CIRAN

D6.1 Baseline Report on missing segments and supply chain vulnerabilities

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Executive summary

Recent mining launches and re-launches (e.g., lithium extraction and tungsten, copper, tin, cobalt and other metal extraction) have been screened for Drivers – Policies – States – Impacts – Responses (DPSIR) elements that may have had a significant share in facilitating the project. Departing from the present inefficiencies and the strategic and legal drivers (case studies derived conclusions, the Critical Raw Materials Act -CRMA- and the Green Deal), societal, environmental, economic and technical aspects are considered including the economic participation of local stakeholders. The current state baseline, missing segments and supply chain vulnerabilities are synthesised in the present report (D6.1) and provide the framework for future policy recommendations.

This first report in the course of WP6 - Towards Efficient Policy Making – takes stock of supply chain vulnerabilities, the objectives of the CRMA and the conclusions from the CIRAN Project case studies from 10 European countries regarding mining of CRM in nature-protected areas (Natura 2000, among others).

Chapter two explores the crucial research question of the report – what are the missing segments and vulnerabilities of the CRM supply chain? After an analysis of the vulnerabilities the focus shifts to the interdependencies and interactions between the policies of the EU and UN, and the desired outcomes of the CRMA and SDGs, in particular in restructuring value chains as part of the transition from linear to circular practices. The comparison of EU and UN approaches shows that prior to the passage of the CRMA the EU paid inadequate attention to the transition from regulation to action. This high-level review is complemented by zooming into battery and e-mobility related strategic materials (SRM), a group to which most of the materials addressed in CIRAN case studies belong.

The current legal EU framework is the CRMA, outlined in detail in chapter three. This itemises the 34 critical and 16 strategic raw materials selected for the EU CRM list valid for this Report. Of these, at least 10% should be extracted, 40% processed and 15% recycled in the EU, and no more than 65% should be sourced from any one country by 2030. After a summary of European legislative framework governing the extractive and processing industries, the primary conclusions from the specific case studies conducted by the CIRAN Consortium members drawn from EU Member States and other Horizon-programme affiliated countries (Norway, UK) are reviewed in terms of issues in permitting, operations and End-of-Life closure and remediation regulations and practices specific to environmentally and socially protected or sensitive areas. The results of these case studies are also considered from a forward-looking policy framework perspective.

The EU and national reviews concluded that the existing, broadly similar, regulatory frameworks in the EU, Norway and UK do not significantly impede mining in general, nor in particular in environmentally protected areas. Projects selected for in-depth CIRAN review were all either permitted or eligible for permitting. Complementary interviews with regulators and other subject-matter experts likewise demonstrated that environmentally sensitive, but also responsible and pragmatic, approaches to operational challenges had been taken by operating companies by adopting the necessary precautionary measures to prevent or mitigate any adverse environmental impact.

The barriers to speeding up permitting in place in all CIRAN consortium-member countries are mainly non-regulatory in nature. The delays are caused by understaffed public agencies, lack of experts in EIA and

permitting, and activists filing objections that cannot be resolved in a reasonable time due to understaffed permitting and legal departments.

Overall, a lack of consistent strategies at member state level is potentially a significant barrier to fully implementing the CRMA. While the CRMA and investors aim for long-term political commitment, policy makers, at least in the past, tended to follow short term mainstream opinions (polls) and trends.

Consequently, the draft recommendations in this report focus on what have been identified as the main barriers: non-legislative political and social issues that do not require revolutionary changes in the legal framework, but a significant change in policy approaches, including a turn towards a long-term commitment to industrial policy and a strategic positioning of the EU in the concert of global economic competition.

27th June 2024

Ludwig Hermann
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1 Introduction

1.1 Objective

This deliverable (D6.1), the first of the two substantive reports of Work Package 6 (WP6) of the EU Horizon CIRAN project, take stock of the diversity and relative severity of the numerous supply chain vulnerabilities impacting perhaps the two most challenging socio-economic transitions currently facing the EU and wider European region. These are a) the transition of the current energy and mobility networks in Europe and b) the transition to a sustainable, circular net zero emission economy.

To put this objective in context, the starting point of this report is to cite the reasons for which the Critical Raw Materials Act (CRMA) was adopted into the EU legal framework:

- to strengthen the different stages of the European critical raw materials value chain;
- to diversify the EU's imports of critical raw materials to reduce strategic dependencies;
- to improve the EU capacity to monitor and mitigate current and future risks of disruptions to the supply of materials;
- to ensure the free movement of critical raw materials on the single market while ensuring a high level of environmental protection, by improving their circularity and sustainability.

Of particular significance to this report is the choice of the phrase “value-chain” in preference to supply chain which in and of itself resets the baseline from linear to circular as that chain is no longer defined by its supply of raw materials from A to B, but by its capacity to deliver value securely and equitably to all stakeholders in that value chain. In that model, what in the Act is defined as Supply Risk (see Section 2) is no longer a single use delivery system, but a continuous, whole lifecycle resource management process. Some of that material will come from secondary resources (i.e. recovery and reuse) the remainder from primary resources. What is critical is the aggregate balance, not the particular origin.

Theis report first characterises and inventories the broken current state baseline in which the recent push for enhancements and reforms as best illustrated by the Critical Raw Materials Act has its origins. It also analyses across a set of 11 selected case studies central to the work of the first half of the CIRAN project, how the process of change is taking a path that is as much developing organically (bottom up/ grass roots) as it is strategically planned (top down). This powerful complementarity is not common, but it is essential to deliver the required fundamental systemic reset.

Accordingly, special attention is paid first to “the ensuring a high level of environmental protection, by improving their circularity and sustainability”. That is the essence of the CIRAN project. But as that objective is literally grounded in land-use, close attention is paid to the interfaces between the CRMA and its potential implementation in Member States, the spatial planning of mining activities in or next to nature protected areas across 11 different jurisdictions, and the inherent socio-economic purposes for which these CRM and SRM are being mined (or recycled) in the first place.

The report references but also contributes significantly to CIRAN’s Key Strategic Objective 2 (KSO2) - development of a **new logical framework** for policymaking and permitting, based on co-creation and transparent consultation processes on rights, obligations, and responsibilities concerning the extraction of CRM in environmentally protected areas, tested and verified in eleven+ EU communities.

The overarching objective of WP6 and the project at large is reconciling the requirements of the transition to a net zero economy with a significant additional consumption of critical raw materials and the protection of the environment, particularly in already protected areas while safeguarding the social and economic welfare of EU citizens, while demonstrating that there is no inherent reason why these two objectives cannot be achieved as two complementary processes.

1.2 Logical framework

The logical framework approach provides a tool for balancing interests and objectives, while ensuring that society's critical needs and environmental vulnerabilities are met. The logic will be similar to that of the Drivers – Policies – States – Impacts – Responses (DPSIR) framework (Gupta et al., 2020). The DPSIR framework will be extended by formulating objectives that are in line with the EU's energy and materials policies and its environmental and biodiversity policies. Such a logical framework also integrates more ambitious objectives for the post-mining period, which reach beyond rehabilitation. Significantly often the "End of Life" restoration process "terminates" in the creation of a new, enhanced, point of departure for the next eco-system life-cycle (often with a new, mixed land use distribution, rather than reverting to a "baseline" set at the point when mining first disturbed the ground. In reality, this may be so far in the past, or so poorly documented, that defining such a state can be akin to science fiction. But even in cases where the *status ante quo* is well known, it may not be environmentally the optimum point to return to. The tailored LogFrame which results from the findings of the report will potentially provide policy makers and implementers with a blueprint for systemic and contextualised approaches to long-term master planning in a circular rather than linear economy.

To better understand and balance different or conflicting positions, it is helpful to subject the policy or planning decision to a DPSIR (Drivers-Pressures-States-Impacts-Responses) analysis (Figure 1). Overarching drivers flow from policy decisions taken at EU or national level, such as the Green Deal and the Energy Transition. These lead to significantly increased pressure on primary mineral resources, even to the point of resource-stress or resource-criticality. Foresight studies conducted against this background will help to better anticipate likely future sources of pressure, including the rapid evolution of demand for specific but rapidly changing types and combinations of CRM. Whatever policy choices are made as EU societies move towards circularity and the rational reuse of resources, a turbulent transition lasting one or more decades is likely before sufficient stocks are available to ensure supply chain security wholly or predominantly through recycling. This means that there will inevitably be a strong focus on the extraction of specific new primary raw materials to enable continuous and smooth technological change to occur (e.g. chemical elements such as lithium or cobalt for batteries and copper for electric lines).

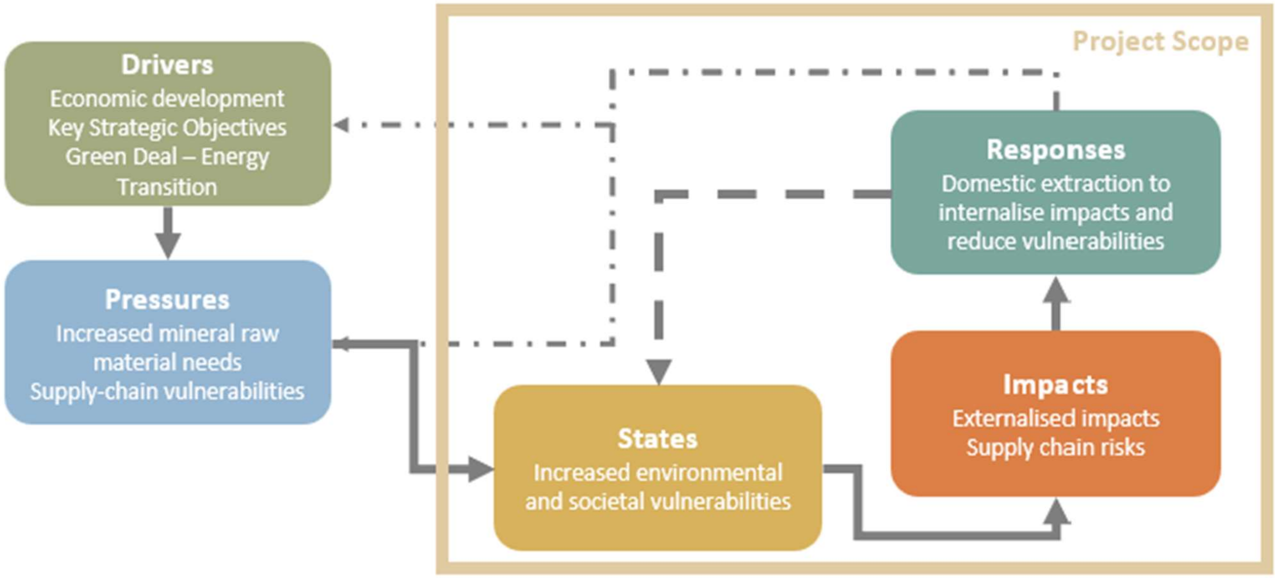

Figure 1 – DPSIR framework for mitigating policy-driven externalities and socio-economic vulnerabilities.
Adapted from Gupta et al., 2020.

At present, primary extraction takes place mainly outside Europe, where the state of societies, the environment and regulatory regimes, including enforcement, may be more fragile than the EU. The results are greater vulnerability and further, potentially more severe, negative impacts, outcomes which are ethically repugnant and expose EU societies to the risks of even more damaging supply chain disruption. To take such "double materiality" risks into account, CIRAN therefore broadens the scope of classical (linear) DPSIR analysis to make the process CE transition sensitive. These include societal impacts, value and supply-chain vulnerabilities and potential conflicts resulting from both unmet demand for primary resources and supply chain insecurity when supply lines extend beyond Europe's sphere of control or influence.

2 Missing segments and supply chain vulnerabilities - Baseline

Supply chains for raw materials are inherently complex and susceptible to a range of vulnerabilities that can significantly disrupt the production and delivery of essential goods. These vulnerabilities often stem from geopolitical instability, natural disasters, and economic fluctuations, which can lead to supply shortages, increased costs, and delays. For instance, geopolitical tensions between countries that are key suppliers of critical raw materials, can lead to embargoes or trade restrictions. These political decisions can abruptly cut off the supply of essential materials, forcing companies to scramble for alternative sources, often at a higher cost and with significant delays. The vulnerabilities create several gaps in the supply chain that can have cascading effects on industries reliant on these raw materials. One significant gap is the lack of diversification in sourcing, which leaves companies exposed to the risks associated with any single supplier or region. Without diversified supply sources, companies face increased risk of production halts and financial losses when their primary suppliers encounter disruptions.

Natural disasters such as earthquakes, floods, and hurricanes can also wreak havoc on supply chains by damaging infrastructure, halting production, and delaying transportation. The COVID-19 pandemic highlighted how a global health crisis could disrupt supply chains, as lockdowns and restrictions led to factory closures, reduced workforce availability, and transportation bottlenecks. Recently, not only the Covid-19 pandemic but also the war in Ukraine have exacerbated the supply chain vulnerability and raised the awareness further (Rizos and Righetti, 2022).

The EU's concerns about raw material supply risks are not new but are well founded. The first calls for action can be traced back to the Council's Second Environmental Action Programme, which noted the Community's dependence on raw materials from beyond its borders (Council of the European Communities, 1977). Two decades later, the European Commission adopted the Raw Materials Initiative, the first integrated strategy to improve access to raw materials (European Commission, 2008). In 2011, this led to the establishment of a first list of critical raw materials (CRM)[1], defined as such by a combination of high economic importance, high supply risk and a shortage of available substitutes.

Despite the recognition this brought at a policy level to the need for a strategic planning concept of "criticality", which flagged that availability constraints on the supply chains of certain natural resources of such high economic importance could reach, at the level of action little if anything was actually done to avert or pre-empt a potential supply chain/ resourcing crisis. Three revisions followed at 3-yearly intervals in 2014, 2017, and 2020, the last of which, was published in September 2020 six months after the World Health Organisation had pronounced a state of global pandemic for the Covid-19 virus. By that time a high state of supply chain criticality had already been reached, one not confined to the materials on the CRM list. Almost everything by then had reached criticality of supply, rather a case of taking out house insurance when the building was already on fire.

In 2017 itself, somewhat curiously, the rationale for having a CRM list in the EU, and the methodology for how it was compiled, was summarised not by the EU but by UN Department of Economic and Social Affairs within the context of its analysis of the 17 Sustainable Development Goals[2]:

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[1] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52011DC0025

[2] https://sdgs.un.org/partnerships/list-critical-raw-materials-eu-2017-linked-renewed-eu-industrial-policy-strategy

> "The list of critical raw materials provides a factual tool for trade, innovation and industrial policy measures to strengthen the competitiveness of European industry in line with the renewed industrial strategy for Europe, for instance by:
>
> - Identifying investment needs which can help alleviate Europe's reliance on imports of raw materials;
> - Guiding support to innovation on raw materials supply under the EU's Horizon 2020 research and innovation programme;
> - Drawing attention to the importance of critical raw materials for the transition to a low-carbon, resource-efficient and more circular economy."

The UN analysis, framed in terms of "missing segments and vulnerabilities", identifies two critical gaps:

- Targeted Investment: There is an unmet need for strategic investments aimed at reducing dependence on raw material imports from non-EU countries. These investments could either alleviate the reliance on imports or potentially substitute them entirely.
- Supply-Chain Knowledge: There is a significant lack of understanding about how Resource Use Efficiency (RUE) and enhanced economic circularity contribute to the decarbonisation process. This gap in knowledge exists both for each concept individually and for their combined effect.

The analysis also emphasises that addressing both these missing segments is crucial for achieving effective decarbonisation. It highlights the interconnectedness of investment strategies, resource efficiency, circular economy practices, and the overarching goal of reducing carbon emissions.

The 2020 Report that accompanies the updated CRM list of that year (released in September, 6 months into the pandemic) makes no reference to COVID; given that the list is about criticality, and even if there had not been time (in the approval process?) to revise and revisit what was said in the Report, it is a strange omission that COVID passes without even being commented as a matter for immediate follow-up. If mine permitting times need to be radically streamlined surely the same would apply to reports on the criticality status of materials of concern, i.e. these need to be published as and when needed, not as a matter of historical record. But the report does cite certain key criticality indicators which can be applied to analysing "missing segments and vulnerabilities" in the CRM baseline: "increasing global population, industrialisation, digitalisation, increasing demand from developing countries and the transition to climate neutrality with metals, minerals and biotic materials used in low-emission technologies and products". These indicators are almost all weighted to the demand side, while factors bearing on gaps and vulnerabilities in the then just-in-time (JIT) supply chain which COVID had ruthlessly exposed are left unidentified.

There is also no reference to strategic contingency planning for managing lengthy periods of supply chain disruption, but which is not meant making provision for increasing JIT stockpile quantities from 7 to 28 days, but rather to 180 or 360 days. These stockpiles will not simply comprise non-perishable raw materials but specialist essential or critical components and the skills and experience to maintain and repair them.

2.1 Strategic and tactical investments: inserting the missing segment of the social resource contract

Taking the three salient UN comments above on the 2017 EU CRM List release as a point of departure for considering weaknesses in investment policy and practice in the supply chain. Addressing these weaknesses requires a dual approach, encompassing a strategic and a tactical aspect. The strategic is the more significant of the two as it determines the nature of the financial instrument through which the investment is made. The form this type of investment is increasingly likely to take is "ESG" Investment – environmental, social and governance. This means the return on investment (ROI) is spread across both tangible and intangible forms of return, which speaks a) to the way the EU CRMA itself is framed from a Triple Bottom Line perspective, b) how it maps to intergenerational and public good value considerations which are the glue of many core attributes of a circular economy and c) how negative externalities are eliminated from the system *ab initio*.

In terms of tactical investments, the ability is built into the investment model to "flex" between a purely tangible ROI – financial performance and market performance led – to an intangible one where the security of access to affordable supply, irrespective of capacity to pay if suitably eligible, has primacy in a calculation of "return" on investment. This assigns a specific role for "sufficiency" calculations as part of demand management in which a Social Resource Contract plays the mediating role in the supply chain because it securely ring-fences the case for public good primacy for those who have the critical need but not the capacity to pay for it.

This ring-fencing procedure is inherently much easier to manage in a circular economy (CE) because in CE mode all stakeholders are incentivised by the security of supply and access to the CRM in question to stay in the circular value-chain management contract for the long-term rather than acting as a trader or broker in a volatile linear spot market. In Nash economics, this positions the circular value-chain contract as a "win/win" sustainable equilibrium instrument, and hence transforms the point-to-point supply-chain into a continuous value-preserving/ value-additional value-chain.

2.2 Co-dependency of SDGs and CRM

In complement to the focus on targeted investment to ensure robust and resilient supply chains, the UN analysis draws a tight connection between the creation of a set of 17 universal SDGs and the CRM which are essential for delivering these SDGs in practice in a way responsive to local needs and priorities in all cases. The authors write:

- "Critical raw materials are a priority area in the EU Circular Economy Action Plan, and the list helps incentivising the European production of critical raw materials through enhancing recycling activities and when necessary to facilitate the launching of new mining activities (noting that mining is in full competence of the EU Member States).
- Critical raw materials enable decarbonisation as they are essential to produce the hardware equipment. Rare earth metals are used in the construction of windmills, silicon metals for photovoltaics. In the transition to low-carbon mobility higher quantities of critical raw materials will be needed to enable the large-scale roll-out of electric vehicles - e.g. cobalt, graphite, lithium for batteries, niobium for lightweight vehicle body structures."

The UN comments further:

- "The Commission uses the list as a supporting element when implementing the 2030 Agenda on Sustainable Development and its Sustainable Development Goals, in the negotiations of trade agreements, when challenging trade-distortive measures, developing research and innovation actions.
- It was also used for the Report on Critical Raw Materials and the Circular Economy (2018) which looks at supply side (mining, landfills) and demand side (electrical and electronic equipment, batteries,

renewable energy and other sectors) and which analyses how to increase the supply of critical raw materials through increased circularity.

- 27 raw materials are included in the 2017 list, which builds on an evaluation of 78 raw materials."

From this analysis it is uncomfortably obvious that the UN perspective analytically was superior to that of the EU, at least in pinpointing the critical dependency that of connecting the dots between policy and action, which the EU did not do.

Of course, this particular vulnerability was made doubly visible in spring 2020 by the global supply-chain disruptions of COVID and the breakdown of JIT supply-chain design. But what the Russian invasion of Ukraine two years later brought even more starkly into relief was that disruption could be targeted (by planned invasion) as well as arbitrary (by natural dispersal of a virus). This meant that while a shortage of CRM in a pandemic might deal a severe or even, short-term, fatal blow to plans for decarbonising the energy economy, Russian bombs delivered deliberately on Ukrainian powerplants or water pumping stations could stop flows of electricity and water altogether. Taken together, the pandemic and the war in Ukraine have exacerbated the supply chain vulnerability and raised the vulnerability awareness higher perhaps than at any time than immediately after 1945 (Rizos and Righetti, 2022).

Hence the Social Resource Contract (SRC) which has emerged in UN resource management policy in the wake of both COVID and the invasion of Ukraine[3] has become a means of addressing and moderating supply chain uncertainty and instability whether caused by factors in human control, such as resource weaponisation, or those outside human control, such as pandemics. In such an SRC, the inevitability of both forms of existential instability occurring, whether together or at different time, requires the contract to provide as far as reasonably possible for long-term intergenerational equity, for which secure and stable supply chains are a *sine qua non*. But it also rests on the contractual principle of primacy being given to the inherent interdependence of demand for the progressive if perilous achievement of sustainable development with a secure supply of CRM. CRM are inherently only "C" – critical – in nature because of extraneous human factors, not because they are, perhaps like phosphorus, elementally "critical". Hence the paradox that Sustainable Development Goals can only be achieved on a continuous basis by smart and selective use of Critical Raw Materials depending on specific needs and priorities.

2.3 The Just Transition

A related UN Concept paper ECE/ENERG/GE.3/2021/ 15 **Redefining resource management as a public good: The United Nations Resource Management System as a transition vehicle to the circular economy**[4] shows how the UN Resource Management System (UNRMS) was designed from 2019 to initial release as a paper-based resource in 2021 to resolve the criticality paradox between SDGs and CRM with the aid of UNRMS. In effect, UNRMS is the instantiation of the concept of Double Materiality, whereby risk, for example, in a supply chain, must be assessed not just in terms of the impact on material stocks and flows, but on the social,

[3] https://unece.org/climate-change/news/countries-are-committing-implementation-united-nations-resource-management

[4] See Redefining resource management as a public good: The United Nations Resource Management System as a transition vehicle to the circular economy, ECE/ENERG/GE.3/2021/15, UNECE Geneva, 9 April 2021.

environmental and economic context in which those stocks are found, whose purposes they help fulfil, and whose flows both shape and are shaped by.

As a resource management system, UNRMS inherently depends on sustainable, equitable supply chains for stability and social justice. The UNRMS draft itself was finalised a year earlier, in January 2020, when COVID-19 was still understood as an acute but local crisis focused on Wuhan, China. But even at that stage a link was proposed between the possible causes of such public health crises and intense resource stress in urban and peri-urban settings, often associated with excessive demands being placed on energy and mineral resources, i.e. lead classes of CRM:

> *One quality of places where resource intensity is very high in terms of both production and consumption, such as large cities, is that chronic and acute stress may both be equally observed in the natural and the engineered systems which characterize them.*

This quality is a crucial indicator of catastrophic supply-chain vulnerability, meaning factors such as pandemic and war are such that resilient, stable supply chains are based on having in-built mechanisms for coping with them and that they can give rise to catastrophic public health events. Common attributes of such places are high levels of population density, connectivity, biodiversity hotspots, waste and air pollution. There is a clear overlap between such factors and the drivers of criticality identified in the accompanying Report of the EU 2020 revised CRM List.

What we also now know, which before COVID we did not, or had forgotten, is the extent to which confusion has grown up in the linear economy between "resource intensity" (which typically results in negative externalities i.e. the failure to preserve double materiality) and "resource efficiency", (which typically has highly positive consequences for a sustainable economy, especially one in circular mode, hence fulfilling double materiality benefits. This confusion is having devastating, even fatal, consequences on a global scale, manifest most recently (June 2024) in the IEA's prediction of "more than 8 million barrels per day of excess oil production capacity by 2030 as producers invest in pumping more crude"[5]. These consequences are all the more devastating in that much of the damage caused is avoidable if the necessary evidence to understand, prevent or mitigate the causes – systemic failures in the management of critical resources – is not readily to hand or, worse, if it is ignored or trashed.

The single event which during COVID crystallised the Black Lives Matter movement, the unjust police killing of George Floyd[6] was also to cement the deep cultural and commodity minerals market connection between the linear economic model of resource extraction and the "engines" of extraction, slavery or abundant cheap labour. Such a model is both physically and conceptually linear and by its very nature is not capable of enabling or managing a "just" energy transition because its defining double materiality attributes are injustice and exploitation. Even the semantics of the term "exploitation" make the use of this term deeply problematic when applied to the recovery and use of minerals, especially CRM. In the linear model, resources are mined in one location and then, raw or partially beneficiated, shipped to, value-add processed and profitably sold for use in another. The critical dependency that the source country provides other than the mineral itself is either outright slavery or expendable and inexpensive labour as the vital source of cheap energy for the first stages in the extractive (exploitation) process.

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[5] Internal Energy Agency, Oil Market Report June 12, 2024, as also reported by the Financial Times, https://www.ft.com/content/cfb97534-b71b-490f-b626-6dc3487f595d

[6] See UN action on "Let's fight racism" - https://www.un.org/en/letsfightracism/

George Floyd's death brought home so powerfully that the colonial legacy is still deeply embedded; and as a result, whether intentionally or not, the linear economic model continues to fail the economic test for sustainability and double materiality compliance, set by John Nash, that its transactions should be equitable "win/wins" in which both parties equally benefit. When this is patently not the case, it poses an existential threat to supply-chain security at the deepest level of double materiality failure. How long the coat-tail of damage can be from being on the losing side of the "lose/win" linear transaction of resource management and use is well illustrated not only in low-income countries acting as resource provinces for high-income ones, but also in high-income societies where the descendants of the slaves still live in pockets of exclusion and suffer from poverty, discrimination and injustice.

This is a partly intangible negative externality where the costs imposed on subsequent generations without their knowledge or consent can be measured both in emotional and social damage as well as severe financial disadvantage or exclusion. This may be considered a case of severe negative double materiality in more contemporary economic terms. People are treated with the same disregard and disrespect, effectively with a status similar to natural resource "wastes" (discarded tailings and residues).

The transition to a sustainable circular economy (Figure 2), creates a system within which equitable access to and enjoyment of all natural resources, especially food, energy and water, is available to all. Food, energy and water are prioritized because of their role in meeting fundamental needs, as Brundtland, Our Common Future[7] and Maslow, The Hierarchy of Needs[8] both in different ways made fundamental to the vision of sustainability (the future SDGs) but also encapsulating together what in practice Double Materiality means at the level of the individual citizen of the global village. In that context, the socio-economic reclassification as "Public Good" of the critical resources in this nexus of "fundamentals needs" is a core principle of UNRMS. A vital outcome of the reset to a circular economy will be negotiating a new Nash equilibrium for inclusive development where resource provision for critical needs becomes such a public good).

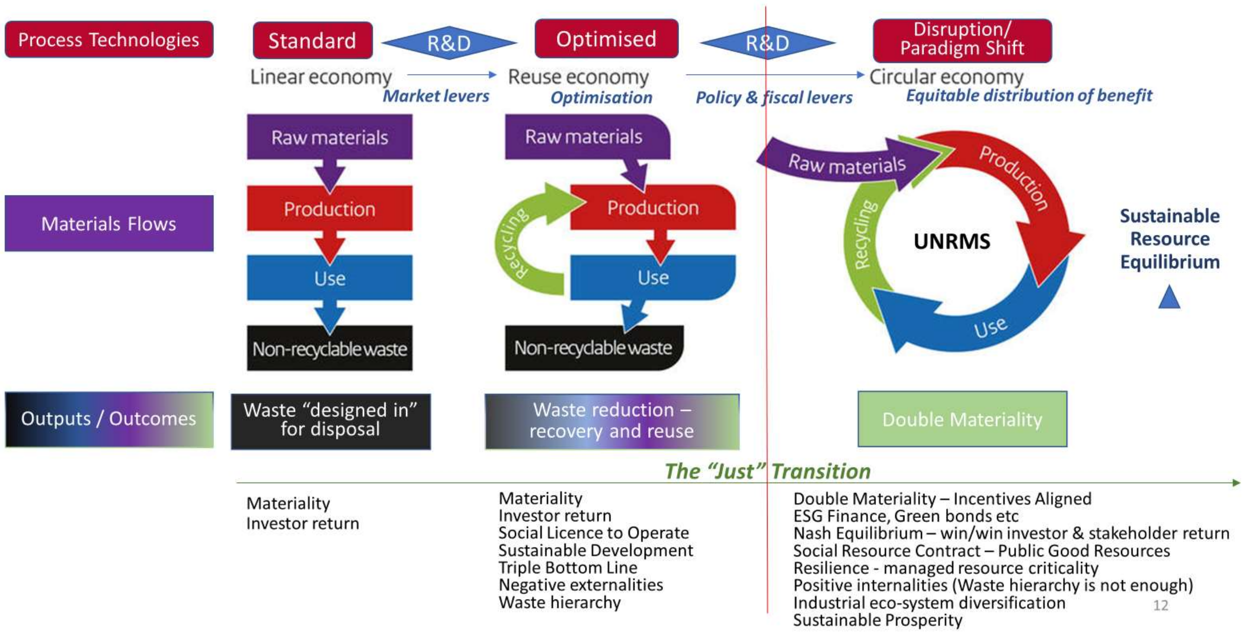

Figure 2 – The disruptive "Just Transition" from a linear to a circular economy.

[7] Gro Harlem Brundtland, Our Common Future: The World Commission on Environment and Development (The Brundtland Report), 1987. https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

[8] Abraham Maslow, "A theory of Human Motivation" Psychological Review, 50, 370-396, 1943. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.318.2317&rep=rep1&type=pdf

The transition from a linear to a circular minerals' economy must negotiate a new point of alignment with the Nash equilibrium in which markets continue to function, but with full provision for meeting critical needs of those without the capacity to pay. Of the critical needs zero hunger, SDG 2, is perhaps the most obvious but to which access to clean water, SDG 6, and to affordable and clean energy, SDG 7 belong with equal importance. Double materiality compliance encapsulates both "necessary" and "sufficient" conditions for measuring impact and progress of a systemic attempt to mitigate or eliminate criticality risk to such essentials as food, energy and water ("The FEW").

This is the space into which the concept of double materiality necessarily fits:

> *"After years of debate over the definition of materiality, 2020 has brought a consensus that materiality is double - meaning that businesses should report on financially material topics that influence enterprise value as well as topics material to the economy, environment, and people"*[9].

2.4 Addressing an acute vulnerability – professional and societal resistance

In complement, there is one key vulnerability addressed by the UN analysis which can be addressed by managing an equilibrium of market and public good resource management, equitable both within and through time, through using a value chain managed by highly responsive and flexible "smart" contracts (i.e. using blockchain and AI) within a UN Social Resource Contract frame. This value chain can also be protected from the illicit flows of materials and monies which causes in principle avoidable annual losses in the African region alone of ~$85 billion[10]. To address this issue, the UN has an ongoing working group developing a digital "Transparency Protocol" (TP) which will also embrace other supply chain safeguards such as Resource Passports and Certificates of Origin or Provenance. This TP will be delivered using blockchain and similar technology.

Other vulnerabilities, more of a societal or professional cultural than economic nature, the EU Horizon programme is only now vigorously tackling – following very late-starting. This vulnerability consists of an amalgam of deeply ingrained attitudes and working practices which the CRMA clearly recognises need to be reformed but is not yet clear how to do it.

The lack of targeted innovative research and development in raw materials under the Horizon programme has resulted in a systemic failure to mitigate supply chain vulnerabilities at source, whether through wholesale resource substitution, secure materials sourcing from within borders under EU control, or radical transformation of demand-side behaviours either by retail customers or industry corporates, or both.

A key dependency for restoring supply-chain security lies in resolving two different approaches as to how best to manage, mitigate or eliminate criticality factors in the cycles of use, recover and reuse of CRM resources. These two approaches are embedded in the UN critique of the EU's management of CRM. The UN

[9] See BSR accessed March 31, 2021, https://www.bsr.org/en/our-insights/blog-view/why-companies-should-assess-double-materiality#:~:text=After%20years%20of%20debate%20over,economy%2C%20environment%2C%20and%20people. See also the Sustainability Accounting Standards Board, https://www.sasb.org/blog/double-and-dynamic-understanding-the-changing-perspectives-on-materiality/, Blog September 2, 2020.

[10] See UNITED NATIONS, Policy Brief: Transforming Extractive Industries for Sustainable Development, New York, May 25, 2021, https://www.un.org/sites/un2.un.org/files/sg_policy_brief_extractives.pdf

is proactive, preventive, predictive: it assumes such challenges will come and accepts the key uncertain is when not if; the EU approach, at least until the double hit of COVID and the invasion of Ukraine, is reactive. “We cross that bridge when we come to it”. The problem as we have seen is that by the time we do come to it, the bridge has been blown up. The underlying critical “metaresource” is time: but in the UN model risk is essentially stochastic, the EU is binomial.

Two examples as to taking different temporal approaches to managing critical risks in the supply chain may stand for a range of others: a) mine permitting and b) End of Life planning. Both are included in the CRMA and both envisage paradigmatic change (disruption) not optimisation (see Figure 2). In the proactive model, the derisking process is continuous; a mine or other repository with a critical resource is always on sufficient standby to “keep the lights on”. But this is costly. In the reactive model, the cumulative saving through not maintaining sufficient reserve on standby reaches a point where the balance sheet tilts in favour of “no action”. Except - when it goes wrong the outcome is even costlier.

2.5 CRM Act paradigm shift 1 - Streamlining Mine Permitting

The CRMA Policy Option 2 “goes further to improve the value chain in the EU by developing stronger obligations on exploration and by implementing Strategic Projects along the value chain of strategic raw materials. These projects would benefit from streamlined permitting and a coordinated access to finance”[11].

In more detail:

- “(5) The list of critical raw materials should include those raw materials which reach or exceed the thresholds for both economic importance and supply risk, without ranking the relevant raw materials in terms of criticality. This assessment should be based on an average of the latest available data over a 5-year-period. The measures set out in this Regulation related to one stop shop for permitting, planning, exploration, monitoring, circularity, and sustainability should apply to all critical raw materials.
- (6) To strengthen Union capacities along the strategic raw materials value chain, benchmarks should be set to guide efforts and track progress. The aim should be to increase capacities for each strategic raw material at each stage of the value chain, while aiming to achieve overall capacity benchmarks for extraction, processing and recycling of strategic raw materials”.

The CRMA has clearly shifted to the stochastic model.

The change goes deeper as CRMA Article 10 makes clear:

> *“Article 10,* Duration of the permit granting process gets granular, imposing a strict time limit for permits to be issued:
>
> 1. For Strategic Projects in the Union, the permit granting process shall not exceed:
>
>   (a) 24 months for Strategic Projects involving extraction;
>
>   (b) 12 months for Strategic Projects only involving processing or recycling.”

[11] See Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) 168/2013, (EU) 2018/858, 2018/1724 and (EU) 2019/1020, p. 6

Building in a time metric which unilaterally reduces mine permitting times on average by as much as 90% in effect reverses the whole nature of linear economic risk assessment in permitting. This shift addresses the core issue of inefficient time management in mine permitting, and encompasses the following key aspects:

- Risk redefinition: in this new framework, delay becomes the primary risk factor, both in terms of time and cost, rather than rushed decision-making.
- Parallel processing: the new norm emphasises simultaneous handling of multiple aspects of the permitting process, replacing the outdated sequential approach.
- Proactive planning: this model prioritises thorough preparation and comprehensive planning from the outset.
- Integrated decision-making: instead of isolated, single-issue decision points, the process encourages a more holistic, interconnected approach to evaluations and approvals.

There is even a shift from the current practice in permitting which defaults to a Boolean "if lack of timely decision, then stop" to a reversed outcome (equally Boolean) "if lack of timely decision, then go". What is very elegant about this paradigmatic shift is that it is essentially pragmatic, not idealistic. A simple study of the history of the CRM list since first publication is that it is constantly changing, even volatile, and at time even a 3-year review cycle it too long. That illustrates the essentially systemic nature of supply-chain risk in the way CRM risk criticality currently managed, that supply and demand are on two completely different decision-cycles determined by temporal periodicity disconnect. This problem of asynchrony between planning and action is alluded to above in the opening observation that an issue raised in the 1970s was recognised but not at all acted upon for some 40 years afterwards. The CRMA observes quite simply that if a permitting system cannot reach decision-making in a maximum of 2 years, in a CRM dependent economy on 3-year review cycle decisions are useless because the risk is very high that a grant of permit to mining a critical resource will almost always come when the need is either not urgent any more, or redundant. In effect supply chain risks in a CE are always simultaneously binomial and stochastic as "past financial success is no guarantee of future performance".

Inevitably given that the CRMA was adopted only three months from the date of release of this report, there is as yet no case study, still less case law, on putting these rules into practice which could be analysed. The issue will however be tracked in CIRAN WP 6 over the remainder of the Project and Deliverable 6.2 (*Triple Bottom Line policy recommendation for permitting, social model contract and ESG reporting*) will report on if and how the desired streamlining is underway or even being considered after more than 18 months from the approval of the CRMA.

2.6 CRM Act paradigm shift 2: the "For Ever Mine"

An even bolder paradigm shift is interwoven into the CRMA as unlike the hard deadline required of streamlining permitting, in transitioning an end point in the Life of Mine to an "End of Life" (EoL) phase within a continuous circular economy (with some special concessions to operators of CRM projects in regard to relaxing certain Lifetime Producer Responsibility provisions) the CRMA takes the first of several linked steps to what might be called a "For Ever Mine".

The steps include:

1. Optimising recovery of all target resources from primary (virgin) materials.
2. Continuous or time-scheduled recovery and reuse (with reprocessing as needed) of raw materials from discarded, used or outdated equipment, etc.

3. Aligning a criticality state to a given CRM or SRM not by the actual or anticipated closure of a particular mine (or source) but to the level of security of supply at a given point of time from BOTH secondary and primary resources.

The combination of these and other measures ends up in the calculation, and continuous recalculation, of the Supply Risk (CRMA Annex 2 Critical Raw Materials, Section 2, 3 Supply Risk)[12]:

The supply risk (SR) of a raw material is calculated as follows:

$$SR = [(HHI_{WGI,t})_{GS} \bullet \frac{IR}{2} + (HHI_{WGI,t})_{EU\,sourcing}(1 - \frac{IR}{2})] \bullet (1 - EoL_{RIR}) \bullet SI_{SR}$$

where:

- *GS is the global annual production of a raw material for a reference period;*
- *EU sourcing is the actual sourcing of the supply to the EU, i.e. EU domestic production plus other countries importing to the EU;*
- *HHI is the Herfindahl-Hirschman Index (used as a proxy for country concentration);*
- *WGI is the scaled World Governance Index (used as a proxy for country governance);*
- *t is the trade parameter adjusting WGI, which shall be determined taking into account potential export taxes (possibly mitigated by a trade agreement in force), physical export quotas or export prohibitions imposed by a country.*
- *IR is import reliance;*
- *EoLRIR is the end-of-life recycling input rate, meaning the ratio of secondary material inputs (recycled from old scrap [or other recovered, reusable resource such as P from wastewater] to all inputs of a raw material (primary and secondary);*
- *SISR is the substitution index related to supply risk.*

As a key finding of this report, the single most significant metric for Supply Risk (SR) is the EoLRIR (End of Life Recycling Rate). This has the same impact on tightening the management of the time sequence (periodicity) of each of the resources' lifecycles of the various CRM as shortening the permitting cycle to 24 months. It builds a pro-active time-based periodicity algorithm into the management materials stocks and flows to enable predictive rather than rear-view mirror resource flow and stock (inventory) management. What radically shortening the periodicity length in effect achieves is a virtual state of continuous, forward- looking planning even though a reporting cycle with a rear-view component is actually still maintained. This has truly the feel of "smart" management. This smart approach will of course be most effective when interfused with blockchain and AI smart inventory systems which can administer the inventory dispassionately and highly adaptively, even in continuous real time.

2.7 Vulnerability of selected CRM

The EU's green and digital transitions certainly depend on the secure and reliable access to several CRM, such as lithium, cobalt, and rare earths, but also on base metals such as aluminium, copper and zinc. For example, the European Commission's Joint Research Centre (JRC) expects lithium consumption to increase up to almost 20 times by 2050, driven almost entirely by the uptake of e-mobility (Carrara et al., 2023). In the case of graphite, overall EU consumption is expected to increase 26 times by 2050 (Carrara et al., 2023).

[12] See CRMA Section2 Calculation of economic importance and supply risk, p.55.

Raw material supply chains are highly concentrated in just a few countries, causing another major vulnerability in raw material supply chains - the reliance on a limited number of suppliers or geographic regions. China is a key player in this domain. For example, the country controls 100% of the global heavy rare earths elements (HREEs) supply, 91% of global magnesium supply and 76% of global silicon metal supply. Heavy market concentration also exists for cobalt – with the Democratic Republic of the Congo controlling over 60% of the global market – platinum (71% controlled by South Africa) and palladium (40% controlled by Russia), among others. Consequently, the EU today is heavily reliant on imports to meet its domestic raw materials needs; for instance, it sources 100% of its HREEs, 85% of its light rare earths elements (LREEs) and 97% of its magnesium supply from China, as well as 99% of its boron supply from Turkey and 79% of its lithium supply from Chile (European Commission, 2023a). Currently, hardly any of the determined strategic raw materials are compliant with the goals of the CRMA as Figure 3 demonstrates[13]. Following the DPSIR logic, drivers and pressures are consequently enormous, and they encounter an ill prepared economic environment.

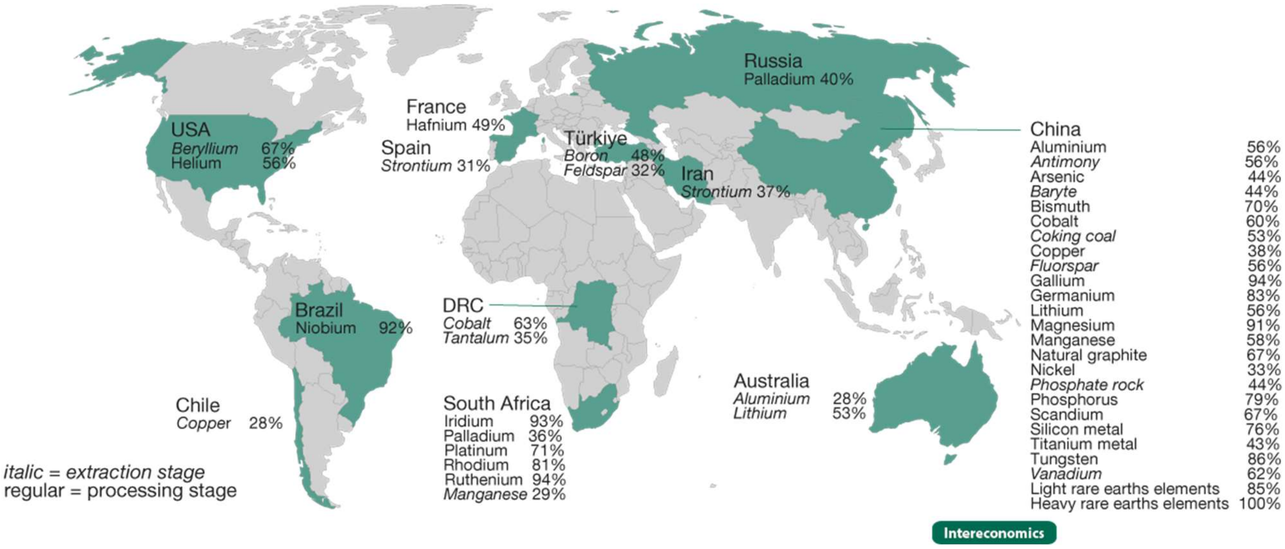

Figure 3 – Global distribution of Critical Raw Materials supply. Source: European Commission, 2023.

In response to these challenges, President von der Leyen's 2022 State announced in her "State of the Union" speech, in March 2023 a proposal for establishing a framework to ensure a secure and sustainable supply of CRM, the so-called Critical Raw Materials Act. Apart from the proposal for a regulation, the development of a relevant domestic mining and recycling capacity in the EU was presented, together with outlining a strategy to diversify supply chains and strengthen global engagement with reliable, resource-rich countries. Besides updating the CRM list, a subgroup of so-called strategic raw materials (SRM), was introduced, containing CRM that are strategically important for green, digital, space and defence applications. The regulation contains a roadmap for creating favourable conditions for critical raw materials extraction projects, among others by streamlining permitting procedures and facilitating access to finance.

[13] In this context the announcement June 17 2024 as this Report is being finalised is very significant that a second BRICS country, Brazil, is planning to loosen China's grip: Brazil joins race to loosen China's grip on rare earths industry, Reuters, Melanie Burton and Fabio Teixeira, June 18, 2024

Consequently, EU policies suggest that upscaling mining and recycling capacity are regarded as preferred pathways for boosting the EU's strategic autonomy in the raw materials sphere. Nonetheless, uncertainty remains regarding the relevance of actual contributions of these sectors and what policy makers can do to make it happen. That said, a joint industry strategy of the EU and its Member States is highly unlikely under the current political framework and one consequent key critical question of this study is if progress can be achieved without revolutionary modifications of the contractual framework of the European Union.

From the DPSIR perspective, the EU has very ambitious goals (drivers), enormous pressures due to the high dependency on supplies of critical materials from third countries that cannot be considered "strategic partners". In addition, political and economic tensions are growing with several of the countries on which the EU his highly dependent for raw material supplies. Consequently, the analysis of the current state is extremely worrying, and the potential impacts are threatening not only the success of the envisaged transition, but the political and economic status of the EU in the world. The impact of the supply chain vulnerability, if used by third countries against the EU strategically, would lead to Europe falling back economically and losing its competitive edge.

2.8 Examples of vulnerable supply chains

2.8.1 Battery manufacturing

Battery manufacturing may be a model sector for showing drivers and pressures in the critical raw materials supply chains. The battery manufacturing industry, which is crucial for sectors such as electric vehicles, renewable energy storage, and consumer electronics, faces several specific vulnerabilities in its supply chain. These vulnerabilities can significantly impact production, cost, and market stability.

Table 1 – Main vulnerabilities identified in CRM supply chains in the EU and their manifestations.

Supply Chain Vulnerability	Impact Caused
Geopolitical Instability	-Sudden supply interruptions due to embargoes or trade restrictions -Increased costs and delays in finding alternative sources
Natural Disasters	-Damage to infrastructure -Production halts -Transportation delays
*Economic Fluctuations	-Price volatility -Budget unpredictability
Concentration of Suppliers in Limited Regions	-High level of dependency -High risk of supply chain disruption -Difficulty in sourcing alternative suppliers
Pandemics and Global Health Crises	-Plants closures -Reduced workforce availability -Transportation bottlenecks
Logistics	-Delays in material delivery -Fickle transportation costs

Supply Chain Vulnerability	Impact Caused
Supplier Reliability	-Production schedule disruptions -Potential quality issues
Technological Failures	-Disruptions in supply chain management systems -Reduced operational efficiency
Regulatory Changes	-Compliance challenges -Increased operational costs
Labor Strikes and Workforce Issues	-Production halts -Delays -Increased labour costs
Circular economy and periodical life cycle	-High level of dependency -Production delays -Supply inconsistencies -Potential loss of market competitiveness
Illicit flows of materials and monies	-Very high financial losses -Uncertainties as to provenance and entitled ownership and benefits -Range of negative externalities including gender discrimination or abuse and child labour and exploitation

Battery manufacturing may be a model sector for showing drivers and pressures. The demand for batteries in the EU is forecasted to increase significantly, driven by the EU regulations regarding the limitation of CO_2 emissions for light and heavy-duty vehicles, as well as increased power system flexibility needs. Figure 4 below shows the approximate metal content portions in a typical lithium-ion battery. There are currently five lithium-ion and several other battery chemistries such as lithium-iron-phosphate in the battery market, so this estimation is only an example (Michaux, 2021).

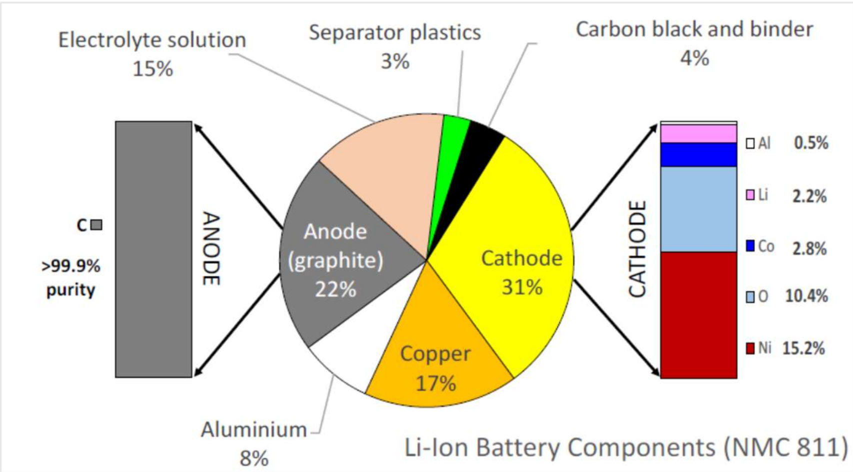

Figure 4 – Lithium-ion battery components by metal (Michaux, 2021).

Europe already hosts several battery manufacturing sites (approximately 175 GWh in 2023). Battery production in the EU could reach 458 GWh by 2025 and 1083 GWh by 2030, on track to meet the forecast

EU demand, but this depends on final investment decisions still to be made, and hence on the technical and economic performance of the first European battery cell manufacturing projects. As outlined in Figure 5, the largest gap between EU domestic production and demand along the battery value chain is expected for critical raw materials, anodes and precursor material production (https://battery2030.eu/).

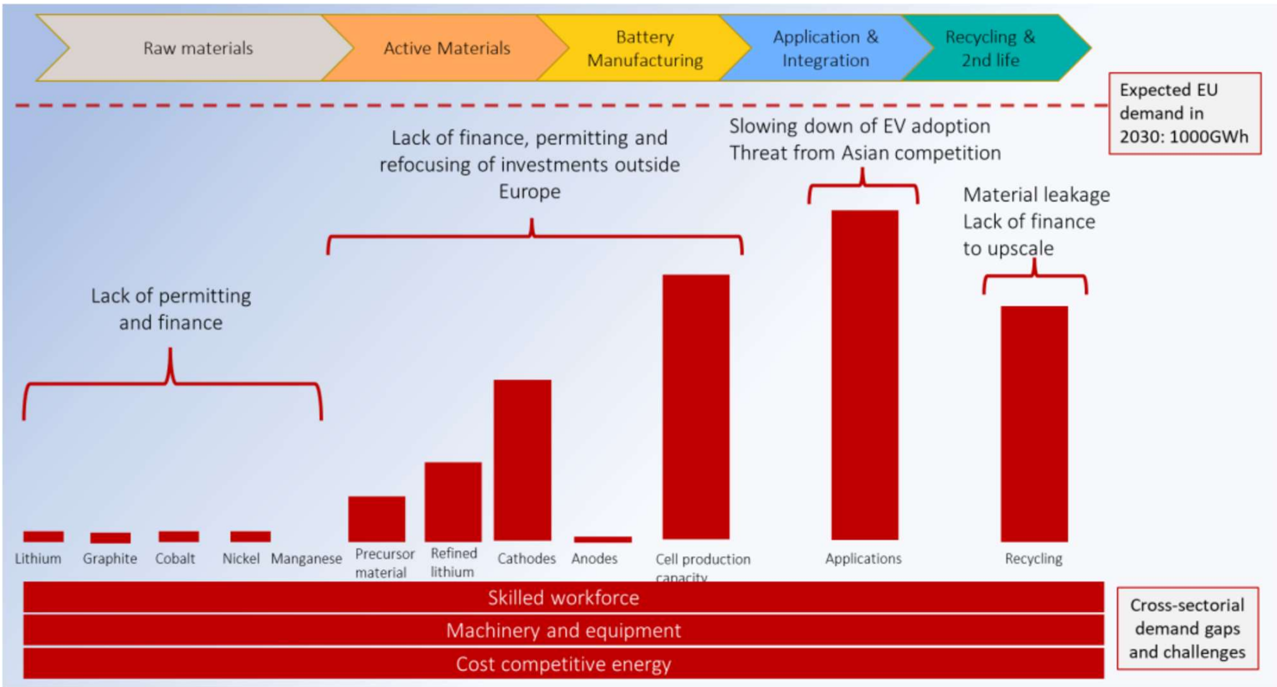

Figure 5 – Estimated share of EU27 production capacity compared to estimated demand based on public announcements with current framework in 2030. Source: EIT InnoEnergy and European Battery Alliance.

Zooming into the battery value chain shows large gaps between EU domestic production and demand anticipated in:

- Raw materials,
- Anodes,
- Precursor material.

A heterogeneous contractual situation (long-term vs. short-term) prevails for material supply and dependencies on raw materials, as well as a strong cost competition e.g. from Asia with more vertical integration of material supply, processing and manufacturing, and subsidies in non-EU countries.

Table 2 – Specific vulnerabilities for the battery manufacturing industry.

Vulnerability	Impact Caused
Raw Material Scarcity	-Supply shortages of critical materials (lithium, cobalt, nickel) - Increased raw material costs - Production delays
Environmental Regulations	- Higher production costs due to compliance - Potential supply constraints

Vulnerability	Impact Caused
	- Slower supply chain processes due to compliance with environmental standards
Market Demand Fluctuations	- Supply shortages due to rapid demand increases - Challenges in scaling production - Inventory management issues - Increased waste and costs
Recycling and Sustainability Constraints	-Material shortages due to insufficient recycling infrastructure - Environmental concerns - Increased regulatory scrutiny - Periodic life cycle

The battery case can stand for almost every other strategic material and product needed for a smooth transition to a net-zero economy in the EU by 2050. China and the US have taken bold measures to secure a competitive advantage, particularly by taking strategic government decisions and providing the required state capital for attracting private investment. While China's government is investing in production capacities that can supply 100% of the global demand (e.g., for LFP batteries as shown by CRU analysts at the CRU Conference in Warsaw in February 2024) and thus outcompete every European LFP battery manufacturer), the US administration has created the 800 bn USD Inflation Reduction Act delivering a combination of grants, loans, rebates, incentives, and other investments to support the President's whole-of-government economic plan. The EU responses, falling short of any significant financial incentives, are reported below.

2.9 CIRAN case studies in response to the battery and e-mobility industry

Twelve out of fourteen CIRAN case studies evaluate operational or planned mining projects for metals needed for battery, battery electric vehicles and related manufacturing. As shown in Table 3, projects are either operational or will receive operating and environmental permits, deal with strategic raw materials (SRM), and will reduce the supply chain vulnerability. Several of the resources have been known at least for decades, if not for centuries, and permitting commonly deals not with opening new but with reopening old (existing) mines that have been temporarily closed due to low returns during periods of undisturbed supply chains.

Observed drawbacks are sometimes multiple, partly insufficiently coordinated permitting authorities - addressed by a "one stop shop" in the CRMA - and time-consuming permitting proceedings, equally addressed by the duration limits stipulated by the CRMA.

Table 3 – Battery and e-mobility related mining projects for SRM subject to CIRAN case studies.

Case Study	Materials mined	Status	Impacts	Mitigating vulnerability
Wolfram AG, Mittersill (AT)	Scheelite ore for Tungsten	Operational as underground mine since 1975	Open pit mining in the eastern part, currently closed but may be reopened	SRM, yes, continuously in operation

Case Study	Materials mined	Status	Impacts	Mitigating vulnerability
Rompas-Rajapallot Lapland (FI), Mawson Gold Oy	Polymetallic Au, Co, U	Exploration since 2008	Local pro, NGOs contra	SRM, yes, start of mining uncertain
Sakatti, Lapland (FI), Anglo American	Nickel, copper, platinum group metals, cobalt	Planning since 2011, underground mining	Local pro, NGOs contra	SRM, yes, potentially strategic CRMA project
Emili/ Beauvoir Lithium Mining Project (FR), Imerys	Mica mining since 1960, Li known since 1970	Exploration & planning since 2019	Locals divided, NGOs contra	SRM, yes, relevant Li resource
Blackstairs Lithium Mining (IR)	Lithium-bearing pegmatites and aplites	Exploration since 2009, initially discovered in 1970	Some controversies with locals, extended exploration	SRM, yes, relevant Li resource
Nussir Copper Project, Northern Norway (NO), Nussir ASA	Copper, gold, silver underground mining	Fully licensed, Sami reindeer herding opposition	Operated 1972-1979, reopened 2024	SRM, yes, End-of-Life plan required
Neves Corvo (PT), Lundin Mining	Copper, zinc, and lead mining	Operational since 1988	Copper and zinc shipped to EU smelters	SRM, yes, continuous reconciliation
Barruecopardo (ES), Saloro	Tungsten	Operations 1902-1982, negative impacts remediated and new operations since 2019	Local support, objection by bird life protectors	SRM, yes, mine reopened
Liikavaara (SE), Boliden	Copper	Planned mining, designated national interest for minerals area	Mitigation of leaching to local rivers; EoL landscape restoration required	SRM, yes
Stekenjokk (SE), Bluelake Mineral AB	Copper and zinc	Past (1976-1988) Cu and Zn mining, applied for permit for reopening	Local support, conflict with reindeer herding	SRM, yes, mine reopening planned
Drakelands Mine (UK), Tungsten West (2019)	Tungsten, open-pit mining	Operational 1919-1920, 1934-1944, 2014-2018 and since 2023	Long mining history, mixed land use, high biodiversity	SRM, yes, mine reopened several times, world class tungsten resource
Redmoor mining project (UK), Cornwall Resources Ltd.	Tin, tungsten and copper, underground mining	Exploration since 2017, ongoing, continued ore body from Drakelands	UNESCO historic mine site, long mining tradition; land-use conflicts	SRM, yes, high-grade, world-class tin resource

2.10 Baseline 2024

As the analysis of the impact of the CRMA on the nature and structure of the CRM Supply and Value Chains into the EU and wider Europe in this section shows, the baseline which the Act is designed to provide is radically reformative of the *status quo ante*. The existing baseline has experienced systemic failure, which a wide range of recent and historical factors has brought to a point of crisis. A new baseline, rethought to suit contemporary needs and values not trying to add more layers of sticking plaster to keep the old one going for a few more years.

The baseline at this early stage in its development (June 2024, i.e. 3 months in) is **principles-based**. These principles are set out at the start of the CRMA as follows:

- to strengthen the different stages of the European critical raw materials value chain;
- to diversify the EU's imports of critical raw materials to reduce strategic dependencies;
- to improve the EU capacity to monitor and mitigate current and future risks of disruptions to the supply of materials;
- to ensure the free movement of critical raw materials on the single market while ensuring a high level of environmental protection, by improving their circularity and sustainability.

Nowhere is this clearer in the CRMA than in the requirement to reduce the mine permitting cycle to 24 months from a current average of 15-20 years, a 90% drop. But it is also clear that such procedures now need to be brought to a disciplined and normalised state, with reasonable but enforceable timelines, which restore the essential synchrony between the policy, operational, policy and investment cycles which is at the heart of both the delivery of the SDGs and the security of supply of critical materials. This applies whether these CRM be for the energy transition or for the safeguarding of resources essential to all life, food energy and water, all now classed as human rights.

The issue of permitting has been addressed in this section, and with it the change in the socio-economic nature of a mine from functioning as the starting point of a linear supply chain that either progresses from mine through processing and use to eventual discard as waste or simply as "discarded" resources "for which no further use is foreseen", or even discarded at the mine site as tailings and hence redesignated as wastes simply because the mining company itself also has no further foreseen use for them. This procedure which characterises industrial-scale mining for the past two centuries, with all the negative externalities that brought with it, mostly imposed those externalities on third countries – from which we now hope to source our new CRM – but not in all cases. For example, coal mining, one of Europe's leading mining activities, resulted in extensive externality penalties to European population groups (often in economically disadvantaged areas) who suffered extensively through accident and injury while on the job, and commonly died of chronic obstructive pulmonary disease) in their 50s or earlier.

But the reach of the CRMA baseline reset goes across all resource values chains, recognising that these are necessarily "balanced and integrated" (UN SDGs), reliant on responsible production and consumption being in equilibrium with a zero-waste outcome (SDG 12) while making good on SDG goals which are also human rights to which we are all equally entitled - SDG 2 zero hunger, SDG 6 clean water and sanitation and SDG 7, affordable and clean energy.

When the vulnerabilities and gaps identified in this section are put up against the CRMA it is clear that the Act makes suitable provision to establish a new baseline and even reaches down into the fundamental resource flow algorithms, such as Supply Risk and the EoLRIR, to make these sustainable and circular, where the EoLRIR is the ratio of secondary material inputs (recycled from old scrap [or other recovered, reusable resource such as phosphorus from wastewater] to all inputs of a raw material (primary and secondary).

The necessary step into the brave new baseline is taken. CIRAN's deliverable 6.2 (*Triple Bottom Line policy recommendation for permitting, social model contract and ESG reporting*) will in 18 months see if there are practical developments starting to take form that show the CRMA has also provided sufficient guidance to make it work, or if such guidance is now itself being put in place to help.

3 EU initiatives in response to the supply chain vulnerability

In 2019, the European Commission published the European Green Deal, which aims at achieving a sustainable EU economy. This is the core of the EU's environmental, climate and industrial policy, setting out the target of climate-neutrality in 2050, zero pollution, and increasing the CO_2 reduction targets to 55% by 2030. Achieving the Green Deal objectives requires access to sustainable raw materials, in particular critical raw materials necessary for clean technologies, digital, space and defence applications, by diversifying supply from both primary and secondary sources and avoiding over-dependence on a single or very limited selection of supplier countries.

3.1 Strategic EU framework overview

The Raw Materials Supply Group (RMSG) including Member States, regional authorities, industry associations, civil society, social partners and research organisations[14] and the European Commission have developed and agreed upon a set of voluntary EU principles for maintaining the secure supply of sustainable raw materials. These principles will feed into an integrated approach to sustainable raw materials extraction and processing in Europe in terms of social-, environmental- and economic performance.

To this end the European Commission adopted several initiatives in 2020 and 2021, each anchored in the European Green Deal and each directed towards specific raw materials. These are set out below:

2020 Industrial Policy for the EU and the 2021 Industrial Strategy Update

The industrial strategy update[15] drives twin transitions to climate neutrality and digital leadership and increasing industry's competitiveness and strategic autonomy at a time of increasing global competition

2020 Circular Economy Action Plan

This Action Plan[16] includes proposals for increasing the circularity and retention of raw materials in the EU economy, including a new regulatory framework for batteries.

2020 Communication "Critical Raw Materials"

The communication "Resilience: Charting a Path towards greater Security and Sustainability"[17], building on the EU's Raw Materials Initiative, updates the list of raw materials critical for the EU and proposes a Critical Raw Materials Action Plan for increased resilience in EU's supply chains through secure and sustainable supply of critical raw materials.

[14] https://erma.eu/eu-policy/

[15] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy_en

[16] https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en

[17] https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en

The Green Deal Industrial Plan for the Net-Zero Age

The Green Deal Industrial Plan[18] aims at enhancing the competitiveness of Europe's net-zero industry and is accelerating the transition to climate neutrality. It does so by creating a more supportive environment for scaling up the EU's manufacturing capacity for the net-zero technologies and products required to meet Europe's ambitious climate targets.

Proposal for a Regulation on batteries and waste batteries

A main building block of the Critical Raw Materials Action Plan is about strengthening the sustainable and responsible domestic sourcing and processing of raw materials in the European Union where public acceptance is an important element. The EU principles for sustainable raw materials support this goal. They have been developed to reflect the practices that are followed within the European Union and that are expected to be applied also by new entrants to the market. For example, the proposal ensuring a competitive, sustainable and circular batteries value chain in Europe includes provisions for more efficient recycling processes and material recovery, thereby mainstreaming circularity and reinforcing secondary raw materials markets[19].

3.2 Critical Raw Materials Act

The main driver of the project and hence of this report, is the EU Proposal for establishing a framework for ensuring a secure and sustainable supply of critical raw materials, COM (2023) 160, in short CRMA[20].

As of 23rd May 2024, the Critical Raw Materials Act has come into force providing Europe with a regulatory framework to strengthen domestic capacities and consolidate the sustainability and circularity of critical raw material supply chains in the EU, while continuing to pursue its diversification agenda. With this Act, the EU will strengthen domestic supply and reduce reliance on single suppliers. As highlighted in the aftermath of Covid-19 and Russia's invasion of Ukraine, strategic dependencies exposed the European industry to supply chain disruption risks.

The Act establishes **benchmarks to increase capacities for extraction, processing, and recycling of critical raw materials in the EU and guide diversification efforts**. In addition, it creates a framework to select and implement Strategic Projects, which can benefit from streamlined permitting and enabling conditions for access to finance; as well as sets out national requirements to develop exploration programmes in Europe. Moreover, the Regulation will improve the **circularity** and the **efficient use of the critical raw materials** by creating value chains for recycled critical raw materials. To ensure resilience of the supply chains, the Act allows the monitoring of critical raw materials supply chains, and information exchange and future coordination on strategic raw materials' stocks among Member States and large companies.

[18] See COM (2023) 62 final, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023DC0062

[19] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52020PC0798

[20] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L_202401252

The CRMA complements existing EU policies and legislation, including environmental and waste management directives, regulations on chemicals, and initiatives for workforce development. The proposal also aligns with international trade obligations, the EU's Arctic policy, and strategic partnerships with third countries. Additionally, it synergizes with other ongoing proposals such as the Batteries Regulation and the Directive on Corporate Sustainability Due Diligence.

Overall, the proposal seeks to ensure a resilient and sustainable supply of CRM, essential for achieving the EU's green and digital transition goals, while mitigating risks associated with supply disruptions and environmental impacts. The Critical Raw Materials Act equips the EU with the policy and legislative tools to ensure the EU's access to a secure and sustainable supply of critical raw materials, mainly through **Setting clear priorities for action.**

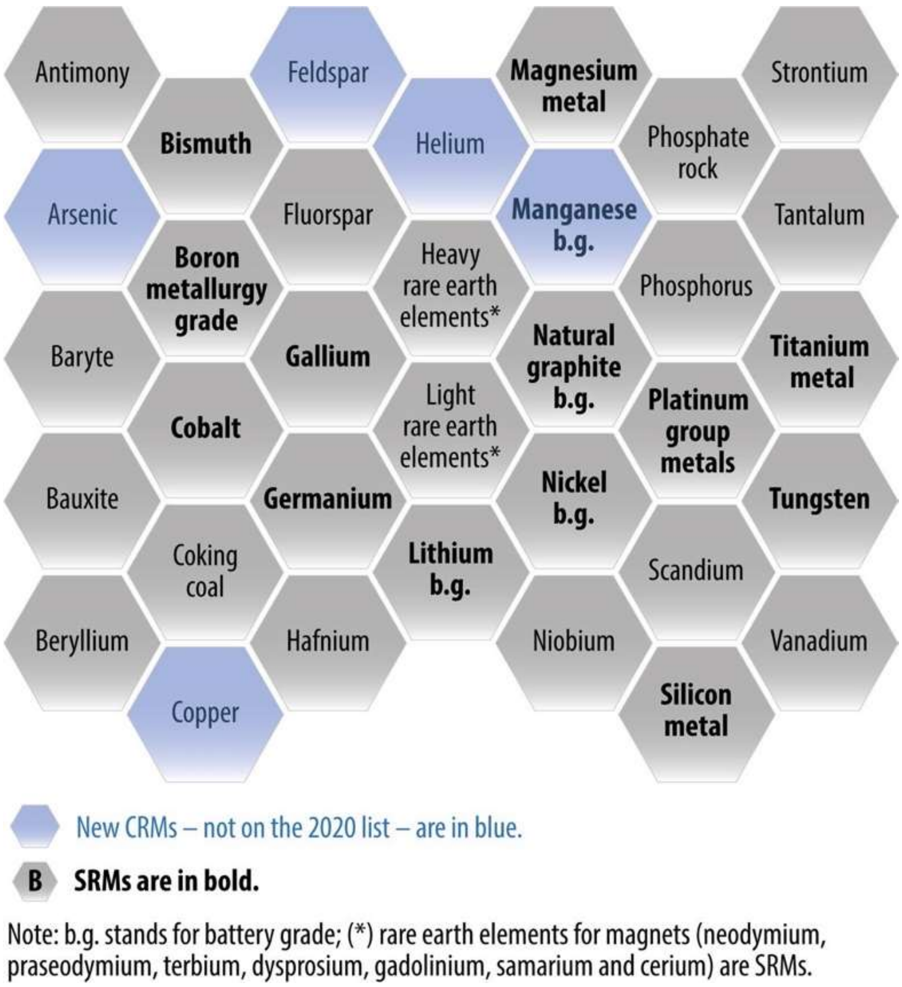

Figure 6 – Critical and strategic raw materials. Source: CRMA, Annex 1.

In addition to an updated list of critical raw materials, the CRMA identifies a complementary list of strategic raw materials, in bold in Figure 6.

Strategic materials are crucial to technologies important to Europe's green and digital ambitions and for defence and space applications, while being subject to potential supply risks in the future. The CRMA embeds both the critical and strategic raw materials lists in EU law. The CRMA sets clear benchmarks for domestic capacities along the strategic raw material supply chain and to diversify EU supply by 2030:

- At least 10% of the EU's annual consumption for **extraction**,

- At least 40% of the EU's annual consumption for **processing**,
- At least 15% of the EU's annual consumption for **recycling**
- Not more than 65% of the Union's annual consumption of each strategic raw material at any relevant stage of processing from a single third country.

Other Annexes (Annex 3-6) cover:

- Annex III - Assessment of the recognition criteria for Strategic Projects,
- Annex IV - Criteria for certification schemes,
- Annex V – Environmental Footprint,
- Annex VI - Relevant products as referred to in Article 26(1) of the CRMA (still an empty list).

Creating secure and resilient EU critical raw materials supply chains: The CRMA will reduce the administrative burden and simplify permitting procedures for critical raw materials projects in the EU. In addition, selected Strategic Projects will benefit from support for access to finance and shorter permitting timeframes (24 months for extraction permits and 12 months for processing and recycling permits). Member States will also have to develop national programmes for exploring geological resources.

Identifying Strategic Projects in the Union and third countries that intend to become active in the extraction, processing or recycling of strategic raw materials. They would benefit from streamlined and predictable permitting procedures in the Union and coordination of support to **improve access to finance.**

Speeding up permitting for all critical raw material projects with a **one-stop-shop** contact. Developing national exploration programmes to boost knowledge on European critical raw materials resources.

On 23rd May 2024 Commissioner Maroš Šefčovič presided the first European Critical Raw Materials Board. Its role is to advise the Commission and facilitate EU-wide coordination and implementation of actions on exploration, monitoring, strategic stocks, strategic projects with third countries and provide advice for Strategic Projects' access to finance. The Board will be chaired by the Commission and comprises Member States and the Commission with representatives from the European Parliament as observers. It will maintain regular contact with relevant stakeholders to properly perform its functions.

3.3 EU Legal framework beyond CRMA

An array of existing EU regulations and directives complements the CRMA. These include those outlined below.

Net-Zero Industry Act (Regulation (EU) 2023/0081)

The Net-Zero Industry Act[21] is an initiative stemming from the Green Deal Industrial Plan which aims to scale up the manufacturing of clean technologies in the EU. This means increasing the EU's manufacturing capacity of technologies that support the clean energy transition and release extremely low, zero or negative greenhouse gas emissions when they operate.

[21] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52023PC0161

Mining Waste Directive (Directive 2006/21/EC)

This Directive[22] aims to prevent or reduce adverse effects on the environment and human health from the management of waste from the extractive industries. It sets out requirements for the permitting, operation, and closure of mining waste facilities, including tailings ponds and waste rock piles.

Industrial Emissions Directive (Directive 2010/75/EU)

This Directive[23] regulates emissions from industrial activities, including mining operations. It sets emission limit values for pollutants and requires operators to obtain permits based on best available techniques (BAT) to minimize environmental impact.

Water Framework Directive (Directive 2000/60/EC)

The Water Framework Directive[24] establishes a framework for the protection and sustainable use of water resources across the EU. It requires member states to prevent and reduce water pollution from mining activities and to achieve good ecological status in water bodies.

Environmental Impact Assessment (EIA) Directive (Directive 2011/92/EU)

The EIA Directive[25] requires member states to assess the environmental impacts of public and private projects, including mining activities, before they are approved. It aims to ensure that projects likely to have significant environmental effects are subject to thorough assessment and public consultation.

State Aid Rules

EU state aid rules[26] govern financial support provided by member states to mining projects. State aid for the mining sector must comply with EU competition rules and may be subject to approval by the European Commission.

These regulations and initiatives aim to promote sustainable and responsible mining practices in the EU while addressing environmental, social, and economic considerations. They provide a framework for balancing the need for raw materials with the protection of the environment and human health.

It's essential to note that while the EU sets overarching regulations, individual Member States have additional regulations and requirements specific to their national contexts.

[22] https://eur-lex.europa.eu/eli/dir/2006/21/oj

[23] https://eur-lex.europa.eu/eli/dir/2010/75/oj

[24] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32000L0060

[25] https://eur-lex.europa.eu/eli/dir/2011/92/oj

[26] https://competition-policy.ec.europa.eu/state-aid_en

4 Findings from CIRAN case study investigations

4.1 EU countries covered by case studies

CIRAN's Deliverable 2.1 (Loudes et al., 2024) summarises fourteen Case Studies addressing different aspects of projects involved in securing supply chains of both Critical and Strategic Raw Materials. Findings from case studies are outlined below and are considered as a key component of this report.

The EU and wider European countries where the case study mines are located are as listed in Table 4 below, with locations shown on the map of Western Europe (Figure 7).

Table 4 – Locations of Case Studies featured in CIRAN.

Nr	Country
1	Austria
2	Finland
1	France
1	Italy
1	Ireland
1	Norway
2	Portugal
1	Spain
2	Sweden
2	UK

Figure 7 – Geographical location of case studies covered by CIRAN.

The CIRAN case studies confirm the in-principal suitability of the existing legislative framework for mining within the European Union, even within protected (Natura 2000) areas, prior to adoption of the CRMA. These case studies provide valuable insights and conclusions derived from various examples of mining in or near protected regions.

First, it is evident that in many instances where mining and/or quarrying occurs within or near protected areas, these activities preceded the designation of these regions as protected under the Natura 2000 scheme. This precedence suggests that mining operations were initially established without the constraints that currently apply to protected areas. The transition of these areas into protected status in some cases introduced new regulatory challenges and requirements, although for the most part such sites were simply designated Natura 2000 compliant *de facto* rather *de iure*. Many of these sites were already protected through national legislation, which provided a suitable, pre-existent framework for conservation.

To add a level of uncertainty, the boundaries of the newly designated Natura 2000 areas often lack clarity, which risked complicating compliance and operational planning for mining companies.

Good practices for operating within protected areas have been identified across all cases studied from the countries covered in the report. These practices are essential for minimising the environmental impact and ensuring sustainable mining operations and mineral exploration. From a regulatory perspective, additional requirements, beyond the standard permitting processes, are necessary to safeguard the protected areas.

Mining projects within Natura 2000 areas often necessitate additional modelling and documentation. The supplementary requirements might include comprehensive environmental impact assessment (EIA) or other detailed documentation that might not be necessary for similar projects outside protected zones.

Protected areas embed multiple values, including social, environmental, and sometimes economic benefits. These values must be considered from a responsible and holistic perspective. Mining operations in these regions emphasise the adoption of low-impact technologies, underground mining techniques, ecological compensation measures, and active and effective communication and stakeholder engagement. These strategies are pivotal in minimising the environmental footprint and fostering community support.

Spatial planning often integrates mineral information, as evidenced in countries such as Austria, Sweden, and the United Kingdom. During the spatial planning phase, potential land-use conflicts were identified and mitigated, ensuring that mining activities do not adversely affect other land uses.

In regions where mineral governance and spatial planning are governed by separate legislation, a single regional authority typically oversees local implementation. This approach, observed in France, helps streamline the regulatory process and reduce bureaucratic complexities. Conflicts concerning the potential impacts of mining projects are usually covered and resolved in the EIA, ensuring that environmental concerns are adequately addressed before start of the project.

The permitting processes for mining projects are generally linear and transparent in most countries covered by the CIRAN case studies. However, exceptions exist in Ireland and Spain, where iterative permitting processes involve multiple authorities. This complexity can lead to delays and increased regulatory burdens for mining companies. In these cases, the "one-stop shop" as required by the CRMA may significantly improve the permitting processes.

The use of low-impact technologies and underground mining techniques significantly facilitates project approval and implementation. This was evident in countries like Austria, Finland, Norway, Portugal, Sweden, and the UK. These technologies help reduce surface disturbances and environmental impacts, making them preferable for operations within protected areas.

Engaging external, certified experts to conduct ecological and environmental studies has proven beneficial. These experts provide credible and unbiased assessments, which can support the permitting process and enhance stakeholder trust. Additionally, compensation measures aimed at improving the ecological status and social cohesion of regions adjacent to mines have positively influenced the permitting process. Such measures demonstrate a commitment to mitigating negative impacts and contributing to the local community.

The concept of "Imperative Reasons of Overriding Public Interest" (IROPI) was not required for the approval of any projects within the studied cases. This indicates that the existing regulatory and mitigation measures were sufficient to gain approval.

Effective communication and trust-building efforts were needed and in general those efforts are often crucial for projects within or near protected areas. Many companies have gone beyond statutory requirements to implement extensive mitigation measures and foster positive relationships with local communities and stakeholders. In several cases, local populations were supportive of mining projects, while at the national-level non-governmental organisations often opposed these projects, particularly in Finland.

In summary, mining projects selected as CIRAN case studies were successfully implemented in nine EU countries. They provide in aggregate a comprehensive, if composite, overview of the regulatory, operational, and social dynamics of mining and/or quarrying within Natura 2000 areas. They highlight the necessity for additional regulatory measures, the importance of adopting low-impact technologies, the value of stakeholder engagement, and the need for clear and effective communication. These insights can guide future mining operations and regulatory frameworks, ensuring that economic development and environmental conservation coexist harmoniously. In all case studies covered in this report, meaningful reconciliation between commercial, social and environmental interests was always found. However, permitting processes were frequently complicated and time consuming. A significant acceleration of permitting processes is needed to comply with the objectives of the CRMA.

5 Reflections on recommendations to mitigate vulnerabilities

As no significant inconsistencies and barriers have been identified in the European and national regulatory frameworks for mining, including in Natura 2000 and other protected areas, the authors have reviewed the supporting framework of UNECE and EU strategies, but also derived draft recommendations from the discrepancies between the European Commission's objectives and national policies. Useful insights are provided by the EU Principles for Sustainable Raw Materials and by the 15th Session of the UN Expert Group on Resource Management in April 2024 (UNECE, 2024). Finally, personal experiences and interviews with current and former officials provide food for preliminary conclusions and hypotheses that may need to be further explored in the second half of the WP6 activities.

5.1 European industrial policy

First and foremost, a **European industrial strategy and policy** is needed to set the framework for sustainable supply chains. Industrial policy should be set at EU level but needs full support and implementation in the Member States - with sanctions for non-implementation. Policy-makers need to agree on the products and production facilities that should be located in Europe (e.g. all or part of electric vehicles, batteries, fuel cells, alternative fuels, H2, electrolysers, semiconductors, heat pumps, etc.), possibly selected from the JRC Foresight Study (Figure 8; Carrara et al., 2023).

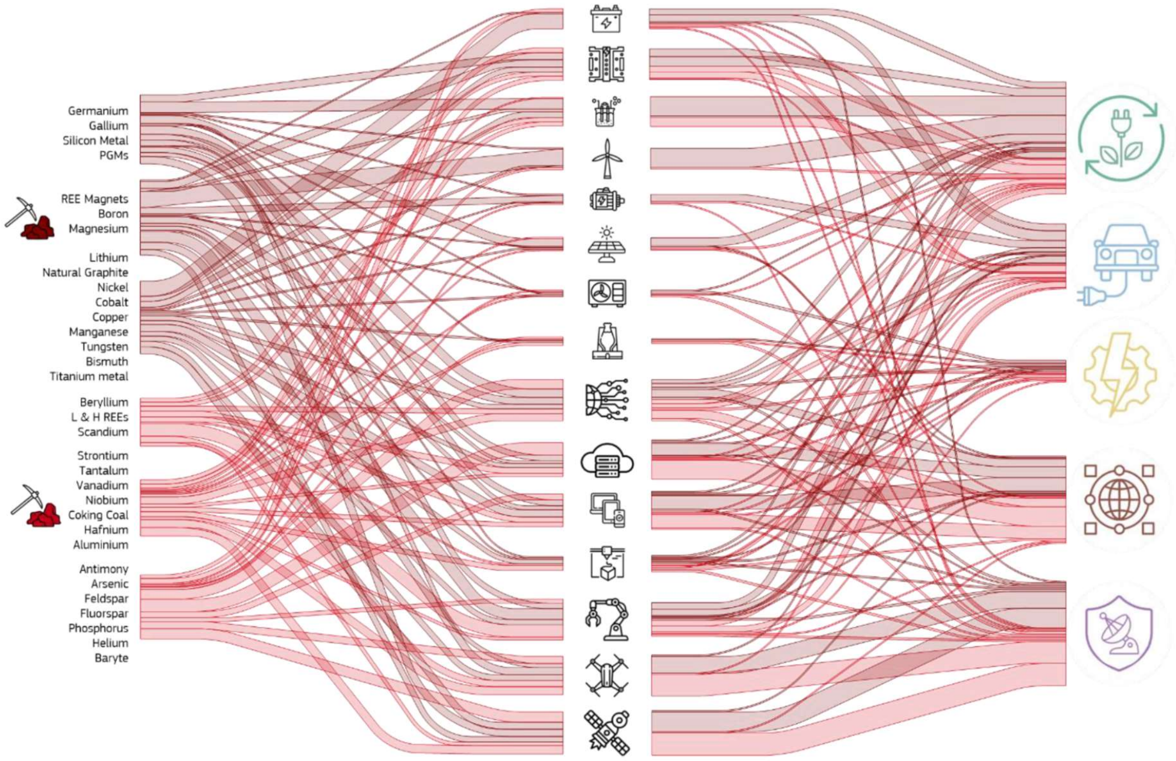

Figure 8 – Supply chains for components needed for the transition to a Net Zero Economy (Carrara et al., 2023).

Zero emission technologies in general and particularly e-mobility require different and more complicated supply (value-) chains than fossil-based processes. While oil and gas are quite easily pumped from underground reservoirs to the surface, and after refining inefficiently combusted, renewable resources need several minerals and metals that need to be mined, beneficiated, processed and sometimes smelted to high purity alloys. Relatively simple flowsheets are replaced by highly complex ones as Figure 8 demonstrates.

The higher complexity and higher variety of raw materials is compensated by two distinct benefits: i) the materials are not emitted to the atmosphere and can be largely recycled and ii) the efficiency of energy conversion, for instance in e-motors, is much higher than in combustion engines. The recyclability benefit is driving the transition to the circular economy, comprehensively discussed in the vulnerability chapter of this report. The forward leap is massive: if one tonne of lithium, copper or manganese are mined and processed to battery cathode materials, the battery has a work life for 8-10 years and will have a second and a third life after recycling. If one tonne of coal is mined and burned, only 45-50% of its energy content are converted to electricity while the other half goes to heat and greenhouse gases. Only the electricity can be stored and used with high efficiency. Some ash remains as solid residues which can be recycled as a construction material. Scientists investigate methods to recycle carbon from CO_2, but this is again complex and far from mature.

The new approach, even with its high complexity, is certainly more convincing but not all raw materials are available in Europe and not all processes and products may find favourable conditions in Europe. Political decision-makers, in co-operation with scientists and citizens, must select the preferred products and processes and commit to their long-term promotion and support. Industrial policies must be kept out of the daily disputes and controversies and parties and policy makers who do not implement the jointly agreed pathway must be penalised, e.g. by withholding European funds that must be created and provided for the transition towards a zero-emission economy.

5.2 Scrupulous supply chain assessment

The next step is to assess the specific vulnerability of the supply chain for all products/processes to be implemented in Europe. For example, if the strategic decision is to produce batteries, the vulnerability of the battery supply chain must be assessed, i.e., the availability of the materials and products shown in Figure 9.

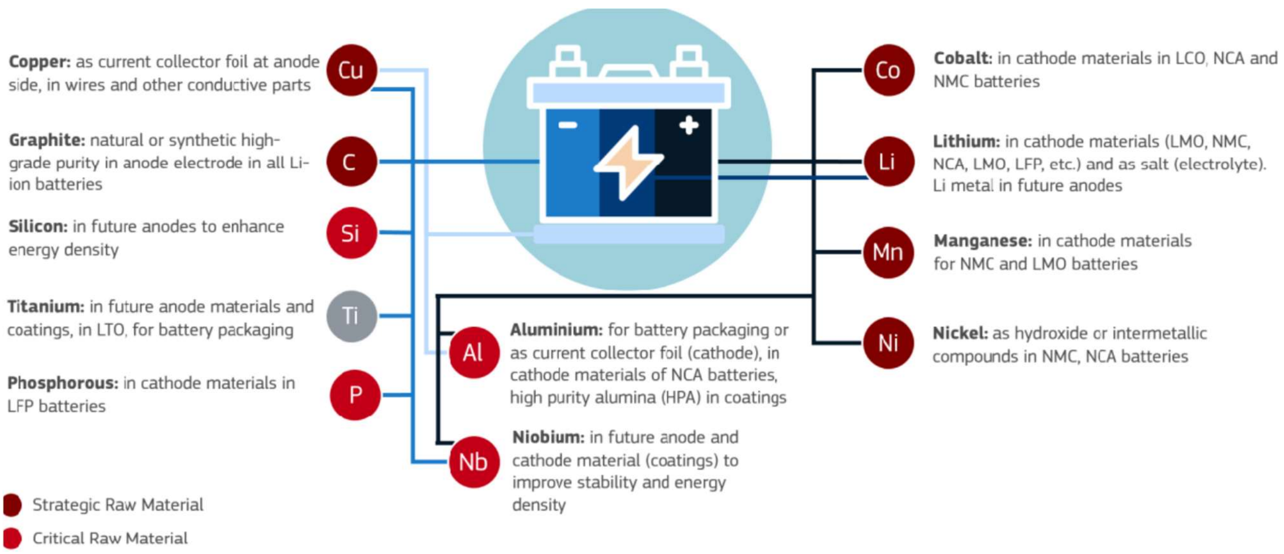

Figure 9 – CRM in the supply chain for battery manufacturing (Carrara et al., 2023).

Battery supply chains involve a number of stages, starting with the sourcing of raw materials, followed by refining them into chemically active materials, followed by component and cell manufacturing, and finally, where necessary, module and/or package assembly (e.g. for large capacity end products such as electric vehicles and energy storage systems). The most technically complex and costly step in the battery value chain is cell manufacturing.

Battery cell manufacturing requires, depending on the battery type, copper, graphite, silicon, titanium, phosphorus, aluminium, niobium, cobalt, lithium, manganese and nickel, six of them labelled as strategic, four as critical and one not labelled.

Without a real industrial policy in place, the EU has attracted a significant number of battery cell projects as illustrated in Figure 10, which together could achieve a cumulative cell production output of 1 TWh in 2030.

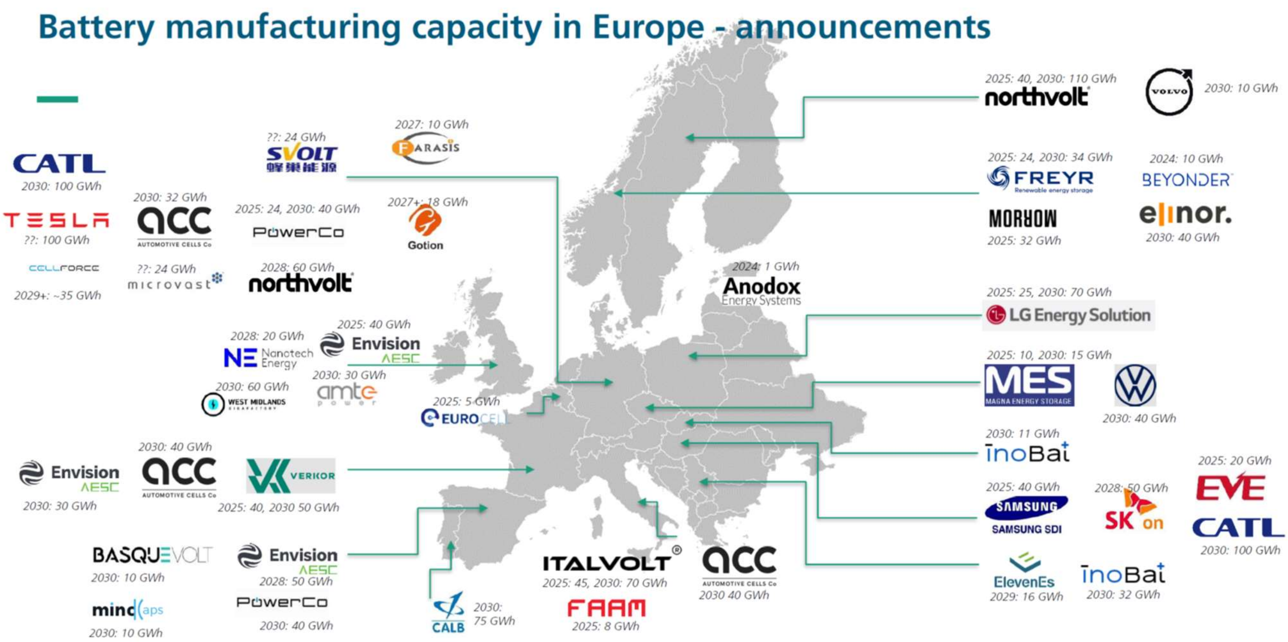

Figure 10 – Announcements of battery manufacturing capacity in Europe. Source: Fraunhofer ISI Cell Production Database -based on public announcements of cell manufacturers, and additional "market intelligence"[27].

The objectives stipulated in the CRMA should be considered as minimum requirements to a reasonably resilient supply chain. Key to the implementation of a resilient strategic raw materials supply chain is the identification and classification of resources, i.e. natural resources for mining until enough EV batteries are in the market for efficient recovery and recycling of secondary raw materials.

5.3 Resource identification and classification

The actual or potential availability of the required raw materials and processes in the EU should be assessed by checking whether primary resources – for the period until the electric vehicle fleet and stationary batteries

[27] https://www.isi.fraunhofer.de/en/blog/themen/batterie-update/lithium-ionen-batterien-open-source-datenbank-veroeffentlicht.html

have attained a significant number and age for supply to recyclers - exist on EU territory. If so, the resources should be assessed and classified (using the UN Framework Classification which is now mandated under the CRMA[28]) and, in the case of a viable extraction project, priority should be given to the development of the mining project, regardless of the status - Natura 2000 or otherwise protected - of the area in which the resource is located. Priority could mean labelling the project "strategic" and possibly co-financing it by the European Innovation fund.

The stages of a raw materials extraction project are shown in Figure 11. The image shows that exploration and extraction are the necessary initial steps for creating a new value chain, even if the final objective are closed loops.

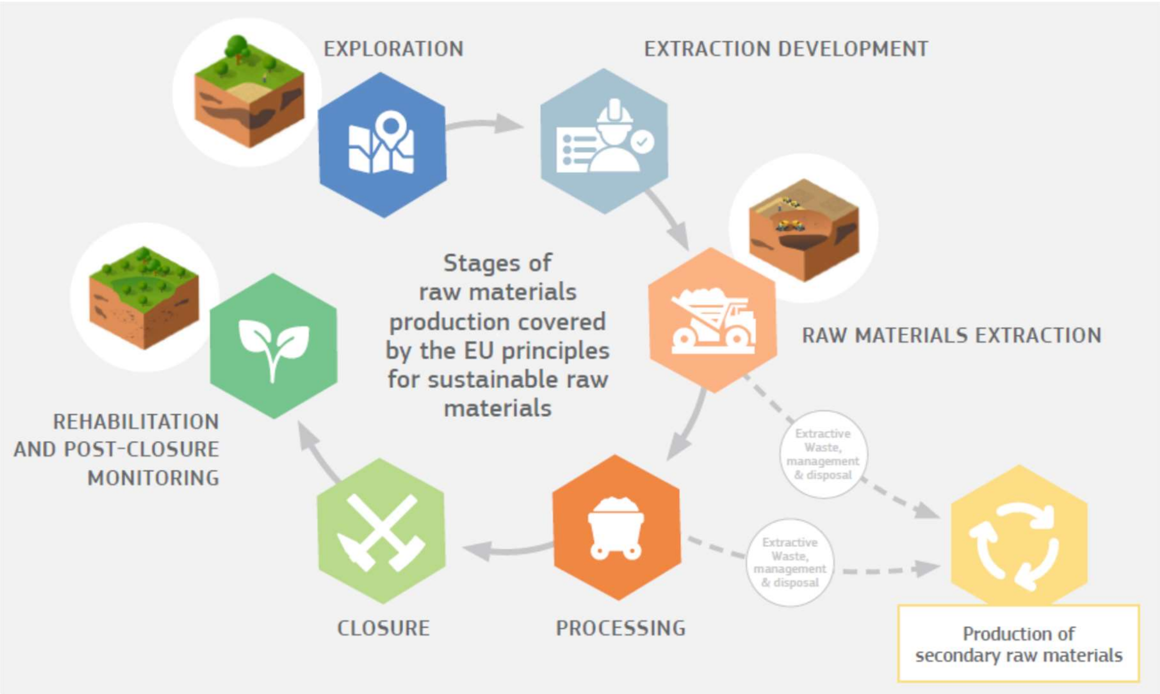

Figure 11 – Stages of raw materials production in compliance with EU sustainability principles (European Commission, 2021).

5.4 The UN Framework Classification

The CRMA refers to the UN Framework Classification (UNFC) for improved classification of mineral and anthropogenic resources. The adaption of the classification system to secondary resources is currently underway, applied, among others to tailings and secondary phosphates.

According to Article 7 of the CRMA, a promoter of a strategic commodity project should be able to apply to the Commission for its project to be recognised as a strategic project. The application should include relevant documents and evidence related to the criteria. In order to better assess the social, environmental and economic viability, the feasibility of the project and the level of confidence in the estimates, the promoter

[28] https://unece.org/sustainable-energy/sustainable-resource-management/united-nations-framework-classification

should also **provide a classification of the project according to the United Nations Framework Classification of Resources**[29].

A UNFC-based inventory will facilitate decision-making by stakeholders related to raw material stocks and flows in Europe. UNFC is a tool to communicate the availability of resources and the maturity level of projects. The objective is achieved by providing generic principles and harmonized terminology for classifying these projects and potential projects and their associated resources. UNFC is a resource classification system. It is currently not a legally mandated standard for financial reporting. UNFC is designed as a system to facilitate the supply of energy and raw materials required for sustainable development. The emerging challenges in these sectors are the sustainable, socially conscious, environmentally friendly, carbon neutral and efficient development and production of raw materials that are required for a growing population.

In compliance with the UNFC, projects are classified according to their environmental, social, and economic viability (E Categories) to their technical feasibility, i.e. stage of development (F Categories) and to their relatively level of geological confidence or certainty (Figure 12). The lower the score the closer to operational and economic viability the project is, and most working mines will score E1, F1, G1. Scores can go both lower and higher and if for example a project's economic viability weakens its score is likely to change from E1 (operational) to E2 (sub-economic). This way the UNFC alphanumeric scoping system can provide decision makers and policy specialists with the information they need to take complex political decisions which they face in either securing supplies of CRM or sustainably managing natural and secondary resources in general, not just those judged critical.

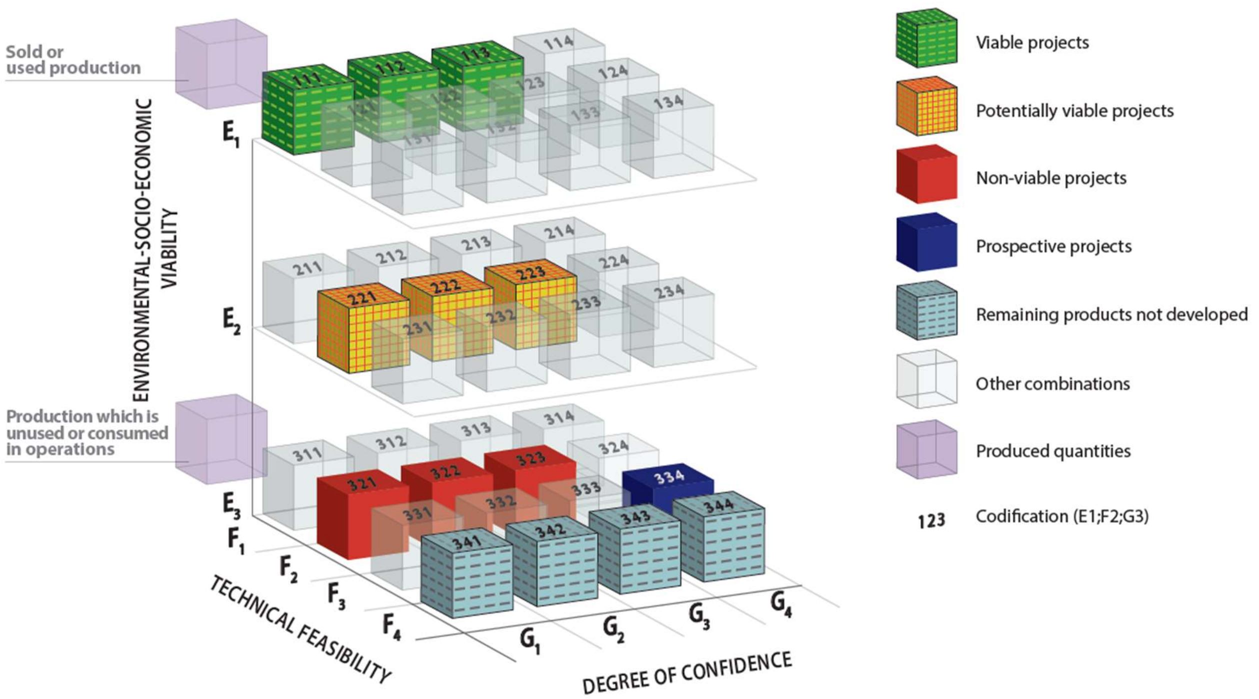

Figure 12 – Three-dimensional outline of the UNFC (UNECE, 2020).

29 https://ec.europa.eu/commission/presscorner/detail/en/ip_23_1661

5.5 Permitting process

At present, the permitting process in the EU countries and regions surveyed is transparent and manageable, as described in this report. In addition, the officials involved in the permitting process are well prepared and usually inclined to grant operating permits. Regulations and an anti-mining bias of the authorised and involved personnel are not the main cause of lengthy permitting processes.

However, delays are caused by reasons other than legislation or resistance from officials. One of the reasons for excessively long approval procedures is the lack of experts – a statement that was confirmed on 9th June 2024 by the Head of the Austrian Institute of Economic Research, Gabriel Felbermayr. After decades of efforts to create a lean state in the European member states, retired qualified staff in government departments have not been replaced. As a result, there is a lack of authorised experts to perform the permitting process in due course[30] [31]. **Consequently, state agencies responsible for permitting processes must be staffed with sufficient experts to process permitting applications within months and not within years**.

In addition, understaffed departments of government agencies have to cope with professional objection agents. In several of the surveyed cases applicants and operators are confronted with perfectly organised activists who do everything to prevent mining or other industrial operations. The activists may have good reasons for their objections, but pros and cons must be duly considered, again within several months and not take years. If objections are filed by activists, they again encounter understaffed public prosecutors' offices and courts. Consequently, several years of technical and then legal proceedings in understaffed courts are responsible for an average duration of 10-15 years until a mining project can be operational in Europe. **Consequently, prosecutors' offices and courts must be staffed with sufficient personnel.**

The authors recommend restricting the parties who can object to a project to those who are directly affected by the project. Mining may cause dust, noise, traffic, soil and water pollution, and air emissions, but except for water pollution, the impacts will be local or at most regional (e.g. in terms of additional traffic), and mining does not typically affect parties living hundreds or thousands of kilometres from the project. The national or global impacts should be reviewed by authorised bodies such as the European Environment Agency. Details must be further elaborated but without certain restrictions to objections the pursued acceleration with not be achieved.

5.6 Access to finance

The transition to a net-zero emission economy requires significant financial resources that can only be mobilised if financial institutions and investors believe in manageable risks and reasonable capital returns.

Overall, the economic framework is not favourable to corporate investments. Many corporations reap high profits that are used to pay generous dividends and to buy back own shares – share buybacks of S&P 500 companies will get close to 1 trillion USD in 2024 and exceed 1 trillion in 2025 (Reuters, 2024). Stock buybacks drive the share value of companies and the income of CEOs and board members up while withdrawing

[30] https://www.theguardian.com/environment/2023/aug/15/shortage-of-experts-and-low-pay-major-barriers-to-uks-net-zero-future

[31] https://commercial.allianz.com/news-and-insights/expert-risk-articles/allianz-risk-barometer-2023-shortage-skilled-workforce.html

potential investment capital from the market. As long as the current legal framework remains in place, these practices guarantee low risk and maximum return.

Consequently, a successful EU industrial strategy and policy would also require a ban on share buybacks by large companies. However, the 2024 EU Parliament election results suggest that the legal and economic environment is unlikely to change in the short term. Alternative solutions will have to be found to raise investment capital beyond the EU Innovation Fund aimed at strategic projects.

The most preferred solution in response to the above-mentioned constraints could be constructive Public-Private Partnership between resource governance, business management and capital allocation. Financing models will depend on the capabilities of capital allocators in financing the activities, and they vary between capital allocators. While some projects, assets or entities may be financed by a single allocator, the very significant investments required to live through and realise the reforms will often require several capital allocators, and also several types of capital allocators. This will mobilise a larger capital base and facilitate the allocation of opportunities and risks in accordance with each contributor's capability and portfolio to manage it. Both the choice of capital allocators and the structuring of their contributions will add to the flexibility required by a Public-Private Partnership, that requires governments, industry and finance to act dynamically together to meet the changing challenges of the required transition. Central to change is the societal expectation for capital allocators to support a just energy transition and projects that are aligned with the Agenda 2030 and the SDGs (UNECE, 2024).

The resources sector, as defined in the UNFC, is a multifaceted and capital-intensive industry that encompasses a wide range of activities from exploration to extraction and processing. The complexity and scale of these operations necessitate that investment decisions be informed by meticulously analysed data and information, based on clearly defined criteria. In this high-stakes environment, financiers and investors play pivotal roles in funding resource extraction and its associated infrastructure development. Their involvement is crucial not only for the financial viability of projects but also for driving innovation, ensuring sustainability, and managing risks. The following list outlines some of the key types of financiers and investors in this sector, each bringing unique perspectives, risk appetites, and strategic objectives to their ownership stakes (UNECE, 2024):

- The EU Innovation Fund: 40 bn € dedicated exclusively for the deployment of innovative net-zero industries from 2020 to 2030, covering up to 60% of the cost and made available through regular calls and auctions for energy intensive industries, renewable energy, energy storage, carbon capture, use and storage and net-zero mobility and buildings. Specific requirements apply.
- Resource-Focused Funds: These are specialised investment funds that focus exclusively on the natural resources sector, including mining. They pool capital from various investors to fund exploration and production activities. They prefer mineral resource projects because they can offer diversification and inflation hedging benefits. Also, some more general funds invest in the resource sector. Examples include hedge and pension funds.
- Government Entities: In some cases, governments set up State owned Enterprises (SoEs) as special purpose vehicles (SPVs) to implement and manage exploration and resource exploitation projects. For oil and gas, the involvement of national oil companies is common. This is done to promote economic development, create jobs, and improve living conditions of their citizenry. Governments also provide finance through the depreciation rules of the fiscal system, which in some instances takes the form of neutral sharing of costs and revenues (cash flow taxes) (Lund, 2014).

- Resource Companies: Established companies may invest in their own projects or joint ventures. They prefer resource projects because they align with their core business and growth strategies. Also, some investors acquire royalty streams. Mergers, acquisitions, and disposals are also common. etc..
- High-Net-Worth Individuals: Individual investors, particularly those with a high net worth, may invest directly in resource projects or through private equity funds.
- Environmental, Social, and Governance (ESG) Funds: Some Environment, Social and Governance - focused investment funds are interested in resource projects that meet strict environmental and social criteria. They aim to promote responsible resource development practices and mitigate negative impacts.
- Commercial Banks: Commercial banks provide project financing to resource companies. This is done through loans or credit facilities to fund exploration, development, and construction of resource projects. They are attracted to these projects because they can generate significant interest income and fees.
- Private Equity Firms: Private equity firms invest in resource projects for potential high returns. They typically provide equity capital to companies in exchange for shares.

The diversity of financial stakeholders in the mineral raw materials sector reflects the mining industry's complexity and the varied opportunities it presents. Each type of investor brings unique advantages, from the long-term vision of government entities to the agility of private equity firms, and from the technical expertise of resource companies to the sustainability focus of ESG funds. This mosaic of financial support not only enables the development of crucial resource projects but also fosters innovation, promotes responsible practices, and helps balance economic objectives with environmental and social considerations. As the sector continues to evolve, particularly in response to global challenges such as climate change and resource scarcity, the role of these diverse financiers and investors will be instrumental in shaping a sustainable and resilient future for the mining industry. Their collective involvement ensures a robust financial ecosystem that can adapt to changing market conditions, regulatory landscapes, and societal expectations, ultimately driving the sector towards more efficient, responsible, and value-creating practices.

6 Learning from history and changing the public perception of mining

While mining is frequently perceived as a destructive practice, it could be a source of long-lasting wealth and eventually become a cultural world heritage that is visited by up to 10,000 tourists per day and suffering from overtourism.

6.1 7000 years of mining towards a European Cultural Capital

Hallstatt (Figure 13), is one of the oldest mining and industrial centre in the world, dating back to the Stone Age 7,000 years ago. Salt and other minerals have been continuously mined in Hallstatt until today, with evidence of trade dating back to 800 years BCE. This is demonstrated by discovery of sword handles made from African ivory combined with locally mined amber.

In Hallstatt, we have the unique opportunity to retrace over 7,000 years of salt production by synthesizing data available from the prehistoric and historic mines, the archives in Hallstatt, Linz and Vienna, the graves of the prehistoric miners and from the particularly informative environmental archives.

The archaeological evidence covering the emergence and transformation of a cultural landscape has been documented across the period from the Ice Age to the present day, seeking to understand how the relationship between man and the environment has evolved over the past millennia[32].

Figure 13 – One of the oldest mining communities in the world – Hallstatt.

Salt production in the Salzkammergut has faced numerous challenges throughout history: including climate crises, natural disasters, political, religious and social upheavals, military invasions, scarcity of resources, and

[32] https://www.salzwelten.at/de/blog/hallstatt-7000-jahre-salzgeschichte

epidemics. Despite these adversities, salt production has continued without interruption from the Stone Age to the present day. The required structures and networks to create a salt community that was able to cope with all challenges were investigated in depth. Even today, we are confronted with enormous challenges such as war, climate crisis, resources scarcity. Even today, stable structures are crucial for facing the future, and we should aim to learn from the history of the salt production.

Notably, the salt industry in Hallstatt recognised - and accepted - the limits of forest and wood resources 3,200 years ago. The forests in the Salzkammergut appear to have been managed sustainably and with foresight for thousands of years, despite the salt works' enormous demand for wood - right up to the present day. The question is why the Salzkammergut was managed very differently compared to other mining regions. Scarcity of resources is a persistent issue and the constant topic nowadays. However, we can see that over 3,000 years ago, certain raw materials used for tools and consumables were already becoming scarce in the Hallstatt mines, forcing miners to switch to alternative resources. Thus, handling and availability of resources through the millennia have been explored to gain insights into past practices and adaptations.

Today, we live in a highly complex and interconnected world, whose mechanisms we can no longer fully grasp. High consumption drives constantly increased production, which in return requires raw materials, human labour and energy. The finished products are then transported around the globe, consumed and then the cycle repeats.

The area around Hallstatt (Figure 14) is an ideal region for researching and understanding these mechanisms to be communicated as a good practice and inspiration. Here, the cycle of production, resources, energy, transport, labour, people and the environment has been going on for 7,000 years. In the Salzkammergut, the fundamental mechanisms of our society can be broken down to the basics, researched and communicated. It is extremely important to understand and accept these connections. With every act of consumption, we become an active participant in the global community, influencing how raw materials and energy are used and how people work and under what conditions. Archaeology can do a lot to make these global networks easier to understand and show how everything is connected and helping us make more informed decisions about our impact on the environment.

Figure 14 – Bird’s eye view of Hallstatt and its environment.

6.2 Looking ahead – digitising smart, invisible mining

When the French School of Mines at Alès (L'École des Mines d'Alès - EMA) was founded in 1843[33], it was a significant part of its founding credentials that effectively every technology available for use in France at the time was deployed in the mining industry and taught at EMA. And as new technologies evolved during the later nineteenth century, so they were incorporated into the mines. Among the more recent 21st century additions to this list are biotechnology/ molecular biology, and digitisation, e.g. 3D modelling.

One of the co-authors of this report was also co-author of a 2021 paper **Making a mine invisible: the coming challenge for geoscientists for sourcing critical raw materials** (Correia et al., 2021). This paper anticipated some of the likely impacts of "NextGen" technologies on the mining and resource recovery processes, notably for CRM.

> Converging technologies in robotics, miniaturisation, and cost-efficient drilling are already being used by European researchers to create a robot-miner prototype[1] for small and difficult to access mineral deposits. This will certainly trigger more research and innovation in scalability, resilience, reconfigurability, collective behaviour and operation of the robot(s) in harsh environments, alongside ore metallurgy and processing close-loop systems. The combination of these technologies and the robotisation of underground mining enable the creation of **invisible mines. Invisible mines** have the potential to reduce the environmental impacts of mines and their footprint while increasing the social acceptance of mining.

A further outcome was the cross-over impact of operational technologies onto business models, especially where these technologies pointed the way to implementing radical new policies such as the EU CRMA:

> Despite efforts to reduce the environmental impacts of mines and their footprint, and to increase the social acceptance of the activity, a conventional economic rationale underpins economic feasibility studies. Under that logic, many minerals are either not extracted or are considered 'waste' an end-up being discarded.
>
> Advances in mining and ore processing methods designed to maximise robotic mining will create a fundamental shift in traditional business models since the extraction and maximisation of the value of all extracted materials increases the number of interactions in downstream industries. This will change traditional feasibility assessments, calling for the development of **intelligent business models**, capable of delivering sophisticated, comprehensive analysis, integrating a range of different value streams.

6.2.1 Drakelands Mine – Tungsten West

Both of the consequences anticipated in the Correia et al., 2021 paper has been applied to open a new chapter in the history of the Tungsten/Tin/Copper Drakelands mine located near the small town of Hemerdon in Devon, SW England (Figure 15).

[33] For L'École des Mines d'Alès (EMA) see https://en.wikipedia.org/wiki/%C3%89cole_des_mines_d%27Al%C3%A8s

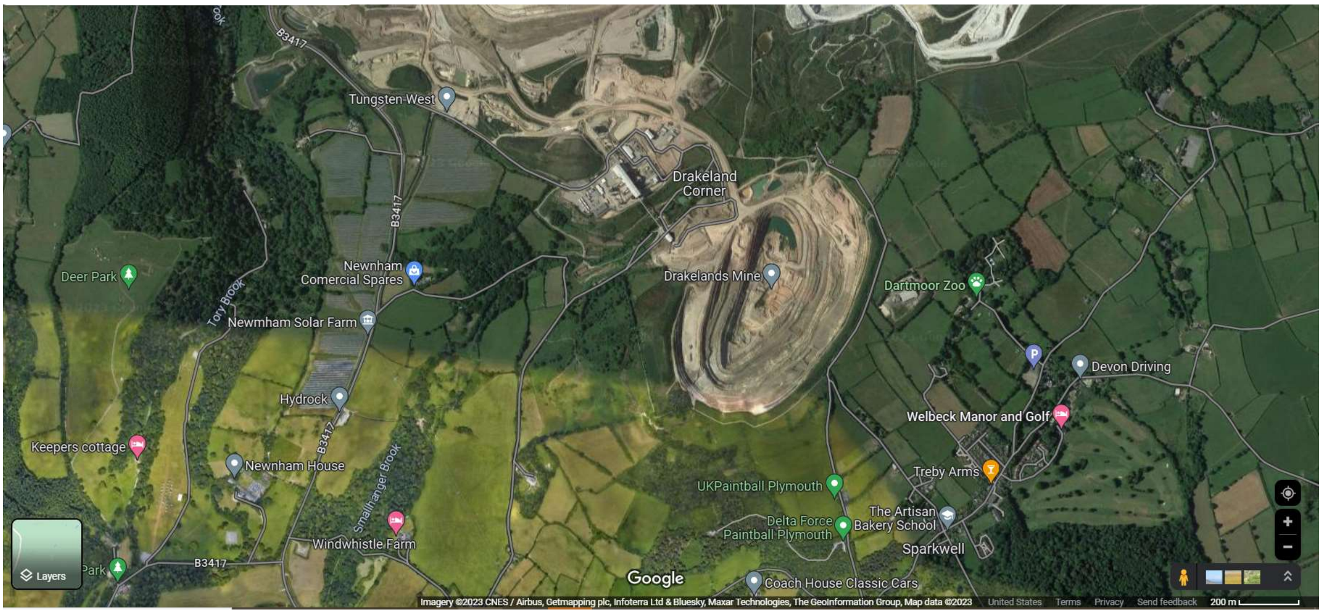

Figure 15 – Drakelands Open Pit Mine – topographical (satellite) view[34].

This project, run by the company Tungsten West[35], is one that in many ways points the way forward for mining in a circular economy context. The name Drakelands is one of the indicators of this change, using the name of perhaps the most famous figure in Devon's history Sir Francis Drake as the source of the name, bringing with it the glamour of a buccaneering entrepreneur of the 16th century who was also a great naval tactician and navigator.

The goal of Drakelands is to reset the knowledge and evidence base on which the decision to restart commercial Tungsten mining at a site with a long mining history is based in three transformative actions:

1. Design a "life of mine" plan that as a baseline (not just as a desired outcome) fully respects and protects a number of protected sites of outstanding natural beauty, scientific interest and UNESCO cultural heritage in the same region – the UNESCO listing is actually for the area's mining history traceable back through Roman times to the Bronze Age,
2. Use innovative investigative technologies for inventorying and correctly characterizing and quantifying the mineral resources the mine contains,
3. Apply state of the art extraction technologies to a) optimize the recovery of Tungsten from newly mined areas, b) recover resources of value from mine tailings from previous cycles of activity.

The most recent cycle of activities was started in 2019 and has received strong further impetus because of its mineral resources (tungsten and tin are on both the UK's and EU's list of CRM). This is the sixth known cycle of the mine's long history. In granting planning permission for the next cycle of activity at the mine, the permitting body, Devon County Council has recognised that the application by Tungsten West has fully taken into account the requirements of the EU EIA Directive and the Habitats Directive, both of which UK continues to adhere to as well. As a baseline for measuring how the whole project will be transformed, Figure 16 shows the open pit in 2023.

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[34] For topographical (satellite) view of Drakelands Mine see https://www.google.com/maps/@50.4099752,-4.0155415,2196m/data=!3m1!1e3?entry=ttu

[35] For Tungsten West see https://www.tungstenwest.com/

Figure 16 – Drakelands Mine - main open-cast pit[36].

The Drakelands tungsten and tin mine open pit is 850m long x 540m wide x 200m deep (current state as of June 2023). As can be seen in the satellite image above, the site is carefully managed from an operational point of view not to cross the boundaries between the surrounding farm land and the mined land, and the level of social acceptance from the surrounding community of Hemerdon indicates that this acceptance is born of a long-standing co-existence of farming and mining communities in the area, as well as the more recent regulatory requirements of protected sites whether for scientific, heritage of natural beauty reasons. In terms of resources, the table of Proved Reserves below (Figure 17) meets the standards of the JORC Code for tungsten and tin quantities recoverable.

		Proved Ore Reserves			
Ore Type	Cut-off WO_3 Eq (%)	Tonnes (Mt)	WO_3 (%)	Sn (%)	WO_3 Eq (%)
Granite	0.0742	32.1	0.18	0.03	0.19
Killas	0.0689	8.3	0.11	0.03	0.13
Granite Stockpiles	N/A	0.6	0.20	0.06	0.23
Total	-	41.0	0.17	0.03	0.18
		Probable Ore Reserves			
Ore Type	Cut-off WO_3 Eq (%)	Tonnes (Mt)	WO_3 (%)	Sn (%)	WO_3 Eq (%)
Granite	0.0742	24.0	0.17	0.02	0.18
Killas	0.0689	36.3	0.10	0.03	0.11
Granite Stockpiles	N/A	-	-	-	-
Total	-	60.2	0.13	0.03	0.14
		Total Ore Reserves			
Ore Type	Cut-off WO_3 Eq (%)	Tonnes (Mt)	WO_3 (%)	Sn (%)	WO_3 Eq (%)
Granite	0.0742	56.1	0.17	0.03	0.19
Killas	0.0689	44.5	0.10	0.03	0.12
Granite Stockpiles	N/A	0.6	0.20	0.06	0.23
Total	-	101.2	0.14	0.03	0.16

Figure 17 – Drakelands Mine – Ore Reserves. Source: Tungsten West.

[36] Image by Southwesterner at English Wikipedia - Transferred from en.wikipedia to Commons by Liftarn using CommonsHelper. Public Domain. See https://commons.wikimedia.org/w/index.php?curid=12096044

The introduction of new X ray extractive technologies will greatly enhance the accuracy and precision of the mining and resource recovery process (Figure 18).

Figure 18 – New x-ray ore body sorting technology arriving on site May 25, 2023[37].

As is clear from the successful turnaround in fortunes of the Drakeland mine, a combination of factors is required to secure Drakeland's role as a founding asset of a UK national and European-regional tungsten supply and value chain.

6.2.2 Cornwall Resources Ltd - Redmoor Mine

The Redmoor Project ("Redmoor") is located quite close to Drakelands in the tin and tungsten mining belt of eastern Cornwall, the neighbouring county to Devon in southwest England (see Figure 19 which marks both Redmoor and Drakelands). This belt has seen numerous projects over the past centuries, some enjoying periods of profitability notably when tin prices were high. These include a former Redmoor mine and the adjacent Kelly Bray and Holmbush mines, the latter of which, Holmbush, is now a historic landmark[38].

Cornwall Resources Limited (CRL) is actively exploring for tin and tungsten. CRL is owned by AIM listed Strategic Minerals PLC (SML). Personnel involved in the Redmoor project are employed through the joint venture vehicle (Cornwall Resources Limited) and, as such, are not directly employed by SML. The SML management team is largely Australian and operates out of Australia.

In two key respects Redmoor, which is currently in a recently relaunched exploration phase, is further down the pathway of the invisible mine than Drakelands. These are the decision to operate fully underground as

[37] https://twitter.com/TungstenWest?ref_src=twsrc%5Etfw%7Ctwcamp%5Eembeddedtimeline%7Ctwterm%5Escreen-name%3ATungstenWest%7Ctwcon%5Es1_c1

[38] For a short history of Holmbush see https://www.cornwall-calling.co.uk/mines/callington/holmbush.htm

and when the mine reopens, and the use of digital analytical techniques and technologies to assess what resources and reserves it may now contain.

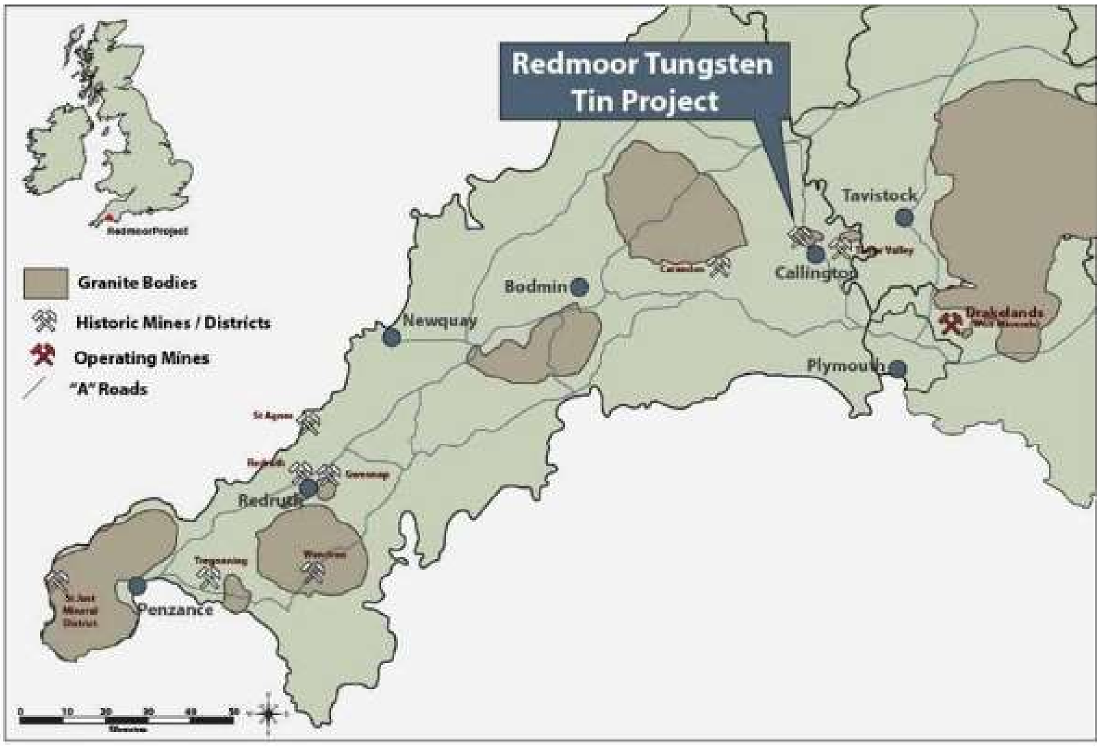

Figure 19 – Redmoor tungsten-tin project, Callington, Cornwall, SW England.

In respect of mining underground the satellite image (Figure 20) shows where a now disused mine-shaft is located (red circle) close to where the new exploration activities are taking place (red oval).

Figure 20 – Redmoor project drilling and trenching (phase 1, 2017-18)[39] with disused Redmoor mine shaft.

[39] See Google Maps https://www.google.com/maps/@50.5175174,-4.3202488,1007m/data=!3m1!1e3?entry=ttu

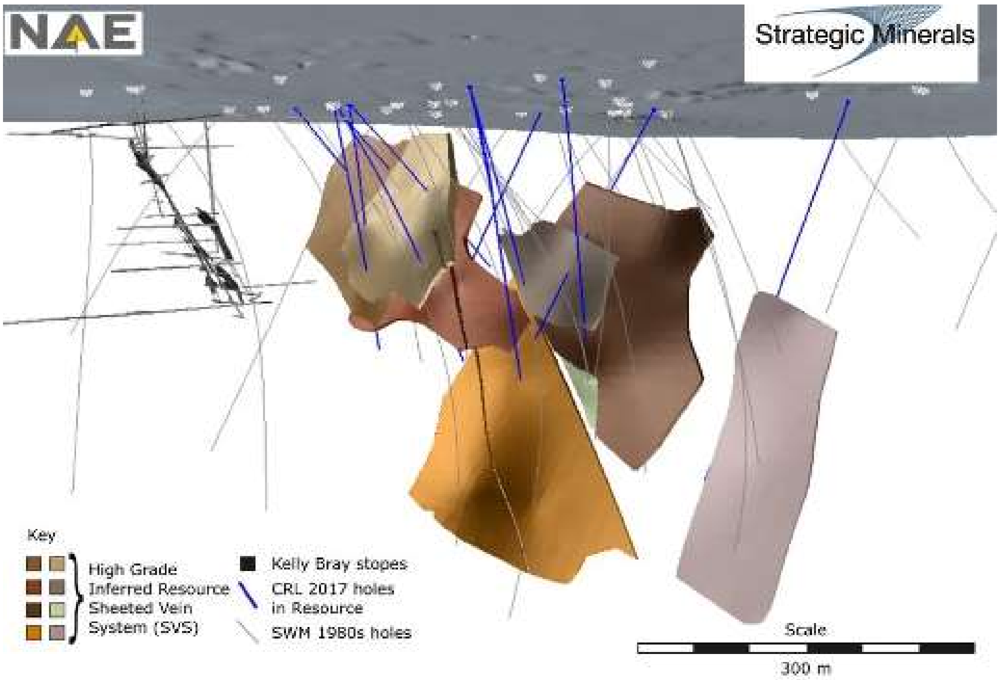

Figure 21– 3D digital view of the Redmoor Deposit Looking Southeast. Source: Deep Digital Cornwall.

Figure 21 shows a fully digital 3D view of the Redmoor deposit, and Figure 22 below presents a more detailed digital representation, with the past exploration results and depths shown in grey (1980s) and the recent results from Cornwall resources in blue showing inferred resources as mapped in 2017. The gain in depth, precision and quality is remarkable.

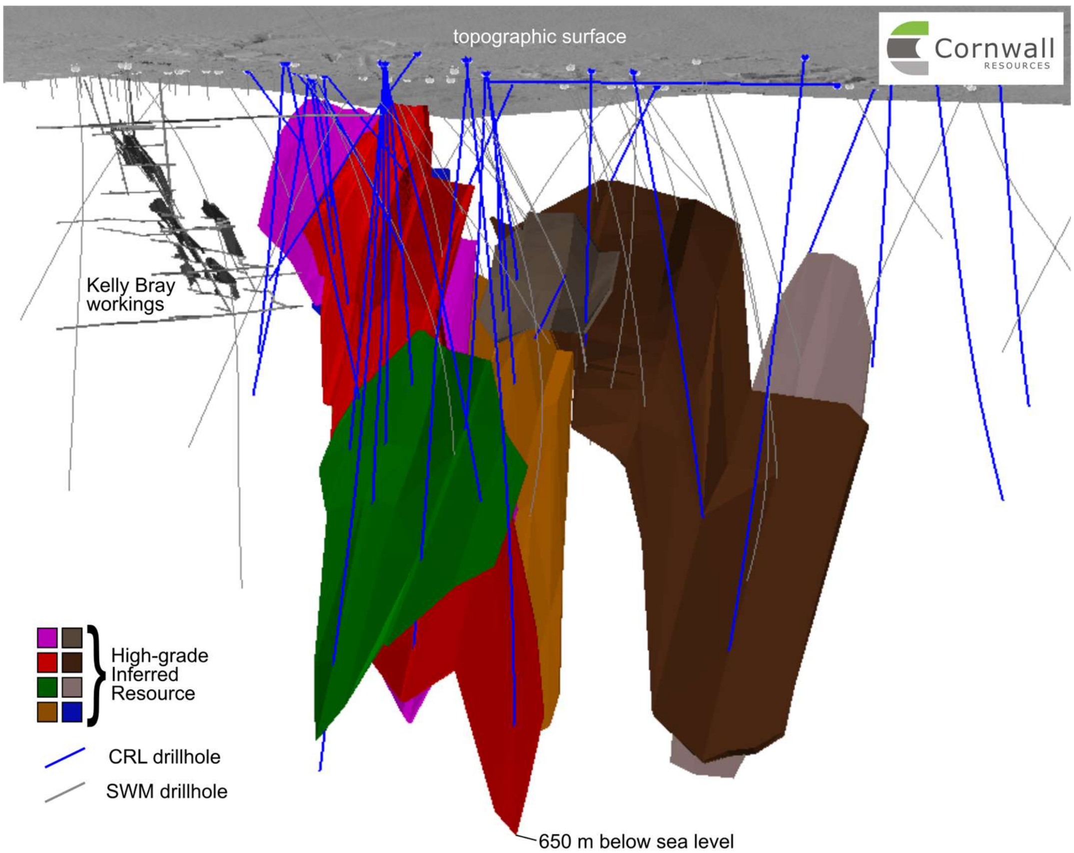

Figure 22 – Deep Digital mapping 2022-23: Redmoor project inferred resources.

an initiative partially funded by the EU Horizon programme. This cutting-edge development showcases the potential for revolutionary approaches in mining exploration and operations.

Redmoor stands out as a prime example of what could be termed a 'truly invisible mine'. This concept represents a paradigm shift in how we envision and implement mining operations, moving away from the traditional, visually intrusive methods that have long been associated with the industry.

This innovative approach points to a future where mining can coexist more harmoniously with local communities and environments. It represents a significant step towards sustainable resource extraction, aligning with the EU's goals for responsible mining practices and technological innovation in the raw materials sector. The success of the 'invisible mine' concept could potentially revolutionise public perception of mining activities and pave the way for more widespread acceptance of responsible resource extraction in sensitive areas.

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