lithium, boron, and potassium from brines, supported by measured concentrations and large brine volumes. While pilot-scale and demonstration activities support technical credibility, full commercial-scale implementation is still ongoing to justify feasibility.</td></tr>
<tr><td rowspan="2">G axis Classification – Degree of Confidence</td><td>Category: G2</td></tr>
<tr><td>Justification:
The Lazio Project resources are reported in accordance with the JORC Code and are based on brine volume estimates of approximately 158.7 billion m³. Resource confidence is differentiated between indicated and inferred categories as follows:

Lithium:
Indicated (G2): 39,000 t @ 190 mg/L
Inferred (G3): 352,000 t @ 90 mg/L
Boron:
Indicated (G2): 1,500,000 t @ 7,500 mg/L
Inferred (G3): 36,800,000 t @ 9,700 mg/L
Potassium:
Indicated (G2): 17,500,000 t @ 84,000 mg/L
Inferred (G3): 84,000,000 t @ 22,000 mg/L</td></tr>
<tr><td rowspan="3">UNFC Classification of the Project</td><td>UNFC Code: E2; F2.1; G2</td></tr>
<tr><td>UNFC Class and Sub-class: Potentially Viable, Development Pending</td></tr>
<tr><td>Justification: Based on the justifications provided for each category separately, the project is potentially viable.</td></tr>
<tr><td>Sources and additional information</td><td>1. Altamin Ltd. – Energia Minerals and Lazio Project information
2. https://www.thinkgeoenergy.com/altamin-secures-grant-for-research-on-critical-minerals-from-geothermal-brine-in-italy/</td></tr>
</table>

Punta Corna

Project Name	Altamin Ltd.
Project Location	Usseglio, Piedmont
Project Type	Extraction
Development Phase	Exploration
Commodity(ies)	Cobalt, Silver, Nickel, Copper
Date of Classification	09/10/2025

E axis Classification - Environmental-Socio-Economic Viability	**Category and Sub-category:** E2
	Justification: Active exploration license, including EIA, and is currently progressing through systematic early-stage exploration. The project involves geophysical surveys in the 14,62 km2 area of the "Punta Corna" research permit, to assess the presence of mineral resources associated to the Cobalt. Social opposition is apparent. Governance is based on full compliance with national and international standards and regulations.
F axis Classification - Technical Feasibility	**Category and Sub-category:** F2.1
	Justification: Technical feasibility is supported by early exploration data and indirect estimations of potential mineral quantities. Field and airborne reconnaissance, as well as a drill campaign, which has already been authorized by regulators, are ongoing.
G axis Classification – Degree of Confidence	**Category:** G3
	Justification: Resource indications for cobalt, silver, nickel, and copper are based on indirect estimations (geochemical and geological inference) rather than fully validated drilling and internationally compliant resource models. As such, confidence is appropriately low: • Cobalt (Co): 1,020,000 t @ 1.5% — indirect estimation → G3 • Silver (Ag): 984,000,000 oz @ 450 g/t — indirect estimation → G3 • Nickel (Ni): 680,000 t @ 1% — indirect estimation → G3 • Copper (Cu): 2,040,000 t @ 3% — indirect estimation → G3
UNFC Classification of the Project	**UNFC Code:** E2; F2.1; G3
	UNFC Class and Sub-class: Potentially Viable, Development Pending
	Justification: Based on the justifications provided for each category separately, the project is potentially viable.

Sources and additional information	1. https://va.mite.gov.it/en-GB/Oggetti/Info/1760 2. https://www.altamin.com.au/punta-corna

Corchia

Project Name	Energia Mineral Srl. (Altamin Ltd.)
Project Location	Corchia, Nothern Italy
Project Type	Extraction
Development Phase	Exploration
Commodity(ies)	Copper, Lead, Zinc, Nickel, Cobalt
Date of Classification	08/10/2025

E axis Classification - Environmental-Socio-Economic Viability	**Category and Sub-category:** E2
	Justification: A new Exploration Licence has been granted over the historical copper-cobalt mining district of Corchia in northern Italy. Corchia was one of Italy's important copper mining districts, with underground production ceasing in the mid-1940s. The license has been granted to January 2026 and may be renewed for further period of 3 years. The Company's planned exploration will be cost-effective and low surface impact, involving modern techniques with the objective of identifying unmined mineralization, its extensions and any associated satellite deposits.
F axis Classification - Technical Feasibility	**Category and Sub-category:** F2.1
	Justification: Technical feasibility at this stage is constrained by the early nature of the project and reliance on indirect estimations rather than a fully documented and compliant resource model. Brownfield, historic mine. Further drilling, geological modelling, and technical assessments are needed to define a robust extraction concept.
G axis Classification – Degree of Confidence	**Category:** G4
	Justification: Resource estimates are based on indirect estimations without detailed or publicly reported, drilling and compliant resource modelling. All commodities are therefore treated as prospective estimates. All figures are deduced from scientific and academic literature and research. • Copper (Cu): 5,465 t @ 2.53% — indirect estimation → G4 • Lead (Pb): 32 t @ 0.015% — indirect estimation → G4

	• Zinc (Zn): 2,506 t @ 1.16% — indirect estimation → G4 • Nickel (Ni): 162 t @ 0.075% — indirect estimation → G4 • Cobalt (Co): 497 t @ 0.23% — indirect estimation → G4
UNFC Classification of the Project	**UNFC Code:** E2; F2.1; G4
	UNFC Class and Sub-class: Potentially Viable, Development Pending
	Justification: Based on the justifications provided for each category separately, the project is potentially viable.
Sources and additional information	1. https://www.listcorp.com/asx/azi/altamin-limited/news/corchia-copper-project-exploration-licence-granted-2864418.html 2. https://mining.com.au/altamin-prepares-to-start-work-at-newly-granted-corchia-copper-cobalt-project-in-italy/

Pianciano Nuova

Project Name	So.Ri.Com. Srl
Project Location	Castel Giuliano, Lazio Region
Project Type	Extraction
Development Phase	On production
Commodity(ies)	Fluospar
Date of Classification	16/09/2025

E axis Classification - Environmental-Socio-Economic Viability	**Category and Sub-category:** E1.1
	Justification: Operating fluorspar extraction site managed by So.Ri.Co.M. Srl, supplying natural fluorspar primarily for use as a fluxing agent in industrial processes such as cement production. The operation is actively permitted and in production, directly contributing to local employment and adhering to regulatory requirements under Italian and EU mining and environmental laws. It is recognized as part of the limited number of actively mined fluorspar deposits in Italy, with long-standing industrial usage in the region.
	Category and Sub-category: F1.1

F axis Classification - Technical Feasibility	**Justification:** The project is on production. Technical feasibility is confirmed.	
G axis Classification – Degree of Confidence	**Category:** G1	
	Justification: Reported production figures and reserve estimates (~5 million tonnes of recoverable fluorspar, down from historical estimated resources of ~11 Mt clayey and ~7 Mt sandy material, now economically re-evaluated).	
UNFC Classification of the Project	**UNFC Code:** E1.1; F1.1; G1	
	UNFC Class and Sub-class: Viable, On Production	
	Justification: Based on the justifications provided for each category separately, the project is viable.	
Sources and additional information	1. https://it.soricom.it/	

Monte Bianco

Project Name	Energia Minerals
Project Location	Genova Province, Liguria
Project Type	Exploration
Development Phase	Exploration
Commodity(ies)	Copper, Lead, Manganese, Zinc
Date of Classification	03/10/2025

	Category and Sub-category: E3.2

E axis Classification - Environmental-Socio-Economic Viability	**Justification:** Very early stage; only a permit application has been lodged. Baseline environmental and socio-economic assessments are in progress alongside the permitting process, but no comprehensive viability analysis has yet been completed. No public indication of economic studies or development plans that confirm a viable pathway has been published.
F axis Classification - Technical Feasibility	**Category and Sub-category:** F3.1
	Justification: The project has undergone preliminary exploration and geological interest identification, but there are no detailed resource evaluations, feasibility studies, or scoping work publicly available. Resources are inferred indirectly through geological understanding of the area's mineral potential, but not through formal, compliant estimation.
G axis Classification – Degree of Confidence	**Category:** G4
	Justification: The Monte Bianco license contains the old Gambetesa mine which was, at the time, the largest manganese mine in Europe and operated from 1939 to 1971, with mined grades of 28-30% Mn to produce around 50,000t of manganese metal per annum.
UNFC Classification of the Project	**UNFC Code:** E3.2; F3.2; G4
	UNFC Class and Sub-class: Non-Viable, Development Unclarified
	Justification: Based on the justifications provided for each category separately, the project is non-viable at the moment.
Sources and additional information	1. https://www.altamin.com.au/ 2. https://www.capitaliq.spglobal.com/web/login?target=dashboard 3. https://www.mimit.gov.it/images/stories/documenti/allegati/Presentazione_dott_Marcello_De_Angelis_Energia_Minerals_e_Altamin_10-11-2022.pdf

Alpe Laghetto

Project Name	Alligator Energy Ltd.
Project Location	Val Bognanco, Piedmont
Project Type	Exploration
Development Phase	Active

Commodity(ies)	Cobalt, Nickel, Copper, PGEs, Gold
Date of Classification	06/11/2025

E axis Classification - Environmental-Socio-Economic Viability	**Category and Sub-category:** E2
	Justification: Actively explored permit with geological work completed and JORC-compliant indications of multiple metals including nickel and cobalt. There is no active production or immediate development decision, but the results to date indicate economic potential that merits continued consideration and planning. Community and regulatory engagement are underway, but socio-economic viability has not yet been fully assessed through comprehensive economic studies.
F axis Classification - Technical Feasibility	**Category and Sub-category:** F2.1
	Justification: The project is implementing exploration techniques, including ground electromagnetic surveys and geochemical sampling, have identified potential drill targets for further investigation.
G axis Classification – Degree of Confidence	**Category:** G3
	Justification: Resource indications for key commodities are based on limited data and broad JORC-style reporting that does not yet include formally defined and validated resource estimates (no measured or indicated categories reported). The only quantified figures are: • Cobalt (Co) — 0.07% (inferred) • Nickel (Ni) — 1.36% (inferred) • Copper (Cu) — 0.1% (inferred)
UNFC Classification of the Project	**UNFC Code:** E2; F2.1; G3
	UNFC Class and Sub-class: Potentially Viable, Development Pending
	Justification: Based on the justifications provided for each category separately, the project is potentially viable.
Sources and additional information	1. https://announcements.asx.com.au/asxpdf/20180726/pdf/43wsdn8f3tq4l1.pdf 2. https://wcsecure.weblink.com.au/pdf/AGE/02574183.pdf

Zanca

Project Name	Western Metallica
Project Location	Tuscany

Project Type	Exploration
Development Phase	Exploration Permit
Commodity(ies)	Silver, Gold, Bismuth, Copper, Magnesium, Lead
Date of Classification	03/11/2025

E axis Classification - Environmental-Socio-Economic Viability	**Category and Sub-category:** E2
	Justification: Active permit of research for multiple commodities engagement are underway. Basic environmental assessment and permitting processes are underway as part of exploration activities. No economic feasibility study or development decision has been completed yet, but the licence status and ongoing exploration.
F axis Classification - Technical Feasibility	**Category and Sub-category:** F2.1
	Justification: Early exploration stage. Permitted exploration activities do not yet include defined resource estimates or technical evaluation of mining or processing methods. Geological potential is recognized but technical feasibility requires additional drilling and evaluation work (structural, metallurgical, and engineering studies).
G axis Classification – Degree of Confidence	**Category:** G4
	Justification: There are no published, compliant resource estimates for Zanca. The values for Ag, Au, Bi, Cu, Mg, and Pb are indicative prospective or exploratory targets rather than measured, indicated, or inferred mineral resources defined by a formal resource model.
UNFC Classification of the Project	**UNFC Code:** E2; F2.1; G4
	UNFC Class and Sub-class: Potentially Viable, Development Pending
	Justification: Based on the justifications provided for each category separately, the project is potentially viable.
Sources and additional information	1. https://va.mite.gov.it/it-IT/Oggetti/Info/9944

Authorized Projects in Italy

Property	Owner(s)	Development Stage	Activity Status	Main Commodity	Commodity(ies)	Reserves (t)	Resource (t)	Grade (%)	Classification Method	Category	Total (t)	Date	UNFC Code	UNFC Class	source
Gorno	Appian Natural Rsrc Fund II LP, Altamin Ltd.	Scoping Study	Active	Zinc	Zinc		375,000	6.6	JORC	Indicated	528,000	30/06/2024	222	Potentially Viable	1,2,3
							153,000	7.2	JORC	Inferred			223	Potentially Viable	1,2,3
					Lead		98,000	1.7	JORC	Indicated	137,000		222	Potentially Viable	1,2,3
							39,000	1.8	JORC	Inferred			223	Potentially Viable	1,2,3
					Silver		5940000 (Oz)	33 (g/t)	JORC	Indicated	8,040,000 (Oz)		222	Potentially Viable	1,2,3
							2100000 (Oz)	31 (g/t)	JORC	Inferred			223	Potentially Viable	1,2,3
					Cobalt		n/a						324	Non Viable	1,2,3
					Nickel		n/a						324	Non Viable	1,2,3
					Copper		n/a						324	Non Viable	1,2,3
					Lithium		n/a						324	Non Viable	1,2,3
											7,790,000 (t)				1,2,3

Sardinia Tailings	Private Interest, Unnamed Owner, People's Gvt. of Gansu Province	Reserves Development	Temporarily on Hold	Zinc	Zinc		1,846,000	2.07	Non-compliant	Resource		31/03/2010	334	Non Viable	3
					Lead		499	0.56	Non-compliant	Resource			334	Non Viable	3
											89,167,000 (t)				3
Furtei	Sardinia Gold Mining S.P.A	Production - Limited Production	Unknown	Gold	Gold		426,000 (OZ)	2.312 (g/t)	NI 43-101	Measured & Indicated	448,700 (OZ)	9/3/2008	221	Potentially Viable	3
							22,700 (OZ)	2.030 (g/t)	NI 43-101	Inferred			223	Potentially Viable	3
					Copper		14,000	0.243	NI 43-101	Measured & Indicated	14,316		221	Potentially Viable	3
							316	0.09	NI 43-101	Inferred			223	Potentially Viable	3
					Arsenic		3,200	0.056	NI 43-101	Measured & Indicated	3,332		221	Potentially Viable	3
							132	0.038	NI 43-101	Inferred			223	Potentially Viable	3
					Silver		563,000	3.058	NI 43-101	Measured & Indicated	597,000		221	Potentially Viable	3

							34,000	2.952	NI 43-101	Inferred			223	Potentially Viable	3
											6,079,100 (t)				3
Osilo	Sardinia Gold Mining S.P.A	Reserves Development	Inactive	Gold	Gold		167,000 (OZ)	6.5 (g/t)	NI 43-101	Measured & Indicated	374,000 (OZ)	8/1/2007	222	Potentially Viable	3
							207,000 (OZ)	7.5 (g/t)	NI 43-101	Inferred			223	Potentially Viable	3
					Silver		983,000 (OZ)	38.2 (g/t)	NI 43-101	Measured & Indicated	1,586,000 (OZ)		222	Potentially Viable	3
							603,000 (OZ)	21.8 (g/t)	NI 43-101	Inferred			223	Potentially Viable	3
											1,660,000 (t)				3
Novazza	Altamin Ltd.	Reserves Development	Inactive	Uranium	U308		2,877,000 (lbs)	0.15	JORC	Inferred	2,877,000 (lbs)	9/18/2006	223	Potentially Viable	1,3
											870,000 (t)				1,3
Lazio	Energia Minerals Srl	Reserves Development	Active	Lithium	Lithium		39,000	190 mg/l	JORC	Indicated	391,000	30/06/2024	222	Potentially Viable	1
							352,000	90 mg/l	JORC	Inferred			223	Potentially Viable	1
					Boron		1,500,000	7,500 mg/l	JORC	Indicated	38,300,000		222	Potentially Viable	1
							36,800,000	9,700 mg/l	JORC	Inferred			223	Potentially Viable	1

					Potassium		17,500,000	84,000 mg/l	JORC	Indicated	101,500,000		222	Potentially Viable	1
							84,000,000	22,000 mg/l	JORC	Inferred			223	Potentially Viable	1
											158,701,000,000 (m3)				1
Piampaludo	C.E.T	Exploration	Inactive	Titanium	Titanium		9,000,000	6	UNFC	Resource	9,000,000	2021	323	Non Viable	4
Silius	Mineraria Gerrei	Mining Concession	Active	Fluospar	Fluospar		2,200,000	3.18	UNFC	Resource	2,200,000	2024	112	Viable	5,6, 7
Punta Corna	Altamin Ltd.	Exploration License	Active	Cobalt	Cobalt		1,020,000	1.5	Indirect estimation*	Resource	1,020,000	2024	224	Potentially Viable	1,8, 9
					Silver		984,000,000 (Oz)	450 g/t	Indirect estimation*	Resource	984,000,000 (Oz)		224	Potentially Viable	1,8, 9
					Nickel		680,000	1	Indirect estimation*	Resource	680,000		224	Potentially Viable	1,8, 9
					Copper		2,040,000	3	Indirect estimation*	Resource	2,040,000		224	Potentially Viable	1,8, 9
Corchia	Energia Minerals Srl	Exploration License	Active	Copper	Copper		5,465	2.53	Indirect estimation*	Resource	5,465	2023	224	Potentially Viable	1, 9, 10, 11
					Lead		32	0.015	Indirect estimation*	Resource	32		224	Potentially Viable	1, 9, 10, 11
					Zinc		2,506	1.16	Indirect estimation*	Resource	2,506		224	Potentially Viable	1, 9, 10, 11
					Nickel		162	0.075	Indirect estimation*	Resource	162		224	Potentially Viable	1, 9, 10, 11
					Cobalt		497	0.23	Indirect estimation*	Resource	497		224	Potentially Viable	1, 9, 10, 11

Pianciano Nuovo	So.Ri.Com.	On Production	Active	Fluospar	Fluospar		18,000,000	30	Company Report	Resource	5,000,000	2024	112	Viable	12
Lemina	Marcello Bruera	Exploration Permit	Active	Graphite	Graphite							2024	234	Potentially Viable	13
Piedmont	Alligator Energy Ltd., Chris Reindler & Partners	Target outline	Active	Nickel	Nickel			2.48	Non-compliant	Resource		2022	234	Potentially Viable	3, 14, 15
					Cobalt			0.19	Non-compliant	Resource					
					Copper			6.38	Non-compliant	Resource					
					PGMs										
					Zinc										
Castello di Gavala	KEC Exploration	Re-Application	Active	Nickel	Nickel							2022	334	Non Viable	3, 16
					Copper										
					PGM										
Monte Bianco	Altamin Ltd.	Application for Permit	Active	Copper	Copper							2022	334	Prospective	1, 2, 3
					Lead										
					Manganese										
					Zinc										
Zanca	Western Metallica	Exploration Permit	Active	Silver	Silver							2023	224	Potentially Viable	17
					Gold										
					Bismuth										
					Copper										
					Magnesium										
					Lead										

Villar	Altamin Ltd.	Exploration License	Active	Graphite	Graphite							2022	224	Potentially Viable	1, 2, 3
epCRM	Minerali Industriali	Prefeasibility	Active	REEs	REEs							2024	224	Potentially Viable	18, 19
Giacurru	Sabbie di Parma srl	Prefeasibility	Active	Magnetite	Magnetite	6,500,000			Company Report	Probable	6,500,000	2008	222	Potentially Viable	20, 21
					Magnetite	3,100,000			Company Report	Proved	3,100,000		222	Potentially Viable	20, 21
											9,600,000				20, 21
Rio Cannero	Società Alpine Gold Lodes s.n.c	Research Permit	Active	Gold	Gold							2024	224	Potentially Viable	22, 23
					Silver										
					Tungsten										
Alpe Laghetto	Alligator Energy Ltd.	Exploration	Active	Cobalt	Cobalt			0.07	JORC			2018	223	Potentially Viable	24, 25
					Nickel			1.36	JORC						
					Copper			0.1	JORC						
					PGE										
					Gold										
Morghen		Research	Active	Gold	Gold							2022	344	Prospective	9
					Silver										
					Nickel										
					Copper										
					PGE										

* Estimates are deduced and roughly calculated from preliminary studies/research, public data, and news articles, rendering the estimates unreliable as they are not reported by the company. They only serve for the purpose of this inventory.

Production Data

Commodity[2]		2022		Activity		Source		UNFC

METALS									
Aluminum, metal, secondary			769,500		Processing		26, 27		111
Copper, refinery, secondary			15,400		Processing		26, 27		111
Iron and steel:									
Pig iron	thousand metric tons		3,925				26, 27		111
Steel, raw	do.		24,400		Processing		26, 27		111
Lead, refinery:									
Primary			36,400	e	Processing		26, 27		112
Secondary			116,000	e	Processing		26, 27		112
Zinc, smelter:									
Primary			76,000	e	Processing		28		111
Secondary			105,000	e	Processing		28		111
INDUSTRIAL MINERALS									
Cement, hydraulic	thousand metric tons		23,500	e	Extraction		26, 27		111
Clay:									
Ball clay	do.		560	e	Extraction		26, 27		111
Bentonite	do.		32		Extraction		26, 27		111
Common clay	do.		2,000	e	Extraction		26, 27		112
Refractory clay, excluding kaolinitic earth	do.		8		Processing		26, 27		111
Feldspar[e]	do.		2,200		Extraction		26, 27		112
Gypsum, mine	do.		160		Extraction		26, 27		111
Talc, bauxite, and fluorite	do.		385		Extraction		28		111
Iron oxide pigments			19,720		Processing		26, 27		111
Lime, hydrated, hydraulic, and quicklime[e]	thousand metric tons		3,600		Extraction		26, 27		111
Nitrogen, ammonia, N content	do.		600	e					
Pumice and related minerals, pozzolan[e]			47,000		Processing		28		111
Rock Salt	do.		3,017		Extraction		28		111
Sand and gravel, industrial[e]	do.		13,000		Extraction		28		111

Stone, sand, and gravel, construction:									
Sand and gravel[e]	do.		65,000		Extraction		26, 27		111
Stone:									
Crushed, limestone, for lime and cement	do.		41,675		Extraction		26, 27		111

[e] Estimated. [r] Revised. do. Ditto.

[1] Table includes data available through October 3, 2022. All data are reported unless otherwise noted. Estimated data are rounded to no more than three significant digits.

[2] In addition to the commodities listed, barite, chalk, magnesium metal, potash, refined silver, synthetic soda ash, byproduct sulfur from petroleum and metallurgy, and talc and related materials may have been produced, but available information was inadequate to make reliable estimates of output.

Historic data

Raw Material	Quantity (t)	Type	Confidence	Year	UNFC	Source
Antimony	20000	Resource	Historic resource estimate	2019	333	29

Asphalt	20000000	Resource	Poorly documented	2013	344	30
Baryte	3500000	Resource	Poorly documented	2013	344	30
Baryte	3500000	Resource	Historic resource estimate	2019	333	39
Bauxite	2250000	Resource	Historic resource estimate	2019	333	29
Bauxite	1250000	Reserve	Historic reserve estimate	2019	332	29
Bentonite	150000	Resource	Poorly documented	2013	344	30
Cement	10000000	Resource	Poorly documented	2013	344	30
Feldspar	1000000	Reserve	Estimate	2013	332	29
Feldspar	5000000	Resource	Poorly documented	2013	344	30
Fluospar	35000000	Resource	Historic resource estimate	2019	333	29
Iron ore	3100000	Resource	Non compliant resource estimate	2019	334	29
Iron ore	3000000	Reserve	Estimate	2013	332	29
Kaolin	1000000	Reserve	Estimate	2013	332	29
Kaolin	10000	Resource	Poorly documented	2013	344	30
Lead	4000000	Reserve	Estimate	2013	332	29
Lead	100000	Resource	Poorly documented	2013	344	30
Potash	500000000	Reserve	Estimate	2013	332	29
Rock Salt	100000000	Reserve	Estimate	2013	332	29
Rock Salt	3000000	Resource	Poorly documented	2013	344	30
Sulphur	5000000	Reserve	Estimate	2013	332	29
Sulphur	800000	Resource	Historic resource estimate	2013	333	29
Talc	10000000	Reserve	Estimate	2013	332	29
Talc	100000	Resource	Poorly documented	2013	344	30
Zinc	3400000	Reserve	Estimate	2013	332	29
Zinc	100000	Resource	Poorly documented	2013	344	30

Raw Materials Data Classification

UNFC Classification	*111*	*112*	*113*	*221*	*222*	*223*	*224*	*321*	*322*	*323*	*333*	*334*

Commodity												
Antimony											20,000	
Arsenic				3,200		132						
Ball Clay	560											
Bauxite	769,500										2,250,000	1,250,000
Baryte											3,500,000	3,500,000
Bentonite	32											150,000
Beryllium												
Bismuth												
Boron				1,500,000		36,800,000						
Cobalt							1,020,497					
Common Clay		2000										
Coking Coal												
Copper	15,400			14,000		316	2,045,465					
Feldspar		2,200									1,000,000	5,000,000
Fluospar		2,200,000									35,000,000	
Gallium												
Germanium												
Gold				5732715	799982	1206036						
Gypsum	160											
Hafnium												
Helium												
HREE												
Koalin											1000000	10000
Lead					98000	39000					4000000	100499
LREE												
Lithium					39,000	352,000						
Magnesium												

Manganese												
Natural Graphite												
Nickel							680,162					
Niobium												
Phosphate Rock												
Phosphorus												
PGM												
Potash											500000000	
Potassium					17500000	84000000						
Rock Salt	3017										100000000	3000000
Sand and Gravel	78000											
Scandium												
Silicon Metal												
Silver				56300	6399889.00	2999356.00	67,953,367					
Strontium												
Sulphur											5000000	800000
Talc	385										10000000	100000
Tantalum												
Titanium										9,000,000		
Tungsten												
Vanadium												
Zinc		181,000			375,000	153,000	2,506				3,400,000	1,946,000

Supplementary Note on the adopted methodology

The methodology for the application of UNFC to the preliminary inventory of raw materials in Italy, as described in Section 3.2 of the manuscript aims to demonstrate the methodological feasibility of classifying heterogeneous and scattered data sources under a common and structured framework. The approach was developed within the frame of this research with remarks to be taken in consideration, in particular:

- *Data Sources and Classification* where the raw materials data included in the inventory were compiled from three primary categories: (i) Authorized raw materials projects and production data, (ii) Historical data and legacy records, and (iii) Extrapolated data from geological occurrences. Each data type involved a tailored methodological approach to classification, reflecting differences in data acquisition methods, maturity, and confidence levels.
- *Authorized Projects and Production Data* were obtained from regulatory records, international databases, and official statistics. These data pertain to active mining or exploration projects with legal titles and/or production history. The projects were evaluated based on: Permitting status and development stage; Compliance with national legislation and sustainability criteria, to assess environmental-socio-economic viability (E axis); Available production data or reported estimates, to determine resource quantities (G axis). Where CRIRSCO-compliant data were available, the CRIRSCO–UNFC Bridging Document (UNECE, 2025) was used to assign UNFC categories.
- *Historical and Legacy Data* were retrieved from repositories such as Minerals4EU, regional mining records, and academic publications. These datasets often lacked standardization or detailed technical documentation. The classification applied reflected: Low environmental-socio-economic viability (E3), given absence of updated legal or sustainability context; Uncertain technical feasibility, assigned F3 or F4 depending on evidence of past project development; Variable geological confidence, with G2 or G3 used when data showed evidence of drilling or reserve estimation, and G4 where indirect or minimal evidence existed.
- *Extrapolated Geological Occurrence Data* were used to capture broader national potential, the inventory incorporated raw materials data inferred from geological mapping and academic studies. These estimates were typically regional in scope and lacked specific project-level validation. In such cases: E3 was assigned universally due to the absence of socio-economic assessments; F3 or F4 was used to reflect limited or absent technical development; G3 or G4 was based on whether information was derived from direct mapping or indirect geological inference. These entries, such as those based on the national occurrences dataset developed by ISPRA (Fumanti, 2023), were included to highlight underexplored mineral potential, though their classification reflects very low confidence across all three axes.
- *UNFC Categorization Judgement* applied in assigning UNFC categories, the following principles were observed: Granularity: Where possible, individual projects or deposits were assessed, rather than generalized regional data; Conservatism: In the absence of full supporting documentation, lower confidence categories were used; Bridging: When available, data reported under CRIRSCO-aligned standards were mapped directly to UNFC using the official bridging guidelines; and Regulatory Integration: Compliance with Italy’s mining, environmental, and safety legislation supported classification under E1 and F1 categories.

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Appendix E – UNFC Decision-trees for Italian Mineral Projects

Introduction of decision-trees for the UNFC classification of mineral resources in Italy

Italian Minerals Law - Summary

Mining Legislation
Royal Decree No. 1443 / 1927

Mine waste Management
Decree 117/2008

First Category Minerals

- Public Law
- State-owned
- Concession procedure

Regional Governments have power on the governance of extractive sector

Presidential Decree No. 382/1994

Presidential Decree 2/1972 & 616/1977

Governance of research concessions and exploration permits for mining activities

Regions began enacting laws on local mining

Constitutional Law 3/2001

Primary authority to the Regions i.e. assigned coordination of activities to the central governments

Mining Exploration – Royal Decree 1443

Decentralized competencies for concessions – Presidential Decree 620

Permits and Concessions – Presidential Decree 382

Prospecting & Exploration
Require a license/permit

Environmental Impact Assessment required, and administered by the Ministry of Environment and Energy Security (MASE)

If exploration yields positive results

Italian Minerals Law - Summary

Extraction license / Production Permit
Royal Decree No. 1443 / 1927

- Permit always temporary
- Ordained by relevant competent authority (Regional Authority mostly)
- EIA required
- Operational Plan (Regional Mining Plan)
  - Permit holder data
  - Duration of permit
  - Type and method of mine/quarry
  - Spatial Plan
  - Remediation plan
  - Concession fees (royalties)
  - Extractive wastes management

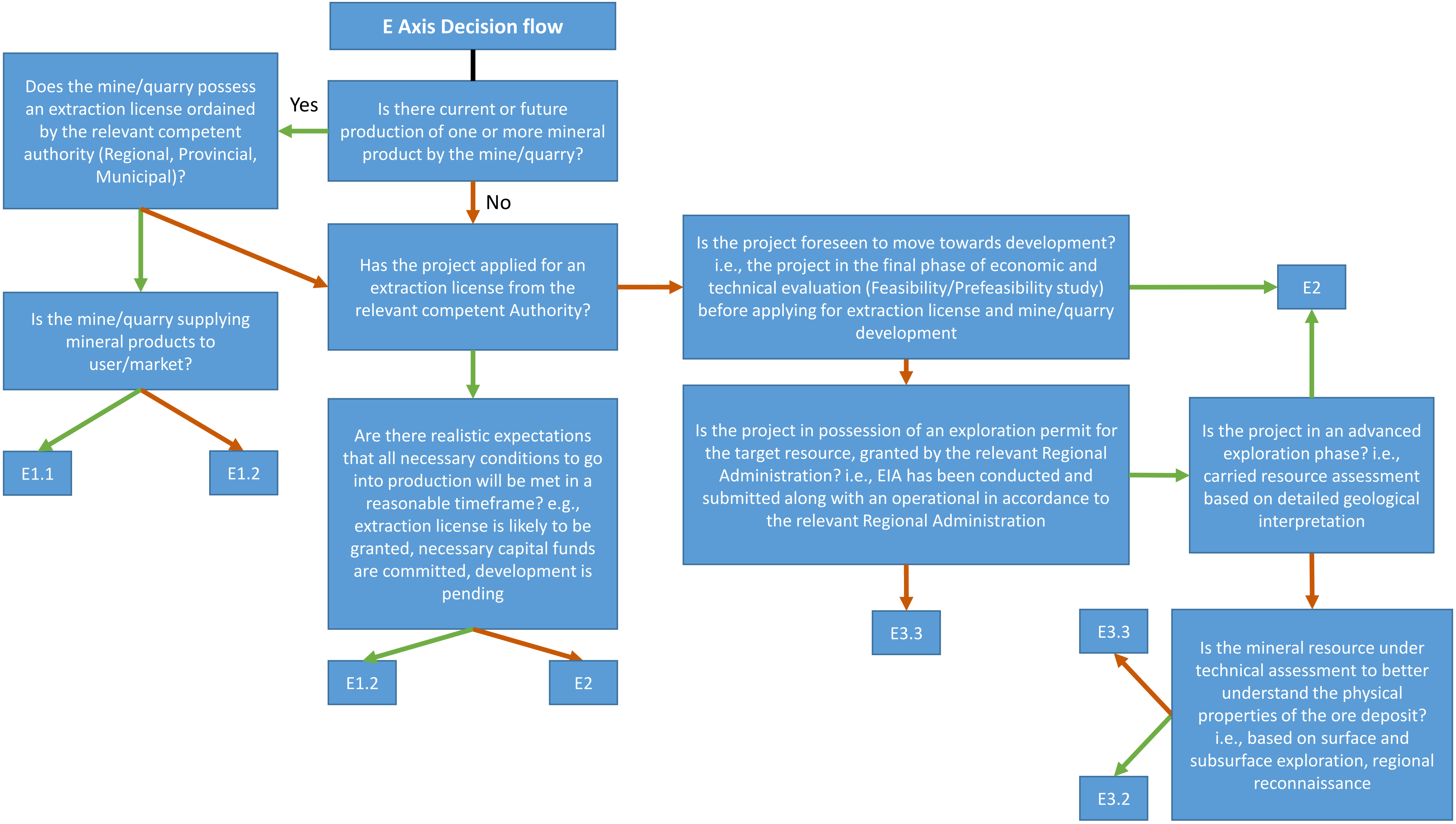
- No National Guidance: Diverse regional planning, heterogeneous databases
- No National Inventory (ceased, active, operating mines)

Conducted at local governments levels in each Region

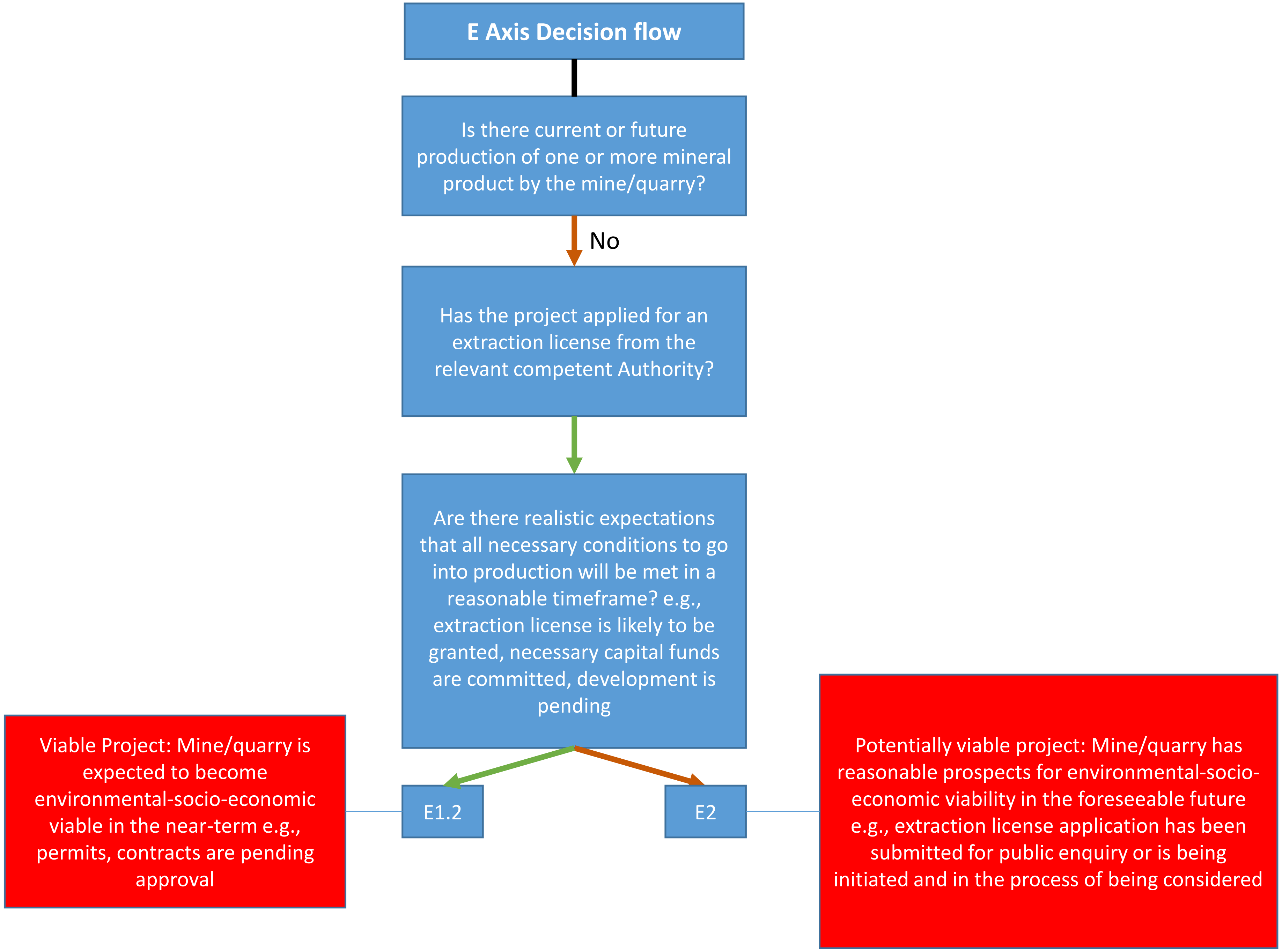
Competent Ministries ← ISPRA → **Local Stakeholders**

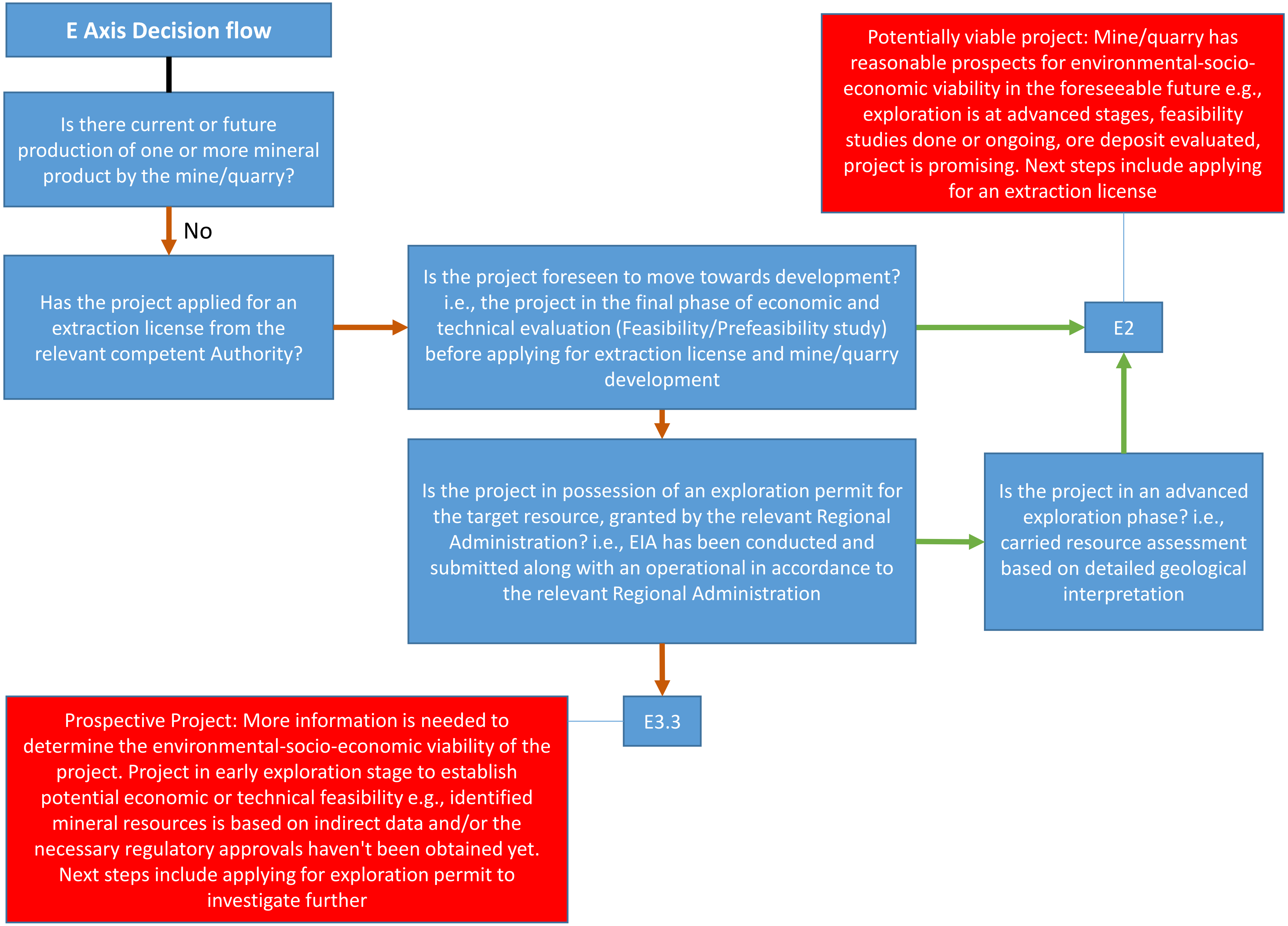
(Regulatory solutions for sustainable management of mining activities)
e.g., recovery from mining wastes

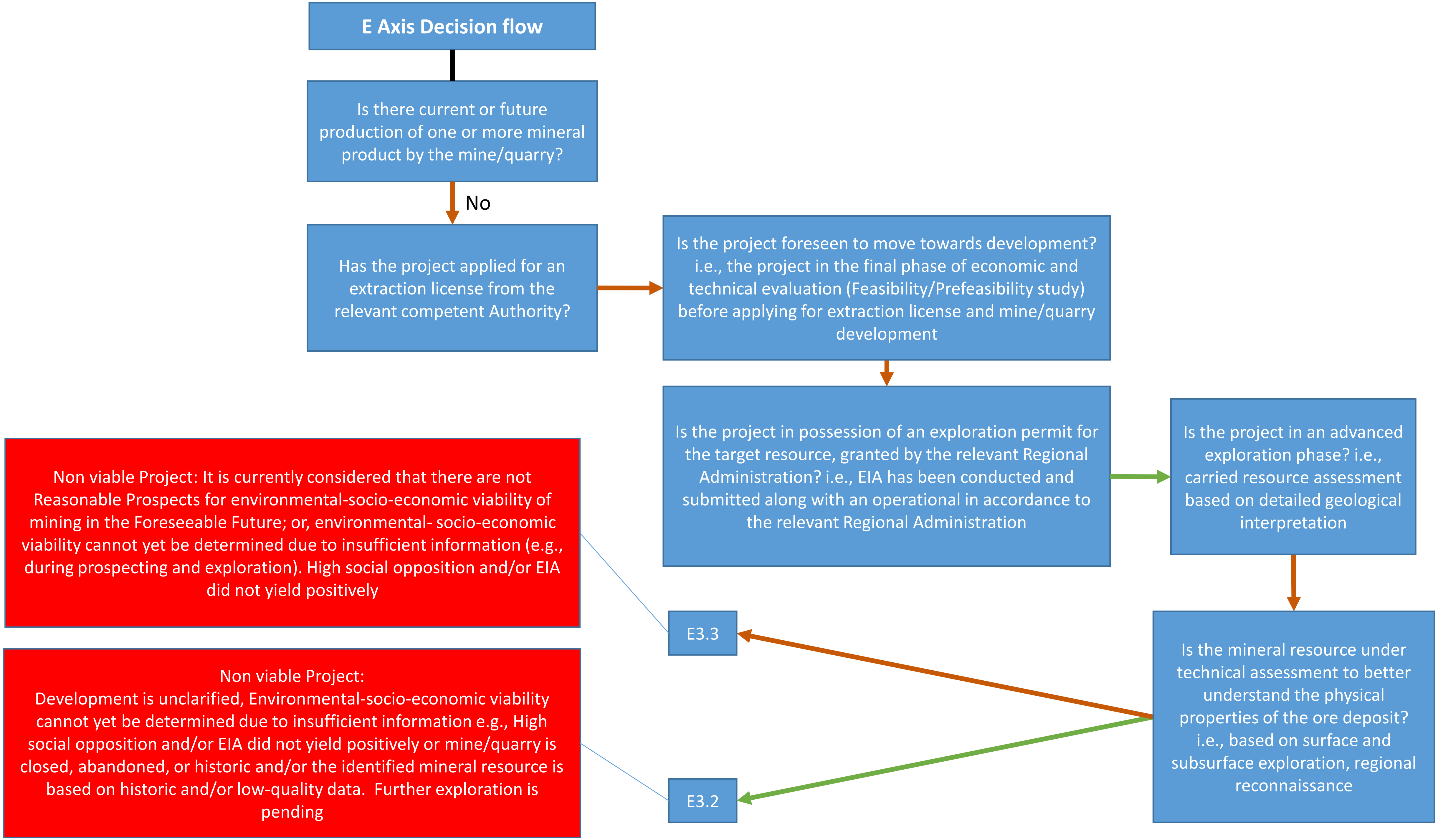
E axis decision tree


E Axis Decision flow
Is there current or future production of one or more mineral product by the mine/quarry?
Yes
Does the mine/quarry possess an extraction license ordained by the relevant competent authority (Regional, Provincial, Municipal)?
No
Has the project applied for an extraction license from the relevant competent Authority?
Is the mine/quarry supplying mineral products to user/market?
E1.1
E1.2
Are there realistic expectations that all necessary conditions to go into production will be met in a reasonable timeframe? e.g., extraction license is likely to be granted, necessary capital funds are committed, development is pending
E1.2
E2
Is the project foreseen to move towards development? i.e., the project in the final phase of economic and technical evaluation (Feasibility/Prefeasibility study) before applying for extraction license and mine/quarry development
E2
Is the project in possession of an exploration permit for the target resource, granted by the relevant Regional Administration? i.e., EIA has been conducted and submitted along with an operational in accordance to the relevant Regional Administration
E3.3
Is the project in an advanced exploration phase? i.e., carried resource assessment based on detailed geological interpretation
E3.3
Is the mineral resource under technical assessment to better understand the physical properties of the ore deposit? i.e., based on surface and subsurface exploration, regional reconnaissance
E3.2


Does the mine/quarry possess an extraction license ordained by the relevant competent authority (Regional, Provincial, Municipal)?
The mine/quarry provided an overall extraction plan in accordance with the Municipality/Province Mining Plan or the Regional Mining Plan, and underwent the EIA procedure
Regional Mining Plan includes:
❑ Permit holder data
❑ Duration of permit
❑ Type and method of mining
❑ Spatial Plan inc. remediation plan
❑ Concession fees (royalties)
❑ Extractive wastes management
Is the mine/quarry supplying mineral products to user/market?
E1.2
Viable Project: Approvals/permits/contracts are in place, and capital funds have been committed. Mine/quarry is environmental-socio-economic viable but not yet producing e.g., project is under development
E1.1
Viable Project: Mine/quarry is environmental-socio-economic viable i.e., operating continuously or intermittently
Additional Explanation

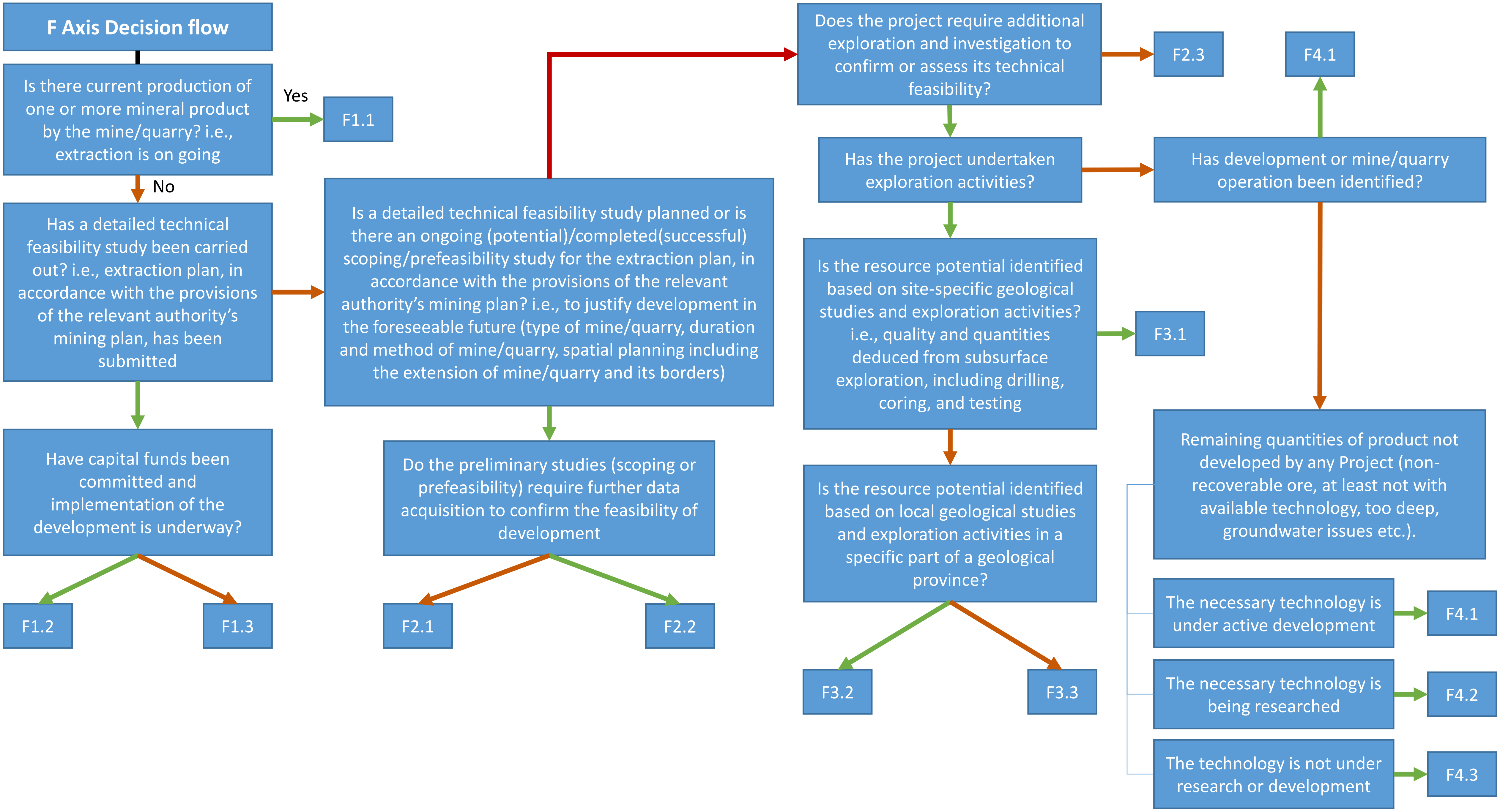

E Axis Decision flow
Is there current or future production of one or more mineral product by the mine/quarry?
No
Has the project applied for an extraction license from the relevant competent Authority?
Are there realistic expectations that all necessary conditions to go into production will be met in a reasonable timeframe? e.g., extraction license is likely to be granted, necessary capital funds are committed, development is pending
Viable Project: Mine/quarry is expected to become environmental-socio-economic viable in the near-term e.g., permits, contracts are pending approval
E1.2
E2
Potentially viable project: Mine/quarry has reasonable prospects for environmental-socio-economic viability in the foreseeable future e.g., extraction license application has been submitted for public enquiry or is being initiated and in the process of being considered

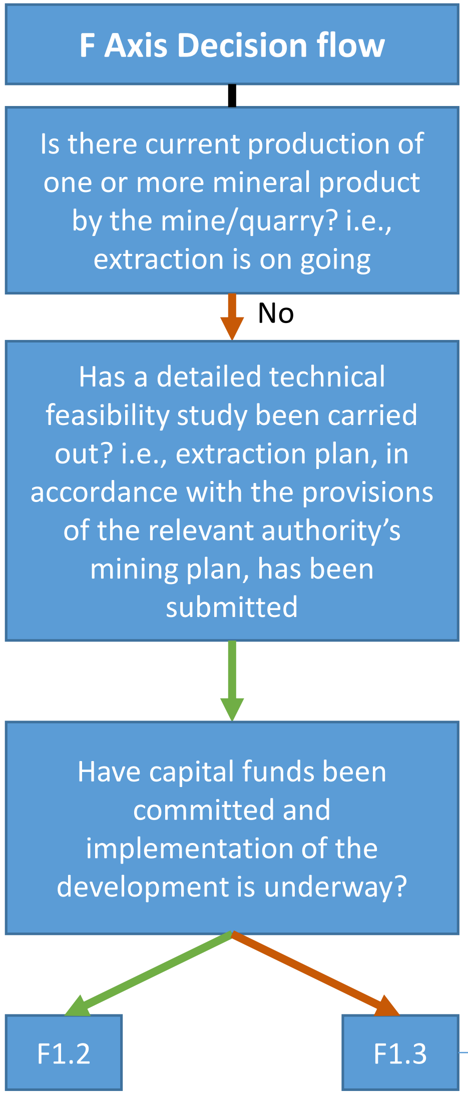

E Axis Decision flow
Is there current or future production of one or more mineral product by the mine/quarry?
No
Has the project applied for an extraction license from the relevant competent Authority?
Is the project foreseen to move towards development? i.e., the project in the final phase of economic and technical evaluation (Feasibility/Prefeasibility study) before applying for extraction license and mine/quarry development
E2
Potentially viable project: Mine/quarry has reasonable prospects for environmental-socio-economic viability in the foreseeable future e.g., exploration is at advanced stages, feasibility studies done or ongoing, ore deposit evaluated, project is promising. Next steps include applying for an extraction license
Is the project in possession of an exploration permit for the target resource, granted by the relevant Regional Administration? i.e., EIA has been conducted and submitted along with an operational in accordance to the relevant Regional Administration
Is the project in an advanced exploration phase? i.e., carried resource assessment based on detailed geological interpretation
E3.3
Prospective Project: More information is needed to determine the environmental-socio-economic viability of the project. Project in early exploration stage to establish potential economic or technical feasibility e.g., identified mineral resources is based on indirect data and/or the necessary regulatory approvals haven't been obtained yet. Next steps include applying for exploration permit to investigate further



E Axis Decision flow
Is there current or future production of one or more mineral product by the mine/quarry?
No
Has the project applied for an extraction license from the relevant competent Authority?
Is the project foreseen to move towards development? i.e., the project in the final phase of economic and technical evaluation (Feasibility/Prefeasibility study) before applying for extraction license and mine/quarry development
Is the project in possession of an exploration permit for the target resource, granted by the relevant Regional Administration? i.e., EIA has been conducted and submitted along with an operational in accordance to the relevant Regional Administration
Is the project in an advanced exploration phase? i.e., carried resource assessment based on detailed geological interpretation
Non viable Project: It is currently considered that there are not Reasonable Prospects for environmental-socio-economic viability of mining in the Foreseeable Future; or, environmental- socio-economic viability cannot yet be determined due to insufficient information (e.g., during prospecting and exploration). High social opposition and/or EIA did not yield positively
E3.3
Is the mineral resource under technical assessment to better understand the physical properties of the ore deposit? i.e., based on surface and subsurface exploration, regional reconnaissance
Non viable Project:
Development is unclarified, Environmental-socio-economic viability cannot yet be determined due to insufficient information e.g., High social opposition and/or EIA did not yield positively or mine/quarry is closed, abandoned, or historic and/or the identified mineral resource is based on historic and/or low-quality data. Further exploration is pending
E3.2

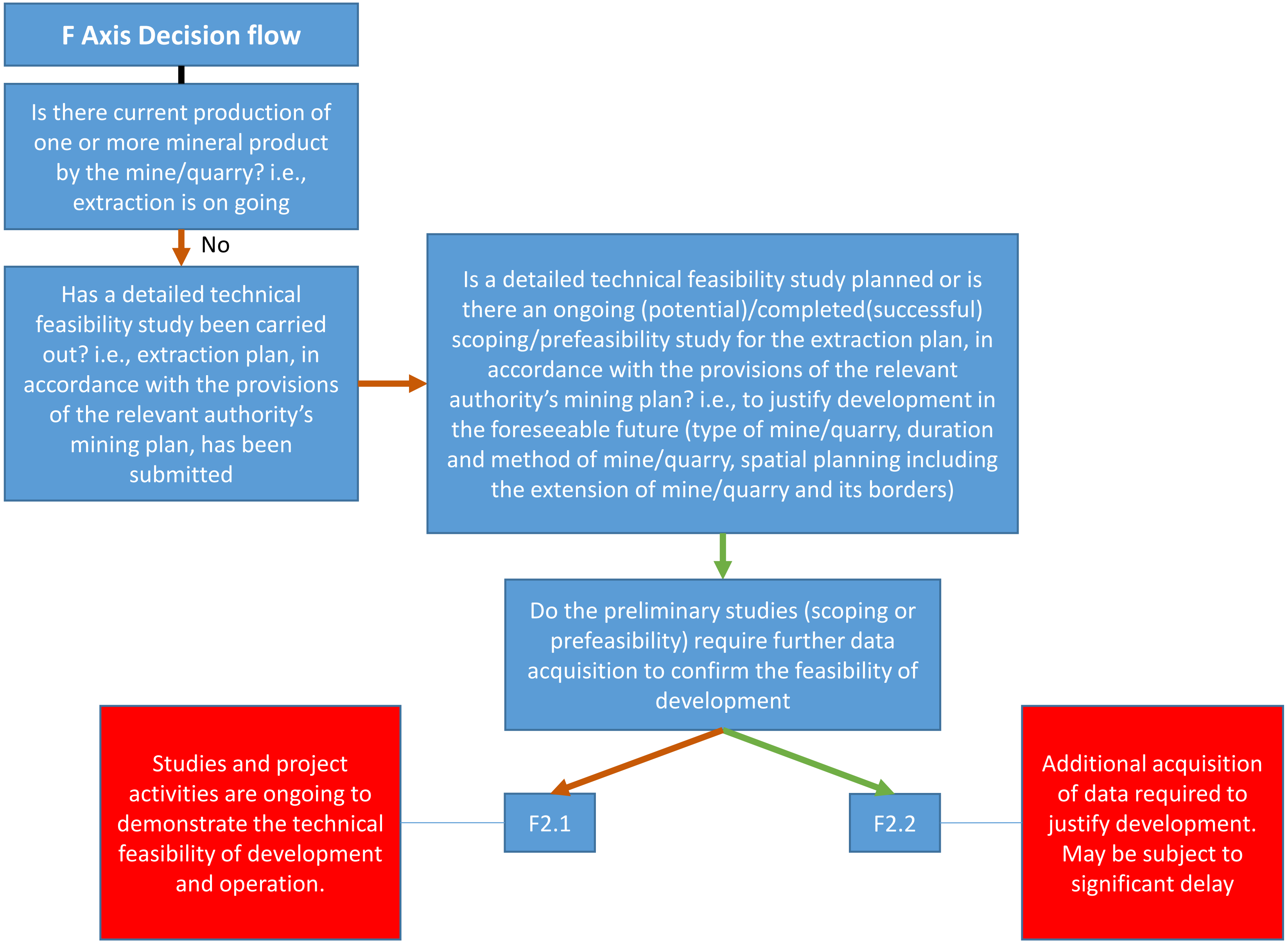
F axis decision tree

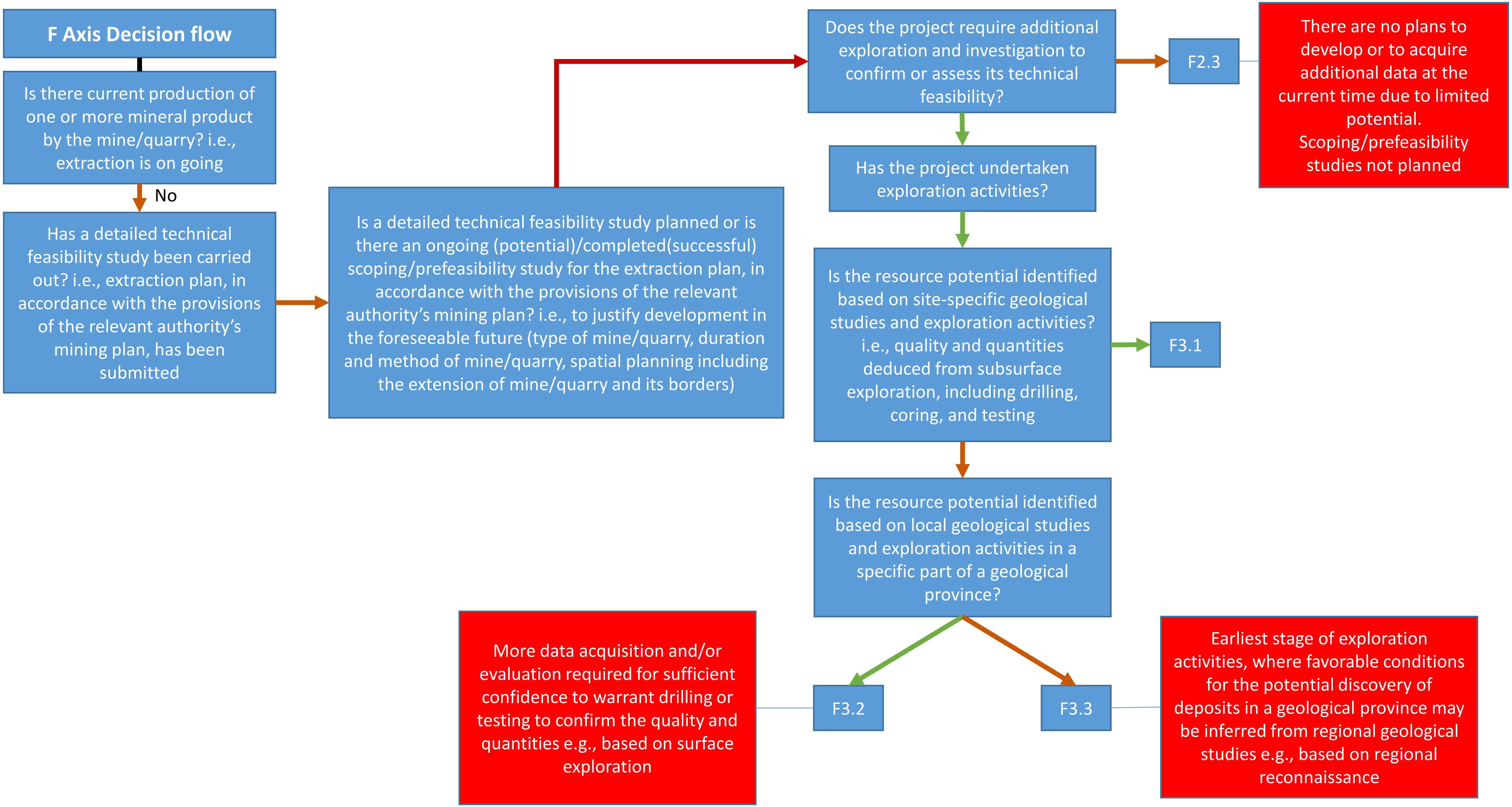

F Axis Decision flow
Is there current production of one or more mineral product by the mine/quarry? i.e., extraction is on going
Yes
F1.1
No
Has a detailed technical feasibility study been carried out? i.e., extraction plan, in accordance with the provisions of the relevant authority's mining plan, has been submitted
Have capital funds been committed and implementation of the development is underway?
F1.2
F1.3
Is a detailed technical feasibility study planned or is there an ongoing (potential)/completed(successful) scoping/prefeasibility study for the extraction plan, in accordance with the provisions of the relevant authority's mining plan? i.e., to justify development in the foreseeable future (type of mine/quarry, duration and method of mine/quarry, spatial planning including the extension of mine/quarry and its borders)
Do the preliminary studies (scoping or prefeasibility) require further data acquisition to confirm the feasibility of development
F2.1
F2.2
Does the project require additional exploration and investigation to confirm or assess its technical feasibility?
F2.3
Has the project undertaken exploration activities?
Is the resource potential identified based on site-specific geological studies and exploration activities? i.e., quality and quantities deduced from subsurface exploration, including drilling, coring, and testing
F3.1
Is the resource potential identified based on local geological studies and exploration activities in a specific part of a geological province?
F3.2
F3.3
F4.1
Has development or mine/quarry operation been identified?
Remaining quantities of product not developed by any Project (non-recoverable ore, at least not with available technology, too deep, groundwater issues etc.).
The necessary technology is under active development
F4.1
The necessary technology is being researched
F4.2
The technology is not under research or development
F4.3



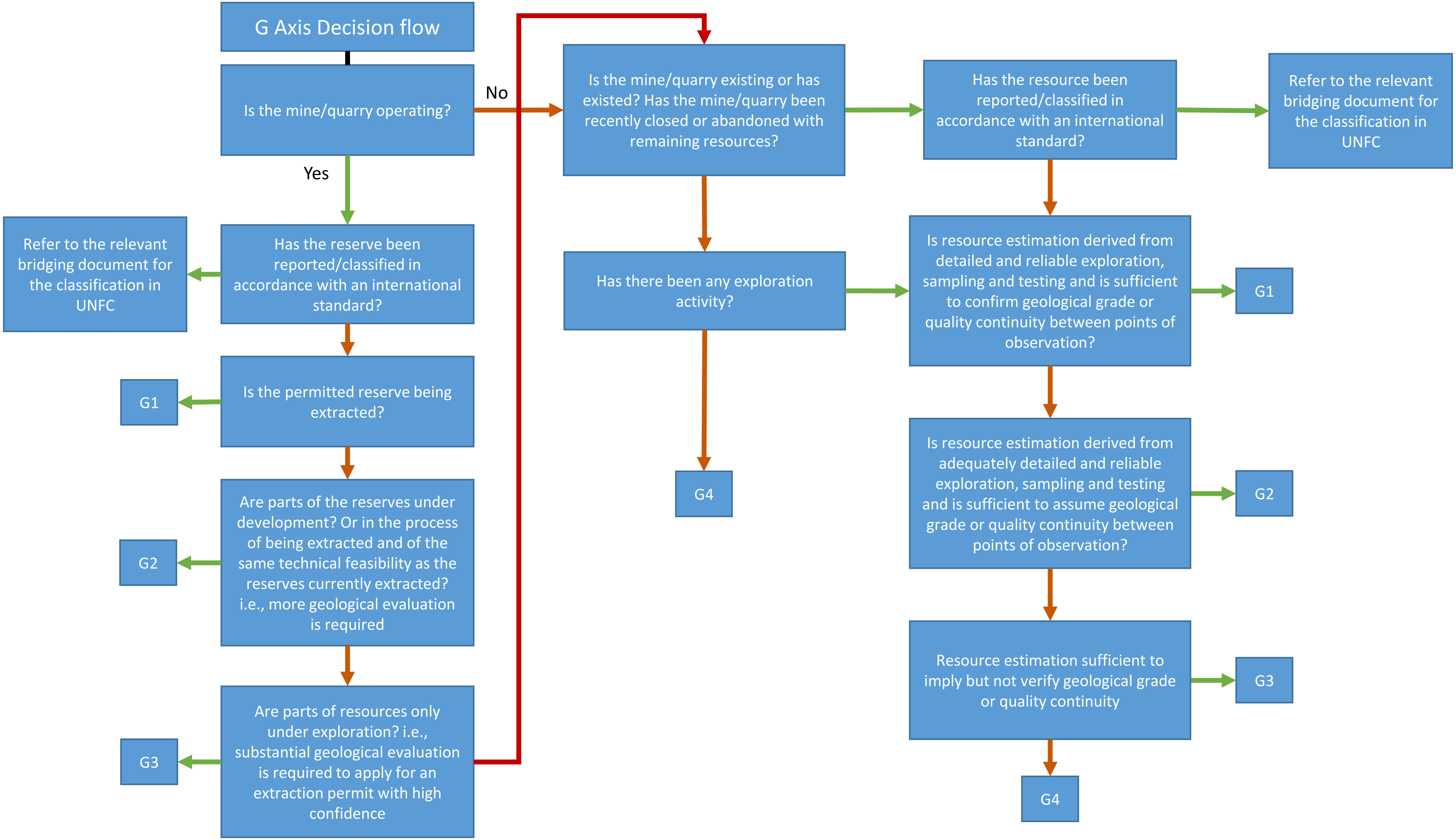
Studies have been completed to demonstrate the technical feasibility of development and operation. There shall be a reasonable expectation that all necessary approvals/contracts for the Project to proceed to development will be forthcoming. The project is likely to be successful based on technological consideration.

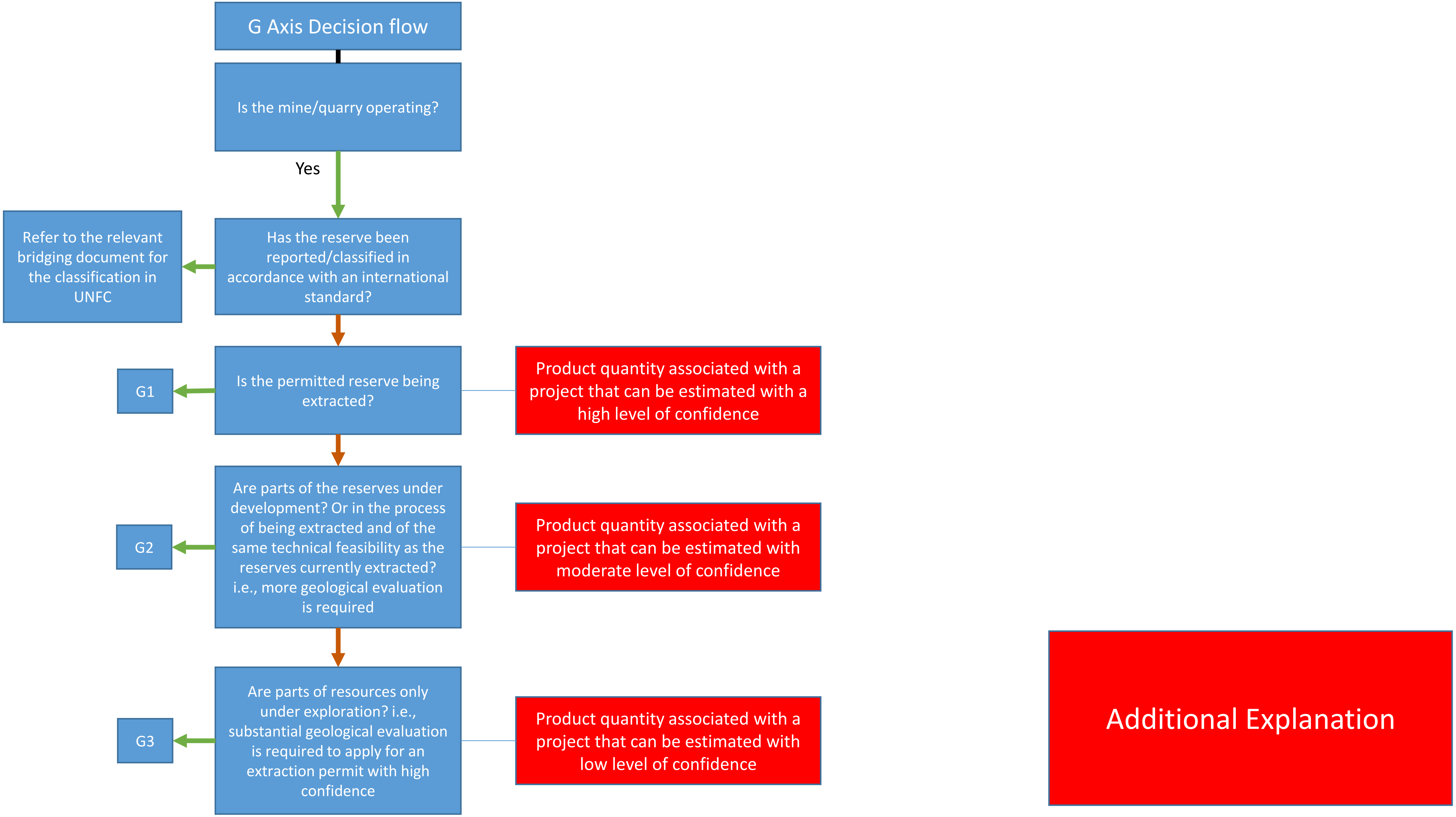
Additional Explanation

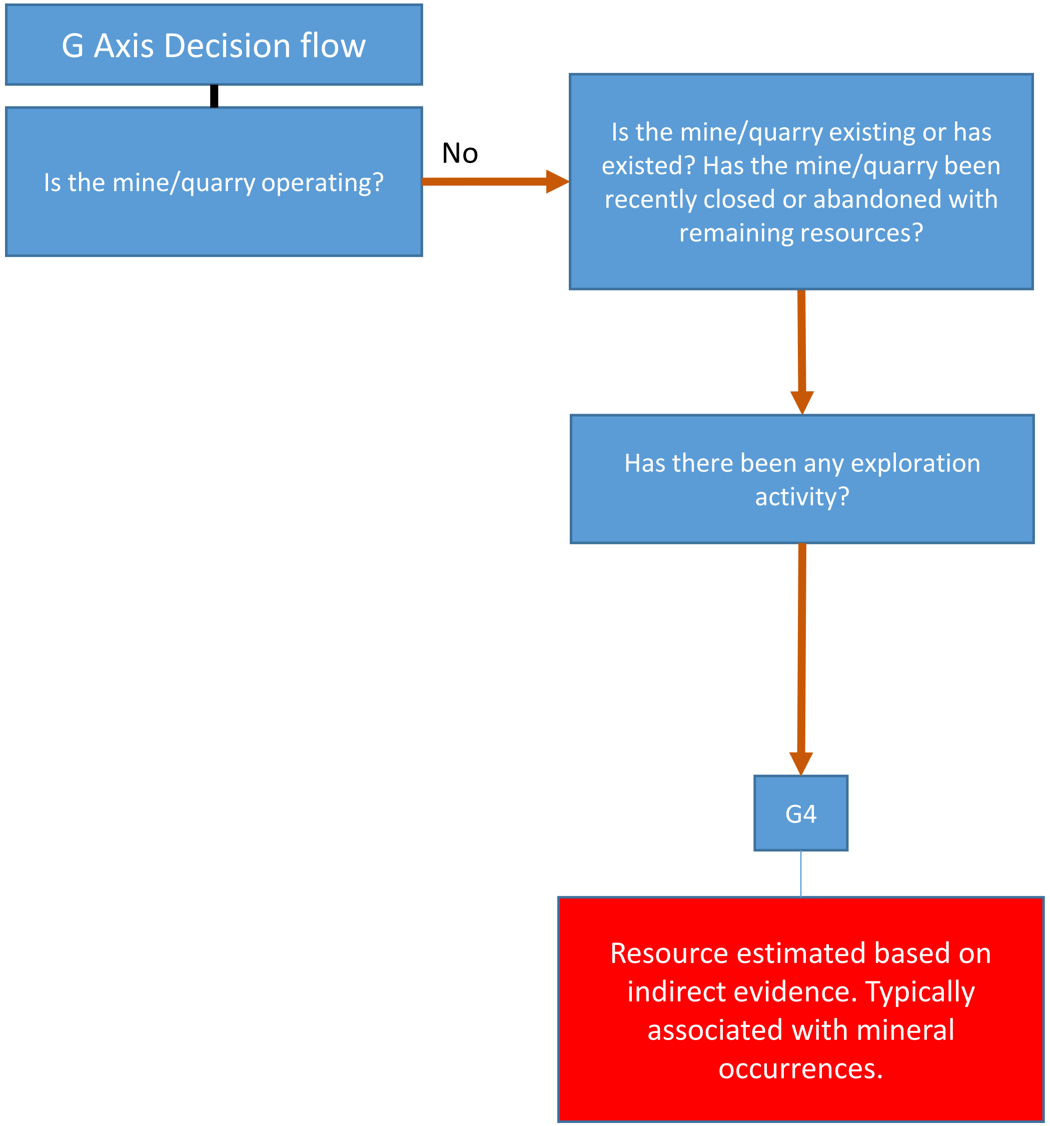

F Axis Decision flow
Is there current production of one or more mineral product by the mine/quarry? i.e., extraction is on going
No
Has a detailed technical feasibility study been carried out? i.e., extraction plan, in accordance with the provisions of the relevant authority's mining plan, has been submitted
Is a detailed technical feasibility study planned or is there an ongoing (potential)/completed(successful) scoping/prefeasibility study for the extraction plan, in accordance with the provisions of the relevant authority's mining plan? i.e., to justify development in the foreseeable future (type of mine/quarry, duration and method of mine/quarry, spatial planning including the extension of mine/quarry and its borders)
Do the preliminary studies (scoping or prefeasibility) require further data acquisition to confirm the feasibility of development
Studies and project activities are ongoing to demonstrate the technical feasibility of development and operation.
F2.1
F2.2
Additional acquisition of data required to justify development. May be subject to significant delay

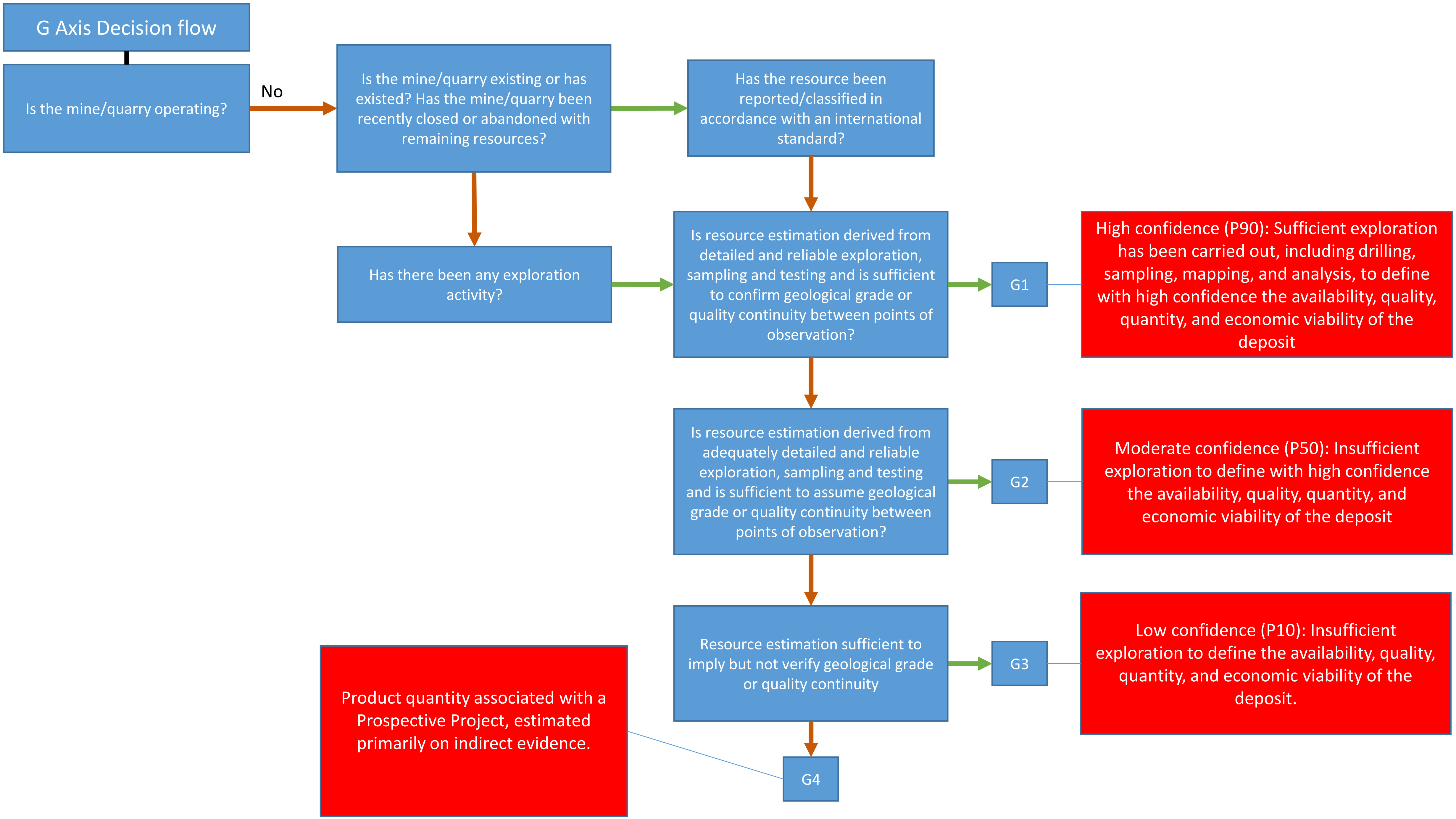

F Axis Decision flow
Is there current production of one or more mineral product by the mine/quarry? i.e., extraction is on going
No
Has a detailed technical feasibility study been carried out? i.e., extraction plan, in accordance with the provisions of the relevant authority’s mining plan, has been submitted
Is a detailed technical feasibility study planned or is there an ongoing (potential)/completed(successful) scoping/prefeasibility study for the extraction plan, in accordance with the provisions of the relevant authority’s mining plan? i.e., to justify development in the foreseeable future (type of mine/quarry, duration and method of mine/quarry, spatial planning including the extension of mine/quarry and its borders)
Does the project require additional exploration and investigation to confirm or assess its technical feasibility?
F2.3
There are no plans to develop or to acquire additional data at the current time due to limited potential. Scoping/prefeasibility studies not planned
Has the project undertaken exploration activities?
Is the resource potential identified based on site-specific geological studies and exploration activities? i.e., quality and quantities deduced from subsurface exploration, including drilling, coring, and testing
F3.1
Is the resource potential identified based on local geological studies and exploration activities in a specific part of a geological province?
More data acquisition and/or evaluation required for sufficient confidence to warrant drilling or testing to confirm the quality and quantities e.g., based on surface exploration
F3.2
F3.3
Earliest stage of exploration activities, where favorable conditions for the potential discovery of deposits in a geological province may be inferred from regional geological studies e.g., based on regional reconnaissance

G axis decision tree


G Axis Decision flow
Is the mine/quarry operating?
No
Yes
Has the reserve been reported/classified in accordance with an international standard?
Refer to the relevant bridging document for the classification in UNFC
Is the permitted reserve being extracted?
G1
Are parts of the reserves under development? Or in the process of being extracted and of the same technical feasibility as the reserves currently extracted? i.e., more geological evaluation is required
G2
Are parts of resources only under exploration? i.e., substantial geological evaluation is required to apply for an extraction permit with high confidence
G3
Is the mine/quarry existing or has existed? Has the mine/quarry been recently closed or abandoned with remaining resources?
Has there been any exploration activity?
G4
Has the resource been reported/classified in accordance with an international standard?
Refer to the relevant bridging document for the classification in UNFC
Is resource estimation derived from detailed and reliable exploration, sampling and testing and is sufficient to confirm geological grade or quality continuity between points of observation?
G1
Is resource estimation derived from adequately detailed and reliable exploration, sampling and testing and is sufficient to assume geological grade or quality continuity between points of observation?
G2
Resource estimation sufficient to imply but not verify geological grade or quality continuity
G3
G4


G Axis Decision flow
Is the mine/quarry operating?
Yes
Has the reserve been reported/classified in accordance with an international standard?
Refer to the relevant bridging document for the classification in UNFC
Is the permitted reserve being extracted?
G1
Product quantity associated with a project that can be estimated with a high level of confidence
Are parts of the reserves under development? Or in the process of being extracted and of the same technical feasibility as the reserves currently extracted? i.e., more geological evaluation is required
G2
Product quantity associated with a project that can be estimated with moderate level of confidence
Are parts of resources only under exploration? i.e., substantial geological evaluation is required to apply for an extraction permit with high confidence
G3
Product quantity associated with a project that can be estimated with low level of confidence
Additional Explanation

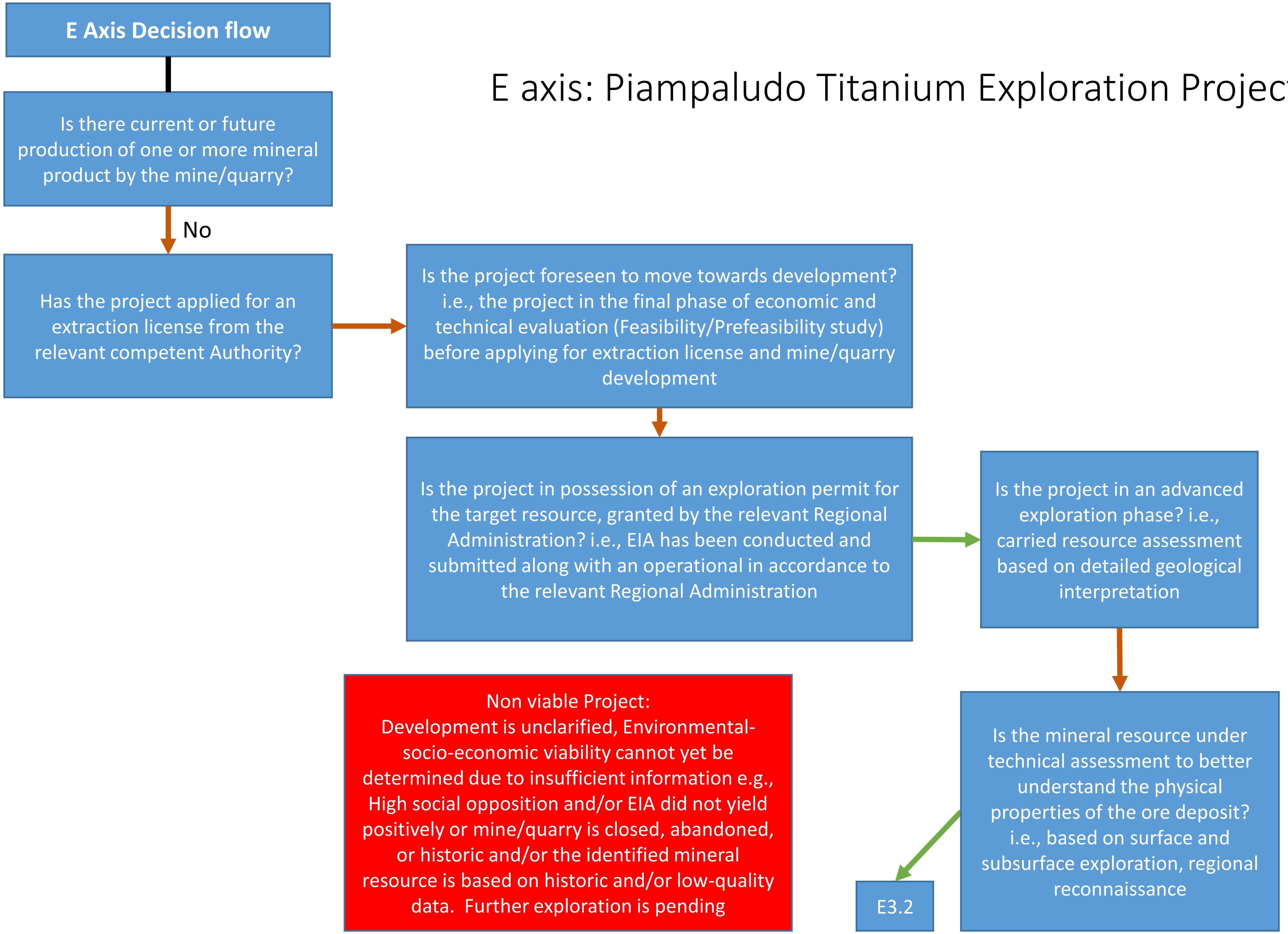

G Axis Decision flow
Is the mine/quarry operating?
No
Is the mine/quarry existing or has existed? Has the mine/quarry been recently closed or abandoned with remaining resources?
Has there been any exploration activity?
G4
Resource estimated based on indirect evidence. Typically associated with mineral occurrences.


G Axis Decision flow
Is the mine/quarry operating?
No
Is the mine/quarry existing or has existed? Has the mine/quarry been recently closed or abandoned with remaining resources?
Has the resource been reported/classified in accordance with an international standard?
Has there been any exploration activity?
Is resource estimation derived from detailed and reliable exploration, sampling and testing and is sufficient to confirm geological grade or quality continuity between points of observation?
G1
High confidence (P90): Sufficient exploration has been carried out, including drilling, sampling, mapping, and analysis, to define with high confidence the availability, quality, quantity, and economic viability of the deposit
Is resource estimation derived from adequately detailed and reliable exploration, sampling and testing and is sufficient to assume geological grade or quality continuity between points of observation?
G2
Moderate confidence (P50): Insufficient exploration to define with high confidence the availability, quality, quantity, and economic viability of the deposit
Resource estimation sufficient to imply but not verify geological grade or quality continuity
G3
Low confidence (P10): Insufficient exploration to define the availability, quality, quantity, and economic viability of the deposit.
Product quantity associated with a Prospective Project, estimated primarily on indirect evidence.
G4

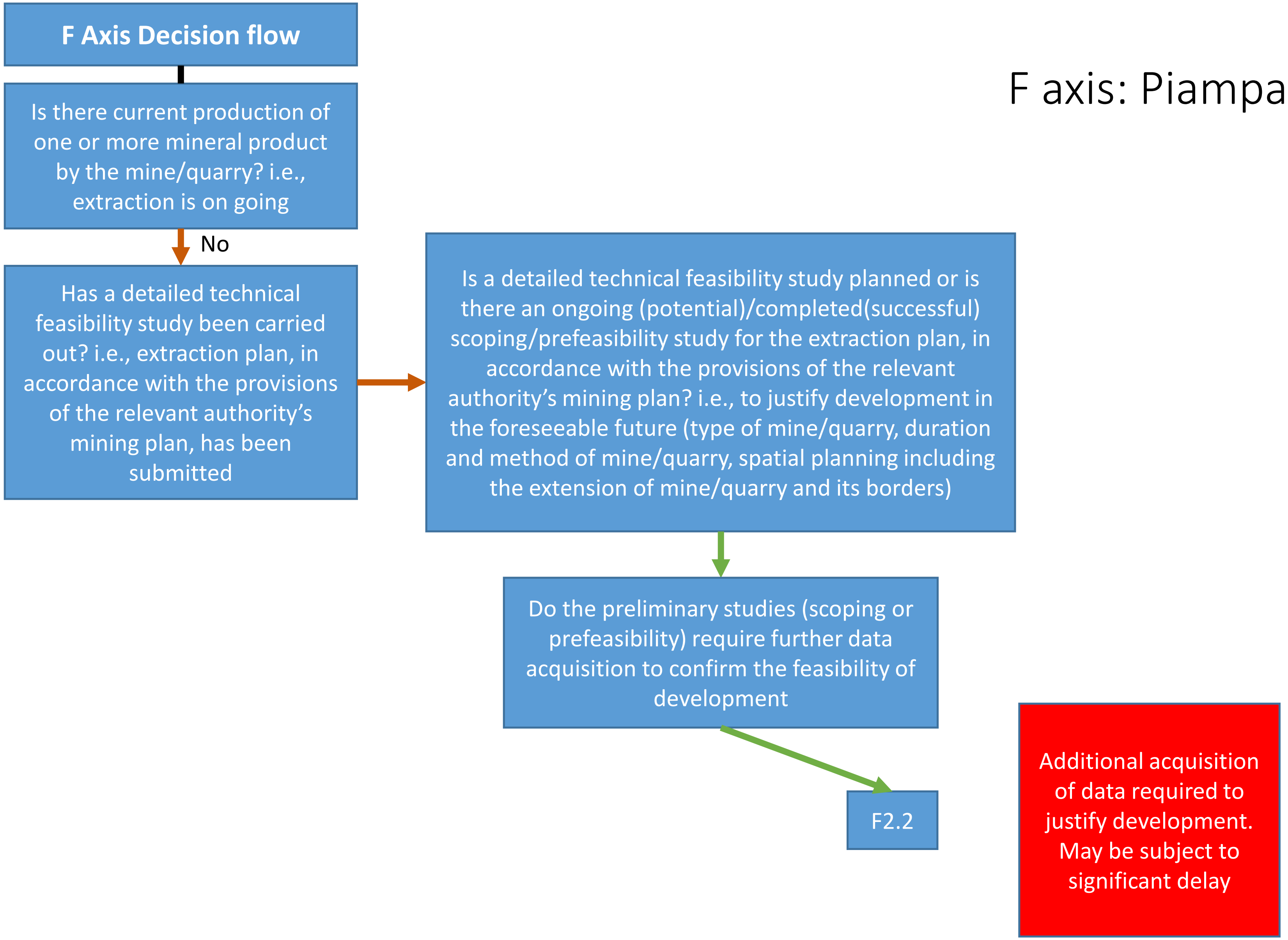
Testing the UNFC decision trees

1. Piampaludo
2. Gorno

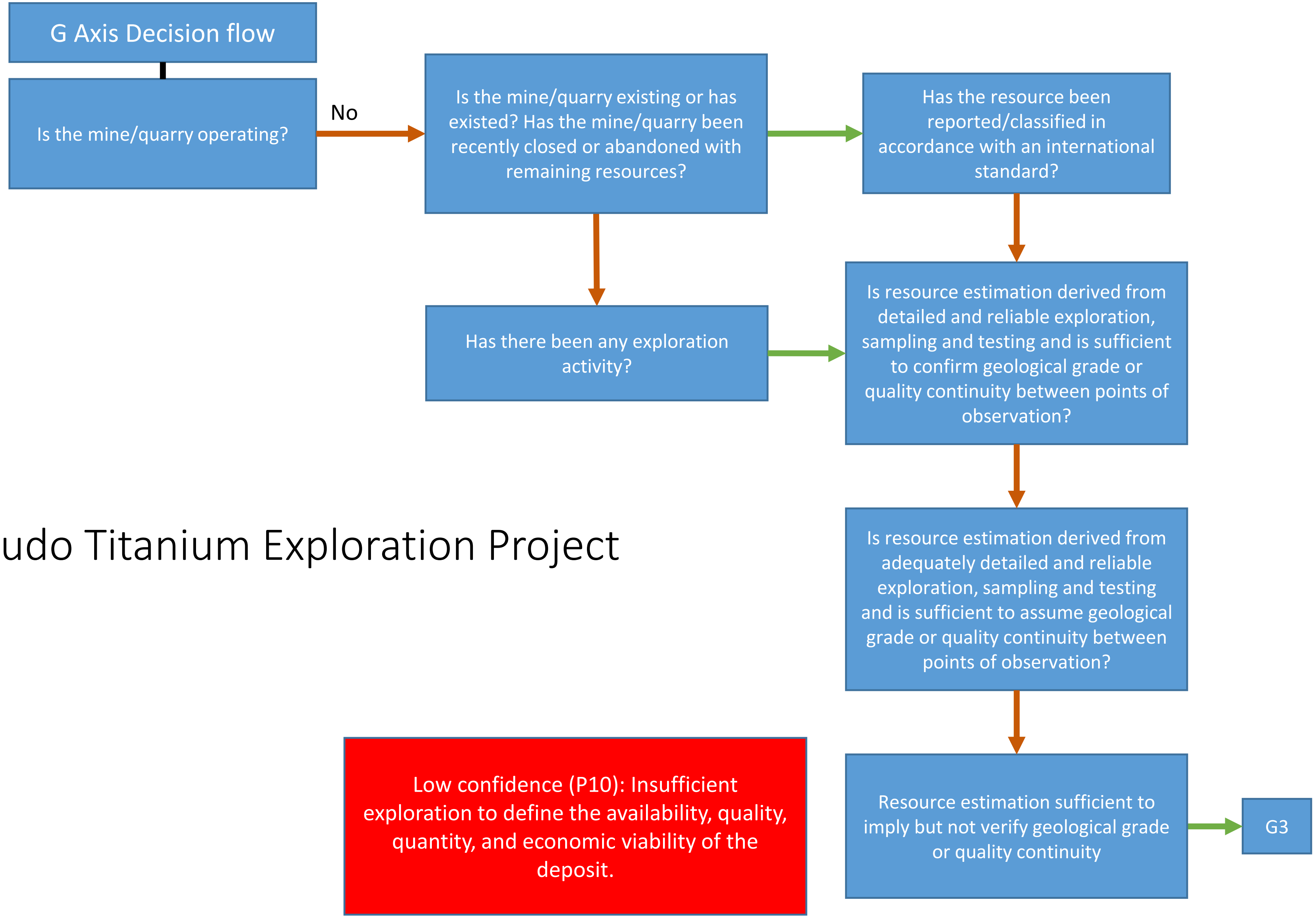
E axis: Piampaludo Titanium Exploration Project

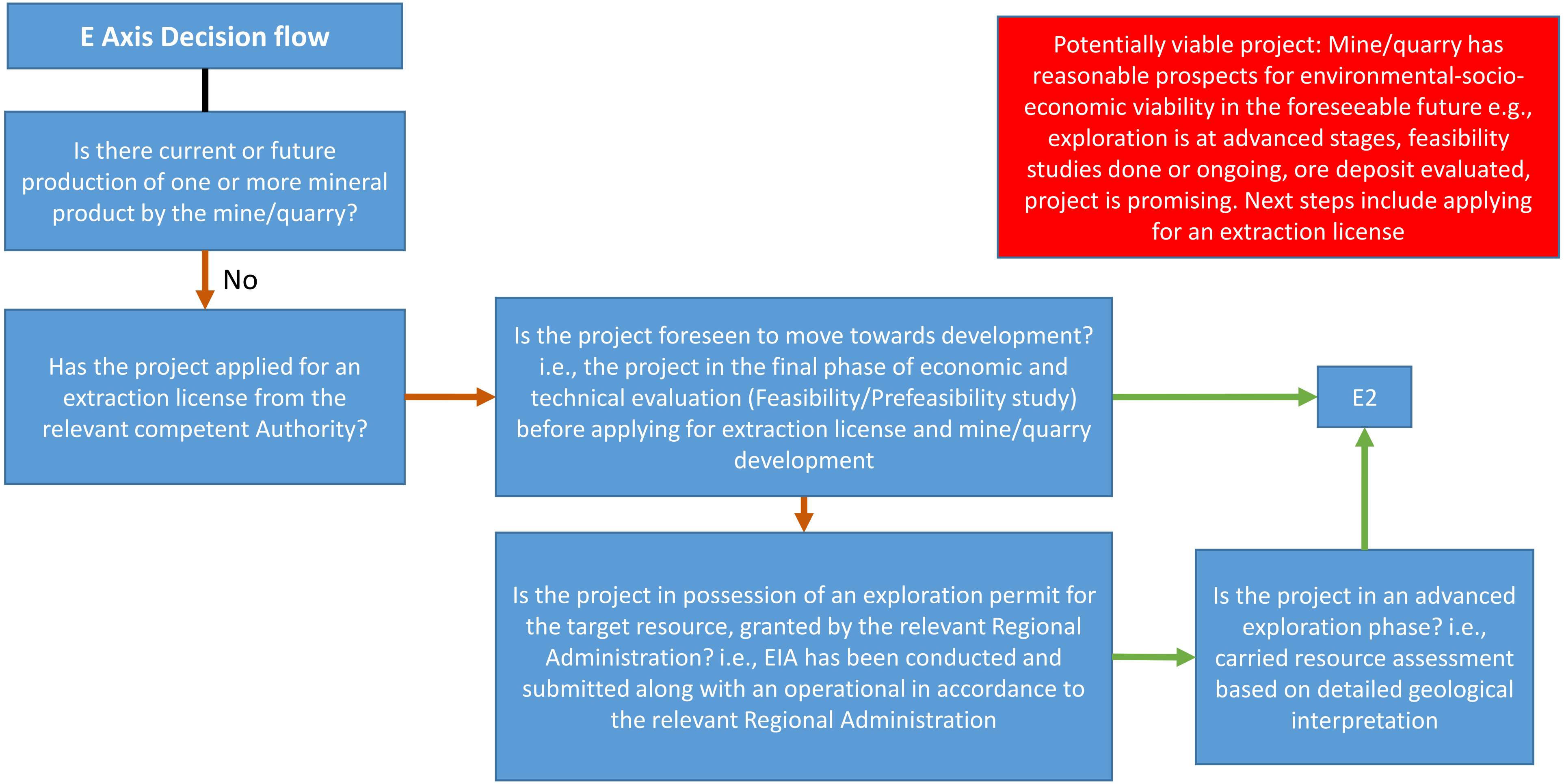


F axis: Piampaludo Titanium Exploration Project



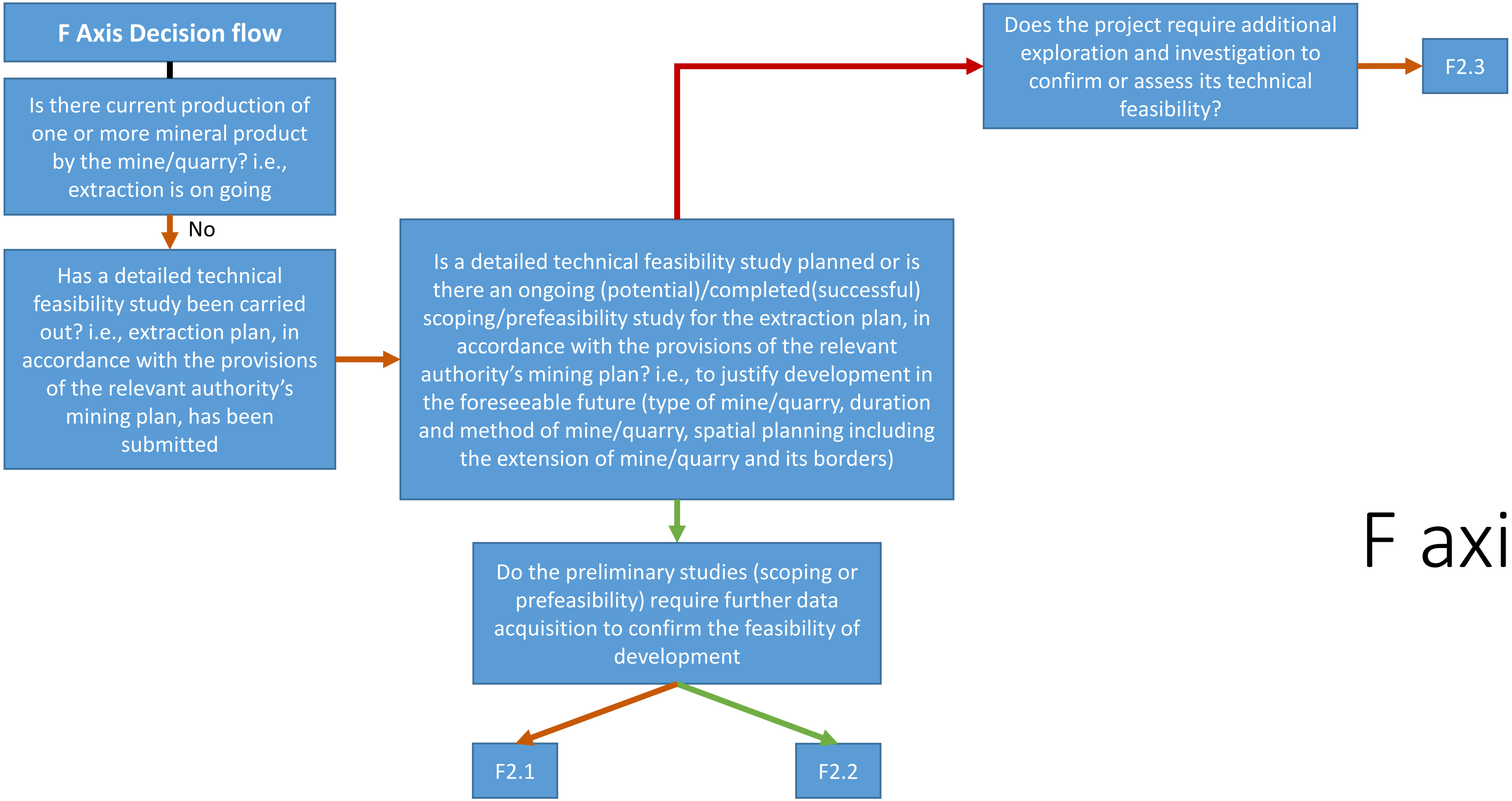
G axis: Piampaludo Titanium Exploration Project



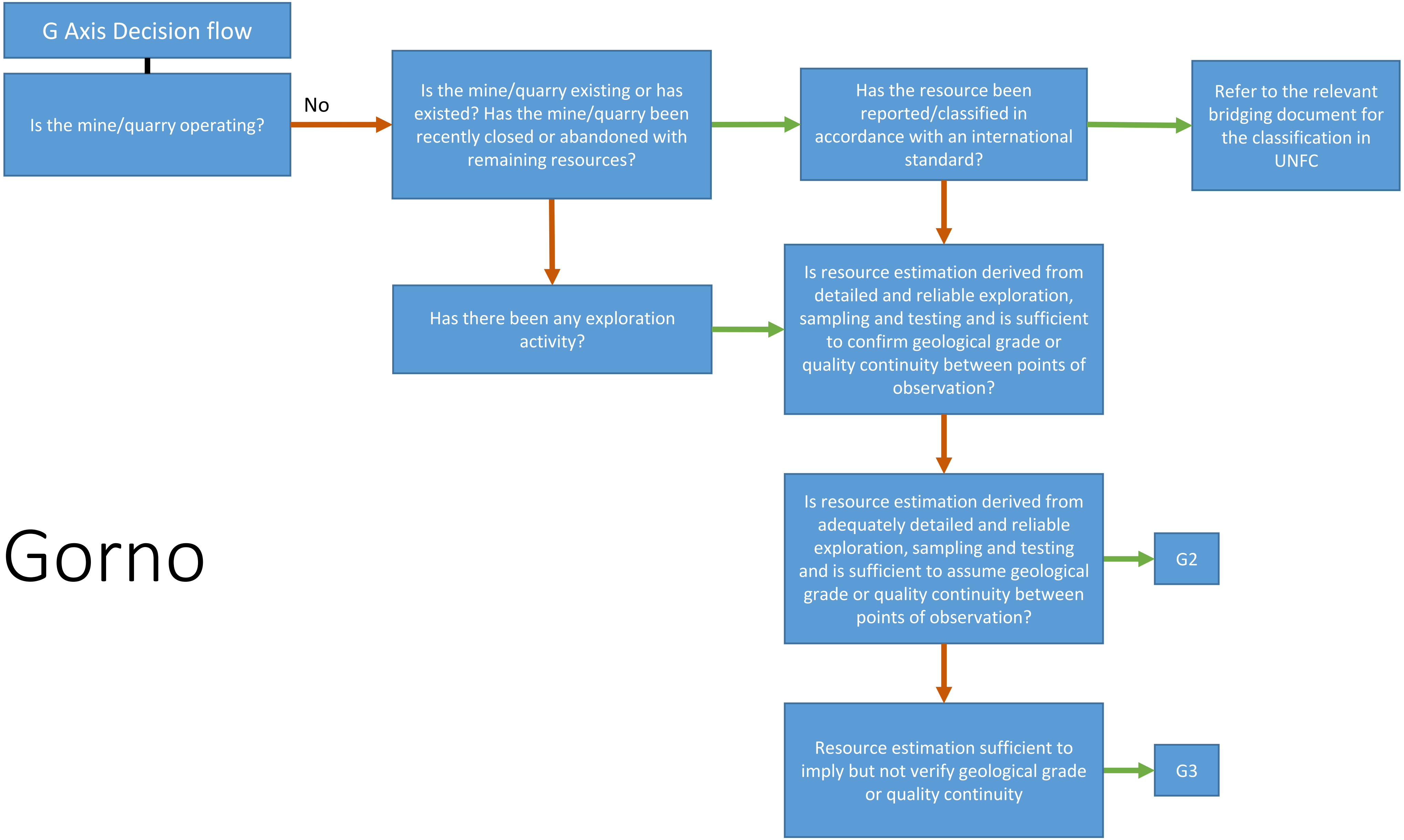

E Axis Decision flow
Is there current or future production of one or more mineral product by the mine/quarry?
No
Has the project applied for an extraction license from the relevant competent Authority?
Is the project foreseen to move towards development? i.e., the project in the final phase of economic and technical evaluation (Feasibility/Prefeasibility study) before applying for extraction license and mine/quarry development
E2
Is the project in possession of an exploration permit for the target resource, granted by the relevant Regional Administration? i.e., EIA has been conducted and submitted along with an operational in accordance to the relevant Regional Administration
Is the project in an advanced exploration phase? i.e., carried resource assessment based on detailed geological interpretation
Potentially viable project: Mine/quarry has reasonable prospects for environmental-socio-economic viability in the foreseeable future e.g., exploration is at advanced stages, feasibility studies done or ongoing, ore deposit evaluated, project is promising. Next steps include applying for an extraction license

E axis: Gorno

F axis: Gorno


F Axis Decision flow
Is there current production of one or more mineral product by the mine/quarry? i.e., extraction is on going
No
Has a detailed technical feasibility study been carried out? i.e., extraction plan, in accordance with the provisions of the relevant authority's mining plan, has been submitted
Is a detailed technical feasibility study planned or is there an ongoing (potential)/completed(successful) scoping/prefeasibility study for the extraction plan, in accordance with the provisions of the relevant authority's mining plan? i.e., to justify development in the foreseeable future (type of mine/quarry, duration and method of mine/quarry, spatial planning including the extension of mine/quarry and its borders)
Does the project require additional exploration and investigation to confirm or assess its technical feasibility?
F2.3
Do the preliminary studies (scoping or prefeasibility) require further data acquisition to confirm the feasibility of development
F2.1
F2.2

G axis: Gorno


G Axis Decision flow
Is the mine/quarry operating?
No
Is the mine/quarry existing or has existed? Has the mine/quarry been recently closed or abandoned with remaining resources?
Has the resource been reported/classified in accordance with an international standard?
Refer to the relevant bridging document for the classification in UNFC
Has there been any exploration activity?
Is resource estimation derived from detailed and reliable exploration, sampling and testing and is sufficient to confirm geological grade or quality continuity between points of observation?
Is resource estimation derived from adequately detailed and reliable exploration, sampling and testing and is sufficient to assume geological grade or quality continuity between points of observation?
G2
Resource estimation sufficient to imply but not verify geological grade or quality continuity
G3

Appendix F – UNFC National Guidance Template

UNFC National Guidance Template

*The purpose of this document is to guide EU countries in aligning their **respective resource classification systems** with the **UN Framework Classification for Resources (UNFC)**. In countries where no mandatory reporting and/or classification system exists, alignment of national framework/context with UNFC is suggested, for a direct application of UNFC to national raw materials. This document is designed for EU Member States planning to develop a National UNFC Guidance document, and ultimately ensure consistency, reliability, and transparency at European level.*

Mapping national resource classification systems to UNFC is a critical step in ensuring standardized, transparent, and consistent resource management across various EU jurisdictions, and achieving harmonized reporting at EU level. Given the variation in national systems (in Europe, countries either follow 1) a GKZ-based national system; 2) a unique country-specific system; 3) international reporting standards; 4) No national specifications for reporting) this document presents a high-level approach to mapping key terms, definitions, and classification criteria to UNFC. The overarching goal is to establish a common framework that facilitates comparability and interoperability between national and international classification schemes with UNFC.

1. Introduction

1.1. National System / Framework

[*Describe the classification and/or reporting for minerals applied within national jurisdictions*]

1.2. UNFC (2019)

The United Nations Framework Classification for Resources (UNFC) is a principles-based classification tool applicable to resource projects using three fundamental criteria:

- E-axis, the environmental-socio-economic viability;
- F-axis, technical feasibility; and
- G-axis, degree of confidence in resource estimates.

These criteria are combined to determine whether a resource project is viable, feasible, and supported by reliable data. UNFC provides a universal, adaptable, and transparent classification tool that allows for standardized resource-project assessments across different industries and jurisdictions. UNFC supports sustainable resource management and informed decision-making, ensuring that resources are evaluated comprehensively and consistently worldwide.

The E-axis classifies the favorability of external conditions that influence a project’s viability, including economical factors, regulatory and legal requirements, social and environmental considerations, and contractual obligations. The F-axis evaluates the maturity of the project, taking into account technical studies, maturity progress, and the necessary commitments for implementation. Projects classified along this axis range from conceptual studies to fully developed operations. The G-axis classifies the level of confidence in product estimates, evaluating based on the certainty of the underlying data, which is essential for transparent and reliable assessments.

UNFC operates as a three-dimensional system, where the combination of E, F, and G categories defines the classification of a resource (Figure 1). Each category (e.g., E1, E2, E3) and sub-category (e.g., E1.1, E1.2) contributes to a structured classification framework. These are combined into numerical codes (e.g., E1; F1; G1 or simply 111) that remain consistent across applications. The classification can be visualized in a three-dimensional model or simplified into a two-dimensional version for practical use.

Figure 1: UNFC Categories and Examples of Classes[1]

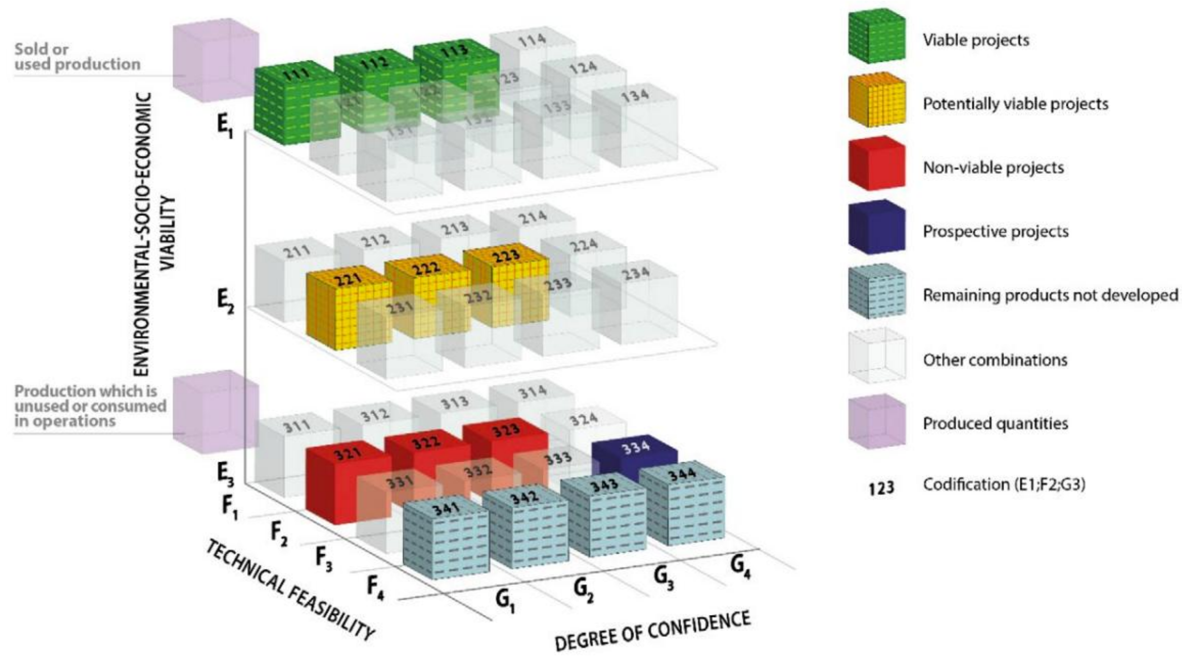


Figure 2: Abbreviated Version of UNFC, showing Primary Classes[1]

[1] United Nations Economic Commission for Europe (UNECE), "United Nations Framework Classification for Resources Update 2019", United Nations, 2019

<table>
<tr><td rowspan="10">Total Products</td><td rowspan="2">Produced</td><td colspan="4">Sold or used production</td></tr>
<tr><td colspan="4">Production which is unused or consumed in operations[a]</td></tr>
<tr><td rowspan="2"></td><td rowspan="2">Class</td><td colspan="3">Minimum Categories</td></tr>
<tr><td>E</td><td>F</td><td>G[b]</td></tr>
<tr><td>The project's environmental-socio-economic viability and technical feasibility has been confirmed</td><td>Viable Projects[c]</td><td>1</td><td>1</td><td>1, 2, 3</td></tr>
<tr><td rowspan="2">The project's environmental-socio-economic viability and/or technical feasibility has yet to be confirmed</td><td>Potentially Viable Projects[d]</td><td>2[e]</td><td>2</td><td>1, 2, 3</td></tr>
<tr><td>Non-Viable Projects[f]</td><td>3</td><td>2</td><td>1, 2, 3</td></tr>
<tr><td colspan="2">Remaining products not developed from identified projects[g]</td><td>3</td><td>4</td><td>1, 2, 3</td></tr>
<tr><td>There is insufficient information on the source to assess the project's environmental-socio-economic viability and technical feasibility</td><td>Prospective Projects</td><td>3</td><td>3</td><td>4</td></tr>
<tr><td colspan="2">Remaining products not developed from prospective projects[g]</td><td>3</td><td>4</td><td>4</td></tr>
</table>

a. Future production that is either unused or consumed in the project operations is categorized as E3.1. These can exist for all classes of recoverable quantities.

b. G categories may be used discretely, or in cumulative scenario form (e.g. G1+G2).

c. Estimates associated with Viable Projects are defined in many classification systems as Reserves, but there are some material differences between the specific definitions that are applied within different industries and hence the term is not used here.

d. Not all Potentially Viable Projects will be developed.

e. Potentially Viable Projects may satisfy the requirements for E1.

f. Non-Viable Projects include those that are at an early stage of evaluation in addition to those that are considered unlikely to become viable developments within the foreseeable future.

g. Remaining products not developed from identified projects or prospective projects may become developable in the future as technological or environmental-socio-economic conditions change. Some or all of these estimates may never be developed due to physical and/or environmental-socio-economic constraints. This classification may be of less value to renewable resource projects but can still be used to indicate the amount of unrealized potential. It is emphasised that the remaining products are quantities which, if produced, could be bought, sold or used (i.e. electricity, heat, etc., not wind, solar irradiation, etc.).

Product estimates in UNFC always involve a degree of uncertainty, which can be expressed either through discrete confidence levels or scenario-based approaches. The discrete method categorizes estimates into high confidence (G1), moderate confidence (G2), and low confidence (G3). These estimates can be determined using deterministic or probabilistic methods, depending on the data available. UNFC organizes projects into common classification groups based on their viability and maturity. Viable projects (E1; F1; G1-G3) are those with clear economic, social, and technical feasibility, while Potentially Viable projects (E2; F2; G1-G3) require further evaluation before development can proceed. Non-viable projects (E3; F2-F3; G1-G3) are those that cannot be developed under current conditions, and Prospective projects (E3; F3; G1-G4) represent early-stage developments with insufficient data for classification. Additionally, remaining products not developed (E3; F4; G1-G4) account for products that are not currently planned for extraction (Figure 3).

Figure 3: UNFC Classes and Sub-classes defined by Sub-categories[1]

<table>
<tr><th colspan="7">UNFC Classes Defined by Categories and Sub-categories</th></tr>
<tr><td rowspan="14">Total Products</td><td rowspan="2">Produced</td><td colspan="5">Sold or used production</td></tr>
<tr><td colspan="5">Production which is unused or consumed in operations</td></tr>
<tr><td colspan="2" rowspan="2">Class</td><td rowspan="2">Sub-class</td><td colspan="3">Categories</td></tr>
<tr><td>E</td><td>F</td><td>G</td></tr>
<tr><td rowspan="8">Known Sources</td><td rowspan="3">Viable Projects</td><td>On Production</td><td>1</td><td>1.1</td><td>1, 2, 3</td></tr>
<tr><td>Approved for Development</td><td>1</td><td>1.2</td><td>1, 2, 3</td></tr>
<tr><td>Justified for Development</td><td>1</td><td>1.3</td><td>1, 2, 3</td></tr>
<tr><td rowspan="2">Potentially Viable Projects</td><td>Development Pending</td><td>2</td><td>2.1</td><td>1, 2, 3</td></tr>
<tr><td>Development On Hold</td><td>2</td><td>2.2</td><td>1, 2, 3</td></tr>
<tr><td rowspan="2">Non-Viable Projects</td><td>Development Unclarified</td><td>3.2</td><td>2.2</td><td>1, 2, 3</td></tr>
<tr><td>Development Not Viable</td><td>3.3</td><td>2.3</td><td>1, 2, 3</td></tr>
<tr><td colspan="2">Remaining products not developed from identified projects</td><td>3.3</td><td>4</td><td>1, 2, 3</td></tr>
<tr><td rowspan="2">Potential Sources</td><td>Prospective Projects</td><td>[No sub-classes defined]</td><td>3.2</td><td>3</td><td>4</td></tr>
<tr><td colspan="2">Remaining products not developed from prospective projects</td><td>3.3</td><td>4</td><td>4</td></tr>
</table>

Although UNFC is a standardized international tool, it is flexible enough to be adapted to national and regional needs. Any modifications should maintain consistency with the full UNFC framework, and any deviations should be clearly documented for transparency. A complete UNFC classification report must include the project category and classification, references to underlying data sources such as feasibility studies and environmental impact assessments, and, if bridging from another classification system, a citation of the original report. Additionally, the evaluator's name, affiliation, and the effective date of the classification must be included to ensure accountability and reliability.

1.2.1. Minerals and Anthropogenic Resources Specifications

UNFC Specifications for Minerals and Anthropogenic Resources provide detailed guidance on applying UNFC to mineral projects and anthropogenic projects (secondary raw materials). While UNFC was originally designed as a generic classification framework for all resource types, its sector-specific adaptations ensure a more precise application in different industries.

Minerals Specifications

For mineral projects, the Supplementary Specifications for the Application of UNFC to Minerals[2], published in 2021, refine the framework's application to metal ores, coal, technical minerals, and aggregates. These

[2] https://unece.org/sites/default/files/2022-01/UNFC%20Mineral%20Specifications%202021.pdf

specifications tailor the descriptions of the E-, F-, and G-axis categories to mining projects, incorporating essential factors such as prospection and exploration work, laboratory sample analysis, deposit type, resource modeling, geological uncertainties, feasibility studies, market conditions, technical operation plans, mining licenses, environmental impacts, stakeholder engagement, beneficiation techniques, and mining waste management. These refinements ensure that the evaluation, classification, and reporting of mineral projects align with industry-specific challenges and requirements.

Anthropogenic Resources Specifications

UNFC Supplementary Specifications for Anthropogenic Resources[3] provide a structured approach to classifying and managing secondary raw materials, including mining residues, post-consumer waste, and industrial by-products. A key aspect of the specifications is their emphasis on resource recovery projects, which include the entire lifecycle of secondary materials, from initiation and production to residue treatment, recycling, and final disposal. The framework evaluates these projects based on their technical feasibility, environmental-socio-economic viability, and degree of confidence in resource estimates. UNFC's role in anthropogenic resource management extends beyond classification; it facilitates the integration of circular economy principles, ensuring that waste materials are efficiently recovered, reused, and reintegrated into production cycles. The specifications highlight best practices in stakeholder engagement, transparency, and quality assurance, enabling industries and policymakers to assess secondary resource projects with greater accuracy and comparability.

1.2.2. UNFC Guidance Europe

The *Guidance for the Application of the United Nations Framework Classification (UNFC) for Mineral and Anthropogenic Resources in Europe*[4] supports European regional and national authorities in establishing and maintaining an inventory of primary and secondary raw materials projects. This inventory, based on UNFC, includes projects involving the recovery of mineral raw materials from geological occurrences (geogenic resources) and extractive industry residues (anthropogenic resources), aiding decision-making across various stakeholder levels. A UNFC-based inventory facilitates reliable data collection on raw material stocks and flows, benefiting public-sector decision-making, economic management, investment planning, and knowledge dissemination. It aligns with global sustainability goals, ensuring that framework conditions enable expertise deployment and financial support for responsible resource management. The document aligns with the Infrastructure for Spatial Information in Europe (INSPIRE) initiative and emphasizes the need for expert-led implementation to maintain quality and comparability (Figure 4).

Figure 4: UNFC Classes defined by Categories and Sub-categories with Mapping of INSPIRE Codes

[3] [Placeholder for updated document]
[4] https://unece.org/sites/default/files/2022-11/UNFC%20GUIDANCE%20EUROPE-FINAL.pdf

UNFC Classes Defined by Categories and Sub-categories								INSPIRE Code List
Total Products	Produced	Sold or used production						
		Production which is unused or consumed in operations *Future production that is either unused or consumed in the Project operations is categorized as E3.1. These can exist for all Classes of recoverable quantities* [c]						
		Class	Sub-class	Categories				
				E	F	G[a]		
	Known Sources	Viable Projects *Estimates associated with Viable Projects are defined in many classification systems as Reserves, but there are some material differences between the specific definitions that are applied within different industries and hence the term is not used here.* [c]	On Production	1	1.1	1, 2, (3)		operating continuously operating intermittently
			Approved for Development	1	1.2	1, 2, 3		under development
			Justified for Development	1	1.3	1, 2, 3		pending approval
		Potentially Viable Projects *Not all Potentially Viable Projects will be developed*	Development Pending	2[b]	2.1	1, 2, 3		feasibility evaluation of the ore deposit
			Development On Hold	2	2.2	1, 2, 3		care and maintenance retention
		Non-Viable Projects *Non-Viable Projects include those that are at an early stage of evaluation in addition to those that are considered unlikely to become Viable developments within the Foreseeable Future.* [c]	Development Unclarified	3.2	2.2	1, 2, 3		resource assessment (geological interpretation, approximate calculation of the resource)
			Development Not Viable	3.3	2.3	1, 2, 3		closed abandoned historic
		Remaining Products not developed from identified Projects *Remaining Products not developed from identified Projects or Prospective Projects may become developable in the future as technological or environmental-socio-economic conditions change. Some or all these estimates may never be developed due to physical and/or environmental-socio-economic constraints.* [c]		3.3	4	1, 2, 3		
	Potential Sources	Prospective Projects		3.2	3.1	4		subsurface exploration
				3.2	3.2	4		detailed surface exploration
				3.2	3.3	4		regional reconnaissance
		Remaining Products not developed from Prospective Projects		3.3	4.1	4		
				3.3	4.2	4		
				3.3	4.3	4		

a - G Categories may be used discreetly, or in cumulative scenario form (e.g., G1+G2).
b - Potentially Viable Projects may satisfy the requirements for E1.
c - Commentaries in *Italics* are essential for further clarifications of related terms.

The Guidance document represents an early step toward full UNFC implementation in Europe, with recommended next steps including:

- Expanding UNFC awareness and application,
- Strengthening the expert community,
- Integrating UNFC data into economic and financial reporting,
- Enhancing quality assurance structures,
- Aligning with financial frameworks such as GFANZ, ISSB, and the EU Taxonomy,
- Strengthening investor relations supporting the Paris Agreement and Sustainable Development Goals.

The guidance references UNFC (2019), the Supplementary Specifications for Minerals (2021), and Specifications for Anthropogenic Resources (2018), ensuring consistency with established classification standards. It also provides Europe-specific guidance on factors influencing classification, such as resource policies, licensing processes, environmental regulations (EU Water Framework Directive, EU Mine Waste Directive), spatial planning, and social considerations. Furthermore, technological readiness levels of mining projects are mapped to UNFC's F-axis categories. A classification template has been developed to standardize UNFC application in Europe, aiding national mining authorities and geological surveys in classifying regional resource estimates, historic mining projects, and potential deposits. The guidance document is non-mandatory but serves as a critical tool for ensuring structured and harmonized resource classification across Europe.

1.3. Competency Statement

The development of a UNFC National Guidance Document and the application of UNFC within national frameworks require a structured and competency-driven approach to ensure accuracy, credibility, and alignment with international best practices. The following summarizes the competency requirements for individuals responsible for these activities, drawing from the *Guidance Note on Competency Requirements for the Estimation, Classification, and Management of Resources*[5]. It is suggested to refer to the template for a statement of a qualified expert annexed in the Guidance note.

The preparation of a UNFC National Guidance Document necessitates expertise in resource estimation, classification, and management. Professionals involved must demonstrate a thorough understanding of the principles of UNFC and the United Nations Resource Management System (UNRMS). In addition, the application of UNFC within national frameworks requires Qualified Experts with demonstrable expertise in resource estimation and classification, possessing the following competencies:

- Professional Recognition: affiliated with a recognized professional organization that establishes and enforces standards of competence, ethics, and continuing professional development.
- Data Analysis and Interpretation: proficiency in acquiring, processing, and interpreting resource-related data, ensuring that resource estimates are based on verifiable, high-quality information.
- Resource Classification and Reporting: ability to apply UNFC categories effectively, ensuring consistency with national reporting standards and facilitating comparability with international classification systems.
- Judgment and Decision-Making: sound professional judgment, considering technical, economic, environmental, and social factors in resource classification.
- Documentation and Record-Keeping: maintain comprehensive records of assessments, methodologies, and data sources to support transparency and auditability of classification decisions.
- Stakeholder Communication: communicate complex technical information clearly and effectively to policymakers, industry stakeholders, and the public is crucial for the acceptance and implementation of UNFC.

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[5] https://unece.org/sites/default/files/2022-11/Guidance_Note_on_Competency_Requirements_25_October_2022.pdf

2. UNFC Bridging Methodology

2.1. Terms and Definitions

Aligning national system with UNFC requires a common understanding of terms and definitions. For national systems / frameworks to align with UNFC, **common definitions** must be harmonized to ensure consistency.

Refer to **Table 1** for key terms across different systems that require **mapping**.

2.2. E axis specifications (aligned with national legislative framework)

Each national classification system is required to map its environmental-socio-economic and regulatory criteria to the E axis categories to ensure alignment. This mapping process helps in identifying gaps and areas where further clarification may be required.

The E-Axis in UNFC represents the environmental-socio-economic viability of a project and should align with national legislative frameworks. Considerations include:

- E1: Environmental, social, and economic viability with regulatory approval:
  - On Production (E1; F1.1)
  - Approved for Development (E1; F1.2)
  - Justified for Development (E1; F1.3)
- E2: Potentially viable but pending economic or regulatory certainty:
  - Development Pending (E2; F2.1)
  - Development on Hold (E2; F2.2)
- E3: Projects currently non-viable:
  - Development Unclarified (E3.2; F2.2)
  - Development Not Viable (E3.3; F2.3)

Refer to **Table 2** for the mapping to UNFC (E axis)

2.3. F axis specifications (aligned with national legislative framework)

Each national classification framework is required to ensure that feasibility assessments align with UNFC's structured classification. The mapping process should highlight potential discrepancies in definitions and assessment methodologies. The F-Axis in UNFC classifies the technical feasibility of the development. National systems should align with the following specifications:

- F1: Feasibility confirmed with defined extraction plans:
  - F1.1: Operational mines
  - F1.2: Projects with all approvals and financing in place
  - F1.3: Technically feasible projects with high probability of approval
- F2: Feasibility pending technical (or non-technical) contingencies:
  - F2.1: Projects undergoing further technical studies
  - F2.2: Projects with unresolved social, environmental, or economic issues
  - F2.3: Technically feasible but uneconomic projects

- F3: Exploration-stage projects:
    - F3.1: Potentially viable exploration targets (warrants further studies)
    - F3.2: Prospective projects requiring more data acquisition and/or evaluation in order to have sufficient confidence to warrant further testing
    - F3.3: Prospective projects with indirect evidence

Refer to **Table 3** for the mapping to UNFC (F axis)

2.4. G axis specifications (resources and reserves estimation)

Countries should ensure that geological assessment standards map effectively to the G axis categories. Where necessary, additional calibration or reassessment of national reporting practices may be required. In this context, the G-Axis represents resource and reserve estimation, corresponding to geological confidence levels. Mapping requires alignment with:

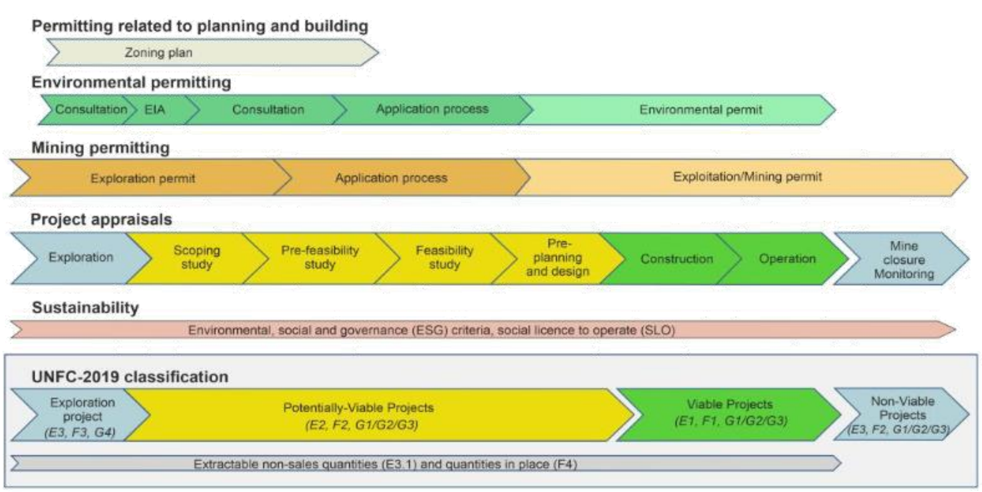
- G1: Product quantity associated with a project that can be estimated high confidence
- G2: Product quantity associated with a project that can be estimated moderate confidence
- G3: Product quantity associated with a project that can be estimated low confidence
- G4: Product quantity associated with a Prospective Project, estimated primarily on indirect evidence

Refer to **Table 4** for the mapping to UNFC (G axis)

2.5. Compare and contrast (both systems)

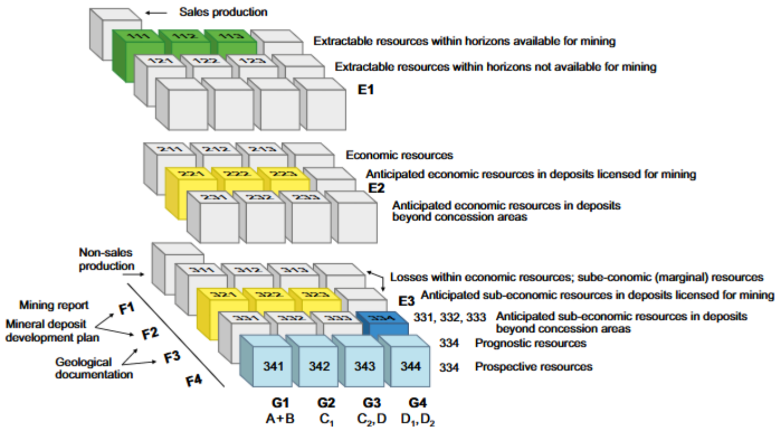
[*Align both systems, including classes and categories, through table/figure translating the mapping from national system to UNFC, use the figures below as reference to better illustrate the translation*]

Figure 5: Schematic of mining-related project life cycles in government and industry processes (conceptual)[6]



[6] https://unece.org/fileadmin/DAM/energy/se/pdfs/UNFC/UNFC-Nordic-Guidance-Public-Comments/20170424_A_guidance_for_the_application_of_the_UNFC.pdf

Figure 6: Correlations between the Polish and international (UNFC Update 2019) classification systems[7]



3. UNFC-based National Minerals Inventory

3.1. Project based

[*Refer to UNFC Guidance Europe*]

3.2. Aggregated levels

[*Refer to UNFC Guidance Europe*]

4. EU Critical Raw Materials Act Specifications

4.1. Reporting in compliance with CRMA

4.2. Templates (guidance for application)

4.2.1. Exploration results

4.2.2. Extractive Wastes

4.2.3. Monitoring

4.3. Strategic Projects

5. Translation

[7] Mineral Resources of Poland, Polish Geological Institute National Research Institute Warsaw 2022 (Nieć, 2010a, with authors' adjustments)

Table 1: Key terms and definitions

Terminology [a]	UNFC	GKZ-based Systems [b]	CRIRSCO-based Reporting	Countries with a Unique National System [c]	No National Specifications
Identified Project	A project associated with a known source	linked to a classified deposit[d]	Not specifically defined,	A project recognized under national criteria	Revise National Framework
Known Source	A source demonstrated to exist by direct evidence	Explored and confirmed deposit	Resource / Reserve	Defined according to national regulations	May exist but unclassified
Potential Source	A source not yet demonstrated to exist by direct evidence but assessed as potentially existing	Prognostic or prospect deposit	Exploration targets or Inferred Resources	May exist in conceptual studies	May exist in conceptual studies (speculative or unknow)
Product	The raw material extracted and/or processed within a project	Classified recoverable commodity	Marketable product from a reserve	Defined per national regulations	Not explicitly defined
Project	A defined development or operation forming the basis for evaluation and decision-making	Defined mining area or a deposit designed for exploitation (with detailed technical and economic analyses)	Although the term 'project' is mentioned frequently in the CRIRSCO Template, the term is not specifically defined. Could be defined as a mining project assessed for reporting	Defined per national regulations	Not explicitly defined
Classification Basis	Environmental, social, and economic viability, technical feasibility, and degree of confidence in product estimates	Geological certainty, economic viability, and state regulations (possibilities and circumstances of exploitation)	Geological knowledge and confidence, and modifying factors	Defined per national regulations	Not explicitly defined

[a] Aligning these definitions ensures a common language between systems and facilitates data exchange across national and EU levels

[b] The terms and definitions provided are for illustrative purposes; the final terminology should be reviewed and aligned with the specifications of each national system

[c] Terms and definitions for countries with unique classification systems should be determined in accordance with national regulations and frameworks

[d] The term "deposit" is used here as a general reference to a geological volume or quantity of potential interest. Terminology varies between classification systems, with alternative terms such as resource, reserve, stock, and occurrence.

Resource Definition	UNFC does not explicitly define "resource". The classification involves quantities linked to a project	Resources (in some cases also reserves), deposits, stocks, occurrences based on exploration stage, economic viability, and confidence levels e.g., A, B, C1, C2 (explored), P1, P2 (prognostic/prospective)[e]	Resources classified as Measured, Indicated, or Inferred	Varies depending on national reporting rules	May not be classified separately
Reserve Definition	What traditional systems call "reserves" corresponds to highest maturity classes of projects, with confirmed or reasonable expectation to confirm viability and technical feasibility (Mainly Viable Projects)	Resources, reserves, deposits, stocks, occurrences based on exploration stage, economic viability, and confidence levels. These also classified by feasibility level and government approval in some systems e.g., A, B (proved), C1 (probable)	Proven, Probable Reserves	Varies depending on national reporting rules	To be defined with national framework, may not be explicit
Viable Project (E1; F1)	Quantities that are confirmed to be extractable under current conditions	Explored and economically extractable resources, reserves, deposits, stocks, occurrences, with feasibility studies (active mining operations or state approved for mining or advanced technical studies with some approvals	Proved, Probable Reserves (operating mine or reserves with feasibility studies and modifying factors considered)	Defined under national production reports, national laws, and planning (economic viability with advanced technical studies and permits)	Not explicitly defined, may be producing projects reporting to authorities
Potentially Viable (E2; F2)	Quantities that have a reasonable expectation of development (pending resolution of technical, economic, or regulatory factors)	Sub-economic (anticipated) resources, deposits, occurrences, stocks with technical studies (also economical but beyond concession areas)	Reserves at pre-feasibility, resources measured, indicated, or inferred	Defined under national guidelines	Not explicitly defined

[e] Terminology and classifications differ between systems. The provided example is intended solely to illustrate this variation.

Non-viable (E3; F2)	Quantities may exist but are currently unfeasible	Prognostic, prospective deposits, with no economic viability	Not applicable or not typically classified separately (may apply on estimates obtained from historical reports)	Defined under national guidelines	Not explicitly defined
Prospective Project (E3; F3)	Potential quantities identified based on poor or indirect evidence, and not yet confirmed by direct exploration	Prognostic, prospective, or speculative deposits	Exploration targets	Defined under national guidelines (may be recognized in conceptual studies)	Not explicitly defined
Exploration Stage	Exploration Project (E3, F3)	Early stage exploration on deposits, occurrences e.g., P1, P2 (prognostic or prospective resources)	Exploration targets or inferred resources	Defined per national exploration framework	Not explicitly classified
On Production (E1; F1.1)	Active mining or extraction operations producing marketable commodities	Active mining operations	Operating mines extracting reserves	Defined under national production reporting	Not explicitly classified
Approved for Development (E1; F1.2)	Projects with all necessary approvals and financing committed, ready to proceed	Projects with state approval for mining	Reserves with feasibility studies and permits	Defined under national mining laws	Not explicitly classified
Justified for Development (E1; F1.3)	Projects technically feasible with a reasonable expectation of receiving necessary approvals	Feasibility-stage projects with some approvals	Probable Reserves with modifying factors considered	Defined under national resource planning	Not explicitly classified
Environmental-socio-economic Viability	E-axis (E1, E2, E3)	Considered within national regulations e.g., Economic or sub-economic (A, B), Non-economic (C2)	Part of modifying factors	Defined by national requirements, may be considered in project approval	Not explicitly defined (adherence to EU regulations is required)

Technical Feasibility	F-axis (F1, F2, F3, F4)	Based on feasibility study requirements e.g., Extractable (A, B), Uncertain feasibility (C2)	Feasibility studies define resources/reserves	Often undefined but depends on national frameworks	Not explicitly required
Geological Confidence	G-axis (G1, G2, G3, G4)	Based on geological certainty Increasing certainty from A → C2	Proved (high), Probable (medium), Measured (high), Indicated (medium), Inferred (low)	Usually lacks formal criteria	Not explicitly classified

Table 2: Mapping to UNFC (E axis)

UNFC Category	Definition	GKZ-based Systems [a]	CRIRSCO-based Reporting [b]	Countries with a Unique National System [c]	No National Specifications [c]
E1	Extraction and sale are economically viable under current conditions	Economic deopists with full feasibility studies and state approval for mining e.g., **A+B+C1 reserves**, fully approved for mining, with confirmed economic feasibility	Reserves classified as Proven and Probable, with modifying factors demonstrating economic viability (feasibility study)	Minerals classified as economically viable under national reporting standards	No formal classification; extraction occurs based on need
E2	Potentially viable but subject to future economic, social, or environmental conditions	Conditional resources/reserves awaiting feasibility validation or regulatory approval e.g., **C2 reserves**, inferred as likely economic but requiring validation (awaiting further economic evaluation)	Proved and Probable reserves (at pre-feasibility stage), and Measured, Indicated, and Inferred Resources with a reasonable prospect for economic extraction but requiring further assessment	Resources identified as contingent on future policy, pricing, or infrastructure	No structured classification; potential resources may exist but are unverified
E3	Not currently viable or only speculative	Prognostic or prospective resources that lack economic justification at present	Exploration targets	Early-stage resources that require significant development and market changes	Not explicitly defined; may be grouped as unknown or speculative

[a] Countries with GKZ-based systems may need to explicitly integrate socio-environmental factors into classification

[b] CRIRSCO-based systems primarily focus on market-driven feasibility; UNFC adds the social and environmental dimensions

[c] Establish economic assessment criteria for raw material projects

Table 3: Mapping to UNFC (F axis)

UNFC Category	Definition	GKZ-based Systems [a]	CRIRSCO-based Reporting	Countries with a Unique National System [b]	No National Specifications [b]
F1	Technical feasibility is confirmed; extraction is possible with current technology	Developed deposits with proven extraction methods and operational projects	Feasibility Study	Mining projects at an advanced stage of planning and approval	No formal feasibility assessments; projects may proceed if extraction is attempted
F2	Technical feasibility is subject to further assessment or advancement of extraction technologies	Deposits with feasibility pending, requiring further technological validation	Proved and Probable Reserves at Pre-feasibility, or Measured, Indicated, Inferred Resources at Feasibility, Pre-feasibility, or Scoping study	Resources identified for extraction but requiring further technological validation	No formal classification; projects may exist but lack technical assessment
F3	No current technical feasibility demonstrated; projects remain in exploration or conceptual stage	Prognostic, prospective, or unproven resources requiring significant technological advances	Exploration targets	Early-stage projects requiring exploratory or pilot studies	No structured classification; resources are speculative and not yet evaluated
F4	No technical feasibility expected; extraction not possible under current conditions	Non-extractable or speculative deposits requiring breakthrough technology. In some cases not classified	Not classified under CRIRSCO systems	May be defined as 'hypothetical resources' in some frameworks	No classification; potential existence of unknown deposits

[a] Often lack structured approach to categorize F3, F4

[b] Introduce or develop criteria to define what constitutes a technically feasible project

Table 4: Mapping to UNFC (G axis)

UNFC Category	Definition	GKZ-based Systems [a]	CRIRSCO-based Reporting	Countries with a Unique National System [b]	No National Specifications [b]
G1	High geological confidence; quantity and quality are well established	Explored resource/reserve with detailed sampling and extensive drilling data, often in a well-defined concession area. Confidence exceeds 90%	Proved Reserves or Measured Resources, with high confidence	Well-documented resources, meeting national exploration standards	No formal geological classification, but deposits may be well known
G2	Moderate geological confidence; quantity and quality are reasonably established	Explored deposits with moderate sampling and inferred continuity. Confidence between 50% and 90%	Probable Reserves or Indicated Resources, with reasonable geological confidence	Moderately documented resources, requiring further validation	No structured classification; deposits may exist with limited knowledge
G3	Low geological confidence; quantity and quality are poorly defined	Prognostic or prospective resources with minimal direct evidence. Confidence less than 50%	Inferred Resources, with low confidence in geological interpretation	Early-stage exploration projects with minimal data	No structured classification; speculative resources may be noted
G4	Very low geological confidence; resources are speculative or hypothetical	Conceptual or speculative resources with little or no supporting data, often not used	Not typically classified under CRIRSCO systems, could apply for exploration targets	Hypothetical resources or conceptual estimates	No structured classification; potential existence unknown

[a] GKZ-based systems follow a structured classification but might require additional reporting mechanisms to align with UNFC categories

[b] Need to adopt geological reporting standards and ensure data quality for resource classification

Table 5: General comparison scheme between UNFC and the GKZ system

Level of Confidence	UNFC					GKZ-based Classification		
	Class	Sub-class	Categories			Balance reserves	Off-balance reserves	Resources
			E	F	G			
High	Viable Project	On Production	1	1	1	A, B, C_1		
		Approved for Development	1	1	2	A, B, C_1 (sometimes C_2)		
		Justified for Development	1	1	3			
	Potentially Viable Projects	Development Pending	2 (3)	2 (3)	1		A, B, C_1	
		Development on Hold	2 (3)	2 (3)	2		C_2 (sometimes C_1)	
	Non-Viable	Development Unclarified	3.2	2.2	3			P_2 (P_3)
Low		Development Not Viable	3.3	2.3	3			P_2 (P_3)
	Prospect Projects	[No sub-classes defined]	3.2	3	4			P_3

Table 6: Standard mapping of CRIRSCO Template aligned estimates to UNFC Categories

CRIRSCO Template			*Corresponding UNFC Category*[c]			*UNFC Class*
Public Report and Study Types[a]	*Standard Definitions*					
Feasibility Study or Life of Mine Plan[b] (for an operating mine)	Mineral Reserves	Proved	E1	F1	G1	Viable Projects
		Probable			G2	
Pre-feasibility Study[d]	Mineral Reserves	Proved	E2	F2	G1	Potentially Viable Projects
		Probable			G2	
Feasibility Study, Life of Mine Plan[b] (for an operating mine) or Pre-feasibility Study[e]	Mineral Resources (exclusive of Mineral Reserves)	Measured	E2	F2	G1	
		Indicated			G2	
		Inferred			G3	
Scoping Study report or other Public Report on a Mineral Resource estimate[f]	Mineral Resources	Measured	E2	F2	G1	
		Indicated			G2	
		Inferred			G3	
Public Report on exploration stage projects	Exploration Target		E3	F3	G4	Prospective Projects
	Exploration Results		Estimates not published			
Not applicable[g]	Estimates obtained from historical reports[h]					Non-viable Projects

[a] The use of a Life of Mine Plan on operating mines, as indicated below, only applies in cases where no material changes to the current operation are envisaged.

[b] In cases where a Life of Mine Plan includes a proportion of Inferred Mineral Resources, and such material has been reported separately, then such material should be coded as E2F2G3.

[c] These are the Categories which would normally be used for a study when the mapping is based on a current (or recently published) study. Where there have been material changes since the effective date of a report, or the study is otherwise no longer considered current, the assumptions used in the study should be reviewed in order to determine whether the results obtained are still valid and whether the E and F axis values need to be altered. For instance, where an operating mine has ceased operation, where mining licences have expired or been revoked, or where there have been material changes in costs of prices the mapping of Mineral Reserves from a feasibility study or Life of Mine Plan would be downrated from E1 to E2 and from F1 to F2.

[d] Estimates included in a Life of Mine Plan which is potentially viable under current conditions.

[e] Estimates of material not included in the Life of Mine Plan which could be economically extracted using reasonably assumed future conditions.

[f] Estimates which are considered to have 'reasonable prospects for eventual economic extraction' under reasonably assumed future conditions.

[g] CRIRSCO Template aligned reporting does not allow the Public Reporting of estimates on non-economic mineralisation.

[h] Historical estimates will generally be downrated to E3 and F3, with the original G Categories being retained.

Appendix G - The Potential Role of the United Nations Framework Classification for Resources in National Raw Materials Inventories

THE POTENTIAL ROLE OF THE UNITED NATIONS FRAMEWORK CLASSIFICATION FOR RESOURCES IN NATIONAL RAW MATERIALS INVENTORIES

Potencialna vloga Okvirne klasifikacije zalog in virov Združenih Narodov v nacionalnih inventarjih mineralnih surovin.

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ABSTRACT

Securing resource supply is essential to maintain and improve living standards. However, ensuring a reliable supply of resources begins with proper sustainable resource management. Sustainable management of raw materials is required throughout the whole value chain, from exploration and mining to processing and recycling. In parallel, the correct application for sustainable management of raw materials is critically dependent on reliable information. The United Nations Framework Classification for Resources (UNFC) embeds all sustainability aspects to ensure the best decisions for sustainable resource management.

UNFC is a project-based classification tool, applicable at any stage of the value chain, that provides stakeholders with sufficient information on environmental-socio-economic viability, technical maturity of the project, and confidence in product estimates. UNFC can be used for cross-resource comparison as it is applied to all energy and resource projects. UNFC can communicate uniform information across countries on raw materials, for aggregated data and harmony at regional scales. UNFC provides an alignment between various classification and reporting systems through the available bridging documents. A UNFC-based national raw materials inventory enables nations to meet their needs in policy formulation, resource management functions, corporate business processes, and financial capital allocation.

Key Words: Classification, Natural Resources, Sustainable Development

POVZETEK

Zagotavljanje oskrbe s surovinami je bistveno za ohranjanje in izboljšanje trenutnega življenjskega standarda. Zagotavljanje zanesljive oskrbe s surovinami začne z ustreznim trajnostnim gospodarjenjem le-teh.. Trajnostno gospodarjenje s surovinami je potrebno v celotni vrednostni verigi, od raziskovanja in rudarjenja do predelave in recikliranja. Pri tem je potrebno vedeti, da so za ustrezno planiranje in izvajanje trajnostnega gospodarjenja s surovinami nujne zanesljive informacije. Le-te so ključne za Okvirno klasifikacijo zalog in virov Združenih narodov (UNFC), ki vključuje vse vidike trajnosti in s tem zagotovi ustrezno osnovo za odločanje v okviru trajnostnega gospodarjenja s surovinami.

UNFC je projektno zasnovano orodje za klasifikacijo virov in zalog, ki se uporablja na kateri koli stopnji vrednostne verige in zainteresiranim stranem zagotavlja zadostne informacije o okoljskosocialno-ekonomski upravičenosti, tehnični zrelosti projekta in oceno zaupanja o količini in kakovosti zalog in virov. UNFC se lahko uporablja za navzkrižno primerjavo različnih naravnih virov, saj se uporablja tudi za energetske in ostale projekte naravnih virov. Z UNFC si lahko države med seboj posredujejo poenotene informacije o zalogah in virih naravnih surovinah in tako združene podatke usklajajo na regionalni / EU ravni. UNFC prav tako zagotavlja uskladitev med obstoječimi različnimi sistemi klasifikacij oziroma razvrščanja ter poročanja s pomočjo že razpoložljivih premostitvenih dokumentov. Nacionalni inventar mineralnih surovin, ki temelji na UNFC, omogoča državam dovolj informacij za potrebe oblikovanja politik, nadalje različnih funkcij upravljanja surovin, kot tudi poslovnih procesih podjetja in dodeljevanju finančnega kapitala.

Ključne besede: klasifikacija, naravni viri, trajnostni razvoj

1. INTRODUCTION

Sustainable resource management is fundamental to delivering on the United Nations Agenda 2030. The aforementioned factors for the sustainable use of raw materials are embedded in the United Nations Framework Classification for Resources (UNFC). UNFC is developed in synchronization with the United Nations Sustainable Development Goals (SDGs), to deliver Agenda 2030. The United Nations Economic Commission for Europe is implementing and deploying UNFC alongside the United Nations Resource Management System (UNRMS) to attain the SDGs regarding living standards, just energy transitions, climate action, and environmental stewardship.

According to the Paris Agreement on climate change, nations must become less dependent on hydrocarbon fuels by 2050. The agreement henceforth binds the commitment of countries to neutralize carbon present in the atmosphere, of which reducing emissions is one of the solutions. Nations are expected to scale-up the production of renewable energy with environmentally friendly technologies to ensure a global energy transition, from hydrocarbon dependency to green energy. However, the development and implementation of green technologies are interlinked with an increase in raw materials demand. The increasing demand for raw materials implies an increase in their supply. National governments can either rely on their natural mineral resources, which depend on the geology of the country or anthropogenic resources, as secondary raw materials obtained from recycling residues and wastes, to respond to the demands.

Attaining the SDGs, the Paris Agreement, and the European Green Deal has amplified the interest in managing energy and raw material resources using sustainable methods. Stakeholders, from governments and industries to investors and communities, became devoted to scale-up sustainable raw materials management.

Mapping a nation's raw materials potential is the beginning of sustainable resource management. A national raw materials inventory is the best way to display this potential in supply and demand. This allows stakeholders in government, finance, and industry to put forward raw material policies and identify strategic raw material projects regarding sustainable decision-making and capital allocation in resource management.

In parallel, sustainable resource management highly depends on reliable and transparent information communicated through stakeholders. The information is also needed to consider sustainability factors such as environmental and socioeconomic aspects of raw material projects, compiled with technical development and geological knowledge. The recovery of available raw materials within country territories requires a coherent and consistent definition and classification at the national level [1].

UNFC has emerged from the need for a universally unifying resource classification standard. UNFC is a principle- and project- based tool for classifying and reporting all forms of energy and resource projects, aligned with Agenda 2030 and the SDGs. UNFC integrates socio-economic and environmental aspects, at its core, together with the technical and resource quantity and quality dimensions. Considering the social and environmental characteristics, UNFC is the only global standard that permits multifaceted expansion through all energy and raw material resources [2].

This paper aims at highlighting the importance of UNFC in national raw materials inventories. UNFC plays a key role in providing necessary information for governments to secure supply of raw materials with sustainable resource management. The paper provides an overview of case studies, applied to minerals and anthropogenic resources, to display concrete implementation of UNFC in different projects. The project entitled *Establishing the European Geological Surveys Research Area to deliver a Geological Service for Europe* (GeoERA) is referenced in this paper to list the learning curves from the application of UNFC and pinpoint the strong and weak points in using UNFC. The need for a UNFC-based national raw materials inventory is corroborated at national and regional levels. Finally, the role of UNFC in national raw materials inventories are discussed with implications for better sustainable raw materials management, and raw materials safeguarding at national levels.

2. THE UNITED NATIONS FRAMEWORK CLASSIFICATION FOR RESOURCES (UNFC)

UNFC was developed by the United Nations Economic Commission for Europe (UNECE) and the Expert Group on Resource Management (EGRM). It is applied to minerals, nuclear, petroleum, anthropogenic resources, injection projects for underground storage of CO2, and renewable energy. The latter includes all related sources, such as wind, water, hydrothermal, solar, and bioenergy. The sources are the foundation of each developed product from a resource or energy project. The resources can be assessed in their natural (primary resources such as minerals) or secondary (such as anthropogenic sources, and mine tailings) state [2].

UNFC is designed to maximize the needs of applications relating to policy preparation based on resource studies, resources management functions, corporate business processes, and financial capital allocation. The classification is planned as a 3-D model, incorporating three essential factors in the form of axes, using a simple numerical coding system. The axes are comprised as follows: Environmental-socio-economic viability (E); Technical feasibility (F); Degree of confidence in the estimate (G). The combination of the above criteria can be visualized by this 3-dimensional system (Figure 1). These three factors are defined by categories, and, in some cases, sub-categories. The first axis (E) is designated to the level of favorable conditions regarding sustainability (environmental, social, and economic) in investigating the viability of the project while considering market prices, legal and regulatory concerns, social and environmental features, and contractual conditions. Secondly, the F axis describes the maturity degree of the project in terms of technological implementation, and the necessary feasibility studies and obligations. This factor integrates a full scope of projects, from preliminary abstract studies through to a fully functional, producing project, which reflects the principles of standard value chain management. The G axis, the third criterion, is appointed to the level of confidence, the degree of knowledge of the estimated quantities of the product from the project [2].

Categories and Sub-categories are joined in the form of "Classes," represented in a more practical 2-dimensional table (Table 1). The classification of this framework is enumerated following the same sequence (i.e., E; F; G) that defines a Class. Each Class has a unique description defined by the selection of the relevant combination of the three criteria of a particular Category or Sub-Category. The combinations, Classes, and Sub-classes, have specific labels that serve as a support to the coding system [2].

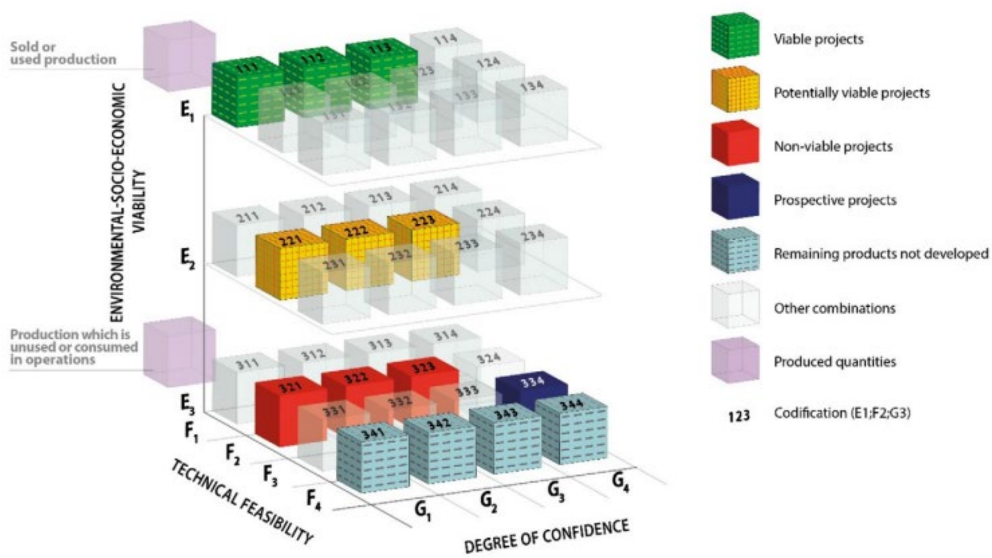

Figure 1 3D model of the UNFC matrix (source: [2])

Table 1 UNFC Classes and Subclasses (source: [2])

UNFC Classes Defined by Categories and Sub-categories						
Total Products	Produced	Sold or used production				
		Production which is unused or consumed in operations				
		Class	Sub-class	Categories		
				E	F	G
	Known Sources	Viable Projects	On Production	1	1.1	1, 2, 3
			Approved for Development	1	1.2	1, 2, 3
			Justified for Development	1	1.3	1, 2, 3
		Potentially Viable Projects	Development Pending	2[b]	2.1	1, 2, 3
			Development On Hold	2	2.2	1, 2, 3
		Non-Viable Projects	Development Unclarified	3.2	2.2	1, 2, 3
			Development Not Viable	3.3	2.3	1, 2, 3
		Remaining products not developed from identified projects		3.3	4	1, 2, 3
	Potential Sources	Prospective Projects	[No sub-classes defined]	3.2	3	4
		Remaining products not developed from prospective projects		3.3	4	4

UNFC has a set of principles and rules with structured guidelines and specifications for its application to the different resources. The specification documents are intended to assist policymakers, governmental officials, companies, and resource experts in the accurate implementation of UNFC while remaining in line with the SDGs. Each specifications document pinpoints further down the relevant terms and definitions undertaken for the given resource-related project. These are supplemented with detailed subdivisions, from general to resource-level, of the categories and subcategories, classes, and subclasses with reference to the axes. Additional support for the application of UNFC to a given resource-related project maturity is sectioned in the guidelines to sub-classify the project.

The minerals specifications clarify the use of certain terms within the mineral industry's context to correctly apply and justify the corresponding Category and/or Subcategory for a mineral project. The classification is constricted within a defined mining project, which aims to produce mineral sources to evaluate the environmental-socio-economic aspect, leading to decision-making. A mineral project provides estimates for the evaluation of the environmental socio-economic feasibility. The mineral project includes all operations taking place during the mineral life cycle. The specifications can be implemented to any mineral project, whether in development or still a concept [3].

The anthropogenic resources specifications clarify the use of certain terms within the context of the anthropogenic resource, material, project, process, and anthropogenic material system. These definitions assist users in correctly applying and justifying the corresponding Category and/or Subcategory for an anthropogenic resource project. In UNFC, anthropogenic resources are concentrations or occurrences from anthropogenic materials sources with reasonable economic importance. This depends on the quality and quantity of the anthropogenic resource. The source of such material can be the recycling of residues or wastes, such as mining tailings, at all material life cycle stages, including recovery, production, use, and end-of-life. The project definition of anthropogenic material sourcing is either from a defined development or sourcing operation, which is essential for the environmental socio-economic assessment and decision-making. The specifications can be implemented to any anthropogenic material project, whether in development or still a concept [4].

3. UNFC IN NATIONAL AND EUROPEAN CONTEXTS

In the European countries where national classification and reporting systems are in place, all mining sites (in many cases also small deposits or just occurrences) are enrolled in the national inventories. These inventories may be public or solely for governmental use. Information from these inventories is the basis for decision making regarding mineral policy and further resource management on the national level. Some countries have a long tradition of national reporting, while others do not have national reporting in place. Certain EU countries, that also have strong regional administrations, may have regional data collection on reserves and resources. Figure 2 shows EU countries with reporting on mineral reserves inserted in the European Geological Data Infrastructure (EGDI), a platform that provides national geological and geospatial data across the Pan-European region [5].

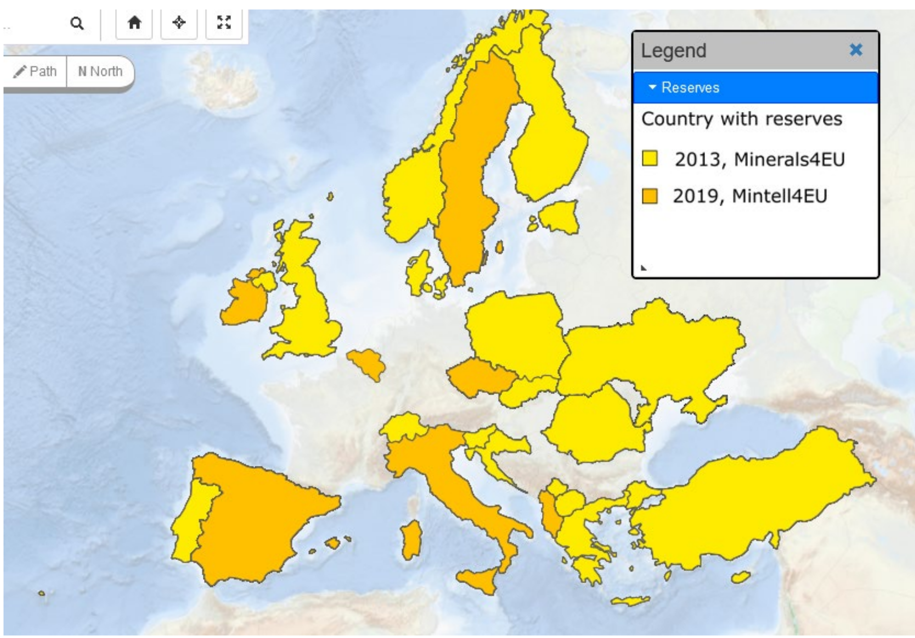

Figure 2 EGDI information on reported mineral reserves in EU countries (source: EDGI [5])

National raw material inventories require country-level specifications that comply with governmental and social standards and requirements. The inventory specifications are also conveyed to regional inventories but on a more general basis.

The UNFC Guidance Europe is a report published by UNFC experts to support national and regional officials in classifying resource projects and in establishing and maintaining inventories of raw materials projects in Europe, using UNFC. The UNFC Guidance Europe Graphical Abstract on how to use UNFC in Europe regarding regional particularities is presented in Figure 3 [6]. Proper use of UNFC Guidance Europe guarantees coherent data aggregation at national levels to obtain the same standard across Europe. At a national level, UNFC Guidance Europe highlights steps to attain harmony across Europe, such as preparing bridging documents to national systems, establishing, and communicating a UNFC-based database, using the database for decision support to stakeholders, and cooperating with the UNECE Expert Group on Resource Management for UNFC development practices [6].

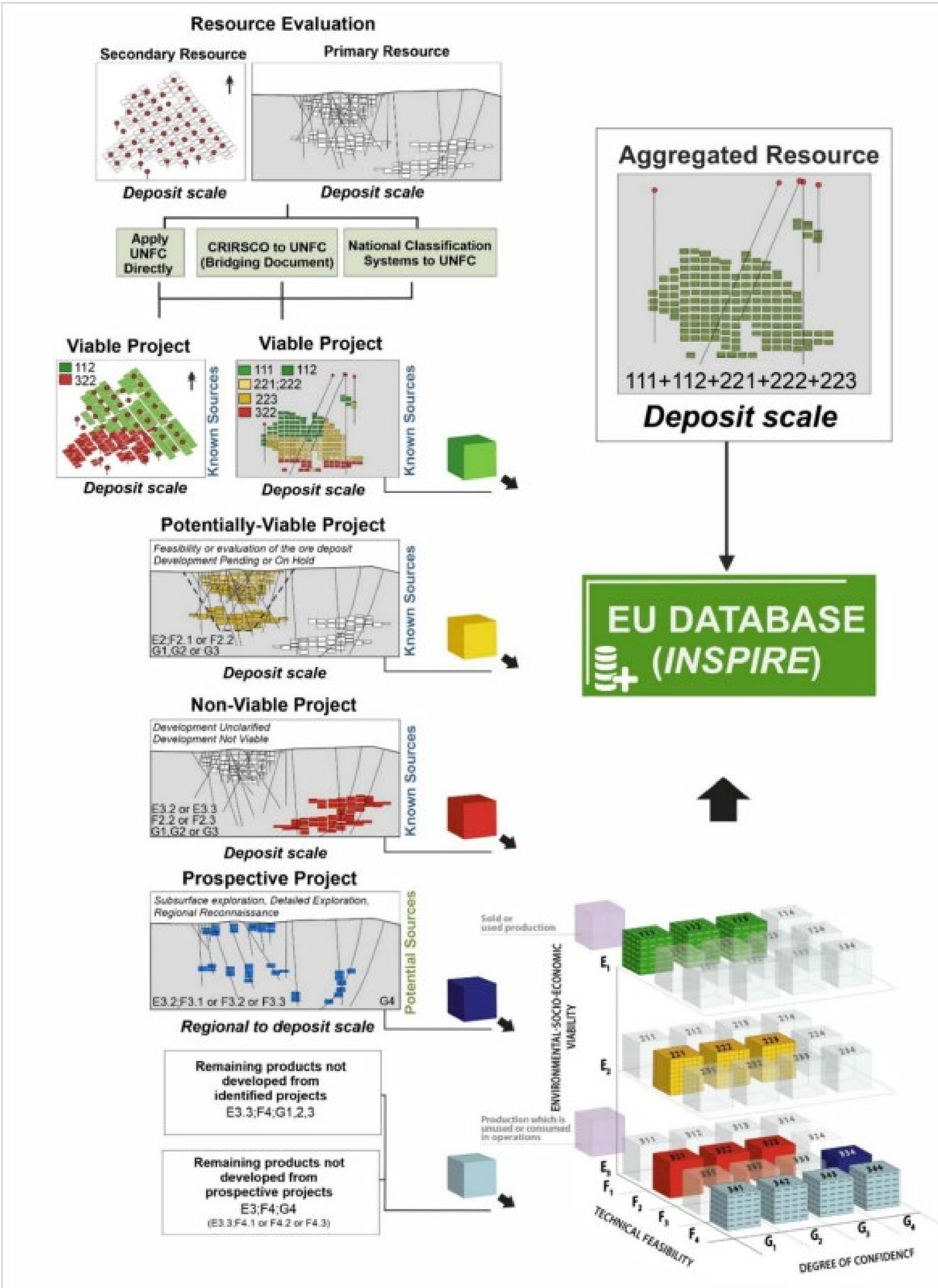

Figure 3 UNFC Guidance Europe Graphical abstract (source: [6])

UNFC CASE STUDIES

Once UNFC documents have been created, the next step was testing the classification on the different, concrete cases, where different raw materials/commodities were taken into consideration, as well as on different scales (ore body, deposit, deposit area, administration, or regional area) and various levels of detail. The case studies are publicly available on the UNECE website. These case studies passed a rigorous review and serve to demonstrate how UNFC could be applied to assure sustainable resource management.

Case studies illustrate the application of UNFC under various conditions. Case studies help countries tailor UNFC to local requirements. The feedback from the case studies helps to improve UNFC principles, specifications, and guidelines. The conditions for the application of UNFC vary according to the raw materials under assessment, the methodology of classification, and the project's phase. To elaborate more, selected case studies are listed to corroborate the different conditions under which UNFC has been applied successfully, including three cases on UNFC application to minerals and one on anthropogenic resources:

1. *United Nations Framework Classification for Resources Case Study from Austria* – Sand and gravel resources in greenfield areas are the focus of the Austria pilot area east of Vienna.
2. *UNFC Case study – A case study on Graphite, Norway* - This case study was done on flake graphite deposits and examines the Trælen deposit (active mine, Skaland Graphite AS) and the Bukkemoen deposit on Senja peninsula, in Troms County in Northern Norway. In addition, UNFC classification was applied to 24 graphite deposits.
3. *UNFC Case study- REE, exploration prospects and secondary resources in Sweden.* Within the study following rare earth element (REE) sites were examined: the Olserum REE mineralization, the Norra Kärr REE deposit, and the Kiruna-Malmberget secondary resource deposit)
4. *United Nations Framework Classification for Resources Case Study from Germany – Tailings Storage Facility Bollrich* - The tailings deposit Bollrich (Germany) was part of the Rammelsberg mining operation, which used to produce mainly Au, Ag, Pb, Cu, and Zn. The deposit is one of Germany's few possible critical raw materials (CRM) sources.

THE GEOERA PROJECT

The GeoERA project was initiated by 45 European national and regional Geological Survey Organizations (GSO). The ultimate objective of the program was to integrate information from GSO and compile it on the understanding of subsurface energy, water, and raw material resources to boost the sustainable use of subsurface resources in dealing with Europe's grand challenges. Part of the project was also testing UNFC through case studies [7].

UNFC pilots produced over 19 case studies. The Pilots were analyzed through the project to showcase the potential and possibility of UNFC implementation, in order to harmonize the classification of mineral projects of different types. The outcome demonstrates that it is feasible for the classification results to be aggregated across countries, as seen in Table 2 [8]. However, certain challenges have been highlighted that need to be addressed. Overall, the GeoERA project corroborated that it is meaningful to use UNFC as an international resource classification tool for cross-country comparison and project data aggregation on the Pan-European scale [8].

Table 2 Outcome of the GeoERA project (source: [7])

N: National,aggregated (8) | n: National,site (3) | R: Regional,aggregated (3) | r: Regional,site (4) | S: Site,site (1)

Country	Gold	Copper	Cobalt	Manganese	REE	Phosphate	Carbonates	Graphite	Aggregates	Natural stone	Peat	Gypsum	Perlite	#
Austria									R					1
Belgium						n								1
Croatia									R					1
Denmark							N		N					2
Finland	N	N	N					N			R			5
Hungary				[S]								[r]	[r]	3
Norway						n		r	r	r				4
Slovenia									N					1
Sweden					r									1
#	1	1	1	1	1	2	1	2	5	1	1	1	1	19

The identified challenges demonstrated that more work needs to be done on UNFC for it to be operational across European countries [8]. The challenges were narrowed down to:

A- Capacity Building. The information communicated through a UNFC classification requires reliability and transparency, with all related data highlighted. Experts and UNFC users are needed to overcome available poor information and interoperability for more clarity. This challenge also falls under the umbrella of having international and national policy and legal frameworks, as well as establishing legal, institutional, and technical infrastructures.

B- Establishing functional systems. The development of data collection systems is required in terms of the data value chain, workflow, and reporting templates to facilitate UNFC dissemination and aggregation of data across projects and countries. This challenge can help overcome data gaps, excessive costs, poor consistency, and time-consuming data compilation.

C- UNFC further method development. To have more transparent, reliable, and consistent results, more details, and a collective understanding of the UNFC is needed.

D- Data quality and interoperable datasets. To make the information cogent, an interoperable dataset is required for geological and geospatial data inputs regarding the UNFC axes. The collection of such data and presenting them as comprehensive datasets support users such as industry and government to evaluate, classify, and report resource estimates in UNFC.

RAW MATERIALS INVENTORIES

National raw material inventories assist governments in identifying raw material projects with strategic importance to enhance raw material supply.

A UNFC-based raw material inventory facilitates the process of decision-making by all stakeholders in terms of stock and flows across the EU. This inventory ensures reliable, transparent, and relevant information on raw materials projects. Raw materials projects with UNFC classification on the resource life cycle are important for the public sector for sustainable decisions regarding resources, and projects, at local, country, and European levels. The raw material inventory enhances economic management of UNFC classified projects on a range of activities (planning, organizing, developing) at a corporate level. The UNFC-based inventory encourages investors to consider the environmental socio-economic aspects linked to a raw material project during the decision-making process.

As an example, Finland took the initiative to map its public mineral resources and reserves data into UNFC. The classification was made through the bridging of the existing reported projects, both active and non-active, into UNFC. The projects were reported either following the CRIRSCO template or other classification frameworks. Besides Finland, there are already a few European countries undergoing the UNFC classification exercise, as seen in Figure 4 taken from EGDI [5].

Having a critical raw material (CRM) inventory at the European level, with classifications in UNFC, is likely to harmonize resource data across the European Member States. Following up on this, the European Commission and Member States can identify projects with commercial potential, and monitor the progress in permitting, social response, and environmental impacts. The CRMs inventory needs to cover primary and secondary raw materials to understand their supply and demand. The database requires frequent updates and inputs to avoid overlapping and to fill data gaps. Monitoring of the project developments facilitated through the database will allow simple integration and cross-country comparisons of CRM projects.

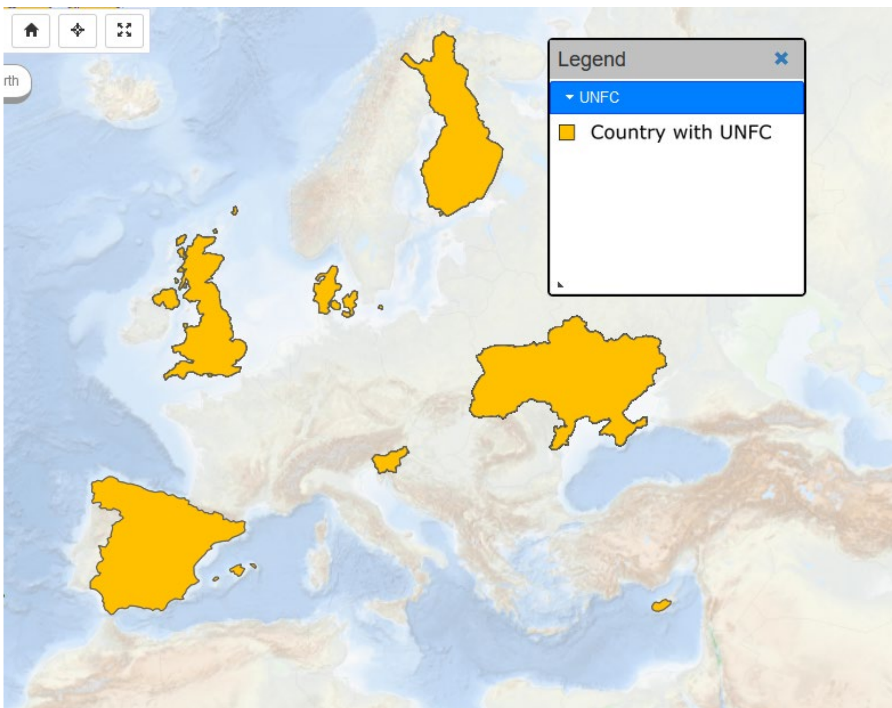

Figure 4 EU countries with in-progress UNFC raw materials inventory (source EGDI [5])

4. DISCUSSION

Achieving Agenda 2030 is the correct global pathway to improve living standards. UNFC is the only global resource classification tool with direct connections to the SDGs [2]. The UNFC promotes optimal management and practices of energy, mineral, and anthropogenic resources. This directly contributes to the efficient use of resources throughout the whole value chain with clean and environmentally sound supply, particularly through the following SDGs:

Goal 7: Affordable and Clean Energy
Goal 9: Industry, Innovation, and Infrastructure
Goal 11: Sustainable Cities and Communities

Goal 12: Responsible Consumption and Production
Goal 13: Climate Action

The factors determining the environmental-socio-economic viability reflect the balance between mineral projects and the SDGs. Mineral products constitute the building blocks of various SDGs, which raises the attention of understanding the impacts during the evaluation of minerals projects on SDGs, as they are integral to societal development, mostly with regards to the environmental, work safety policies and geo-ethics to sustainably operate mineral projects.

Adhering to the Sustainable Development Goals (SDGs) enables the attainment of the Paris Agreement's objectives. UNFC promotes the just transition of the energy system by phasing out fossil fuels, which are still the primary source of energy in today's world. UNFC advocates for environmentally sound technologies, and renewable energy, such as solar, wind, and geothermal. Achieving the Paris Agreement requires a different use of energy patterns, that are embedded in UNFC.

Increasing dependence on renewable energy is linked to increasing clean, green technology development. In return, the technology required relies on CRMs. In the European context, CRMs represent raw materials with great economic importance to orient Europe toward sustainable development yet are subjected to high risks linked to their supply. CRMs are the building blocks for energy transition, and they are key for the sustainable function of Europe's economy. UNFC acknowledges the necessity of CRMs in the classification of strategic projects.

To avoid supply disruptions of CRMs in the EU, a correct mapping of these raw materials is the starting point to increase knowledge on CRMs occurrences and potential strategic projects of primary and secondary sources. This calls for national authorities to aggregate their data into a shared EU database with harmonized information on CRMs projects. UNFC ensures consistency and coherency of these strategic projects to allow the identification of the most promising ones. An EU CRMs database using UNFC can set the grounds for CRMs supply security in Europe.

The UNFC-based EU CRM raw materials inventory can potentially solve the need for harmonized project information for policy-making and correct resource practices on the EU level. UNFC assists Member States to gather and aggregate the relevant project information in a sustainable manner to facilitate an understanding for raw material supply, industry, financial, and infrastructure policies. In the case of Finland, the successful application of UNFC created harmony in project information on the project's development status, and raw materials resources and reserves. UNFC is highly suggested at EU levels for mineral and anthropogenic resources to harmonize data across Europe.

5. CONCLUSION

The information communicated in UNFC provides a complete and exhaustive picture of raw material projects, weighed against the three fundamental pillars for sustainable development. The UNFC classification focuses on environmental considerations, societal factors, and economic functioning. This classification tool is for sustainable development. UNFC is comparable to other existing classification schemes, which enlarges the spectrum for data harmonization across countries with a simple conversion exercise. UNFC is applicable to all energy and resources, using similar classification codes to facilitate cross-resource comparisons. Having all resources classified in UNFC provides national environmental accounting, and national energy and resource statistics. Statistics would be simple to read and understand given the UNFC common denominator.

Classification in UNFC can be held with the given information related to a project. The information evaluated can therefore be sufficient or insufficient. UNFC does not define the level of information needed for classification. It is user-friendly, and the end user can request additional information according to their requirements, meaning that the UNFC classification can be further fine-tuned with respect to the users' information needs with a request for additional information. Thus, the role of UNFC classification is to put forward all available information, whether sufficient or not, but needs to be communicated for transparency. UNFC can be used for all stages of the value chain from raw materials prospecting, exploration, mine development, extraction, benefaction, processing production, use, and recycling. It is used to classify projects at all stages of the value chain.

UNFC has been applied to several case studies in Europe, on minerals and anthropogenic resources at different points in a project's stage, from prospection and exploration to processing and recycling. The case studies were applied on occurrences from the start, meaning that the information was gathered specifically for the UNFC classification, and others demonstrated the use of bridging documents to UNFC classification. UNFC is well disseminated in some countries in Europe as a national classification scheme. However, other EU countries rely on the long tradition of using their national system or other international reporting schemes. The GeoERA project demonstrated that it is possible and meaningful for UNFC to be implemented across Europe as the resource classification system. The project highlights that this step would facilitate raw material projects data harmonization across the Member States, and that it is feasible for the classifications to be aggregated for cross-country comparison. However, certain challenges were identified that can render the UNFC operational in the EU.

Therefore, UNFC needs further development in different directions, on resource, project, and national levels to adapt to stakeholders' requirements, and keep intra- and inter-resource alignment. The cooperation between UNFC and other reporting systems and classifications needs to be complementary in order to avoid duplication and to fill data gaps. UNFC can play a key role in national raw materials inventories by steering governments towards raw materials security, better practices and decisions for raw materials use and management, more sustainable policy-making, and correct investments.

ACKNOWLEDGEMENT

The authors would like to acknowledge two projects that enabled preparing this conference contribution, firstly the project from the Italian National Recovery and Resilience Plan (PNRR), and secondly a project on Implementation of U|NFC and UNRMS in Europe funded by the European Union.

Besides the authors would like to acknowledge the contribution of Walker Darke on the text regarding the direct linkage between UNFC and SDGs and the firm paper proofreading.

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