GBBC
Global Blockchain
Business Council

SUPPLY CHAIN & CRITICAL MINERALS REPORT

GLOBAL STANDARDS MAPPING INITIATIVE 6.0

FROM MINE TO MARKET: UNLOCKING SUPPLY CHAIN VISIBILITY FOR CRITICAL MINERALS THROUGH DISTRIBUTED LEDGER TECHNOLOGY

GBBC GSMI 6.0

GLOBAL BLOCKCHAIN BUSINESS COUNCIL

DC Location:
1629 K St. NW, Suite 300
Washington, DC 20006

Geneva Location:
Rue de Lyon 42B
1203 Geneva
Switzerland

We are living a in a 'new reality' from a geopolitical, trade and technology standpoint.

Cooperation among stakeholders, even traditional competitors – coopetition – is key. In this framework digital tools providing trust, accountability, efficiency, and values sharing have a critical role to play to improve business performance as well as an inclusive, twin and just transition.

This report is focused on critical minerals, key for peace, trade, electricity transition, and prosperity, with blockchain as a "*game changer*." It is not limited to a global 'supply chain' agenda. It concerns as well agreements between countries, investors risk management, tax collection and use, workers, and population rights. This paper is inspired by the World Resource Forum report '*Rethinking Value – Resources for Planetary Wellbeing*' to make resources a driver for shared wellbeing within planetary boundaries, and it also presents an overview of the blockchain ecosystem and blockchain public infrastructure to *enable implementation of relevant regulatory initiatives and international agreements, improve knowledge and governance in the supply chain due diligence, coordinate funding, and attract investors*. It presents a global overview, with an African pilot and recommendations.

Supply Chain: *"A supply chain is made up of interconnected parts of a whole, all of which add up to finished products bought by customers"* (McKinsey)[1]

Value Chain: "The full range of interactions, resources and relationships related to a reporting entity's business model and the external environment in which it operates." (ISSB)[2]

The distinction with supply chain, is that SC refers only to upstream inputs supplied for production of a good or service. Value chain extends that to a wider range of relationships (not only suppliers) and also includes other issues after goods and services are produced and delivered to customers (e.g., disposal, emissions related to product use, which refers to Scope 3, category 11 emissions under the GHG Protocol). Across this report, we refer to both supply chain and value chain as they are relevant according to these definitions.

INTRODUCTION

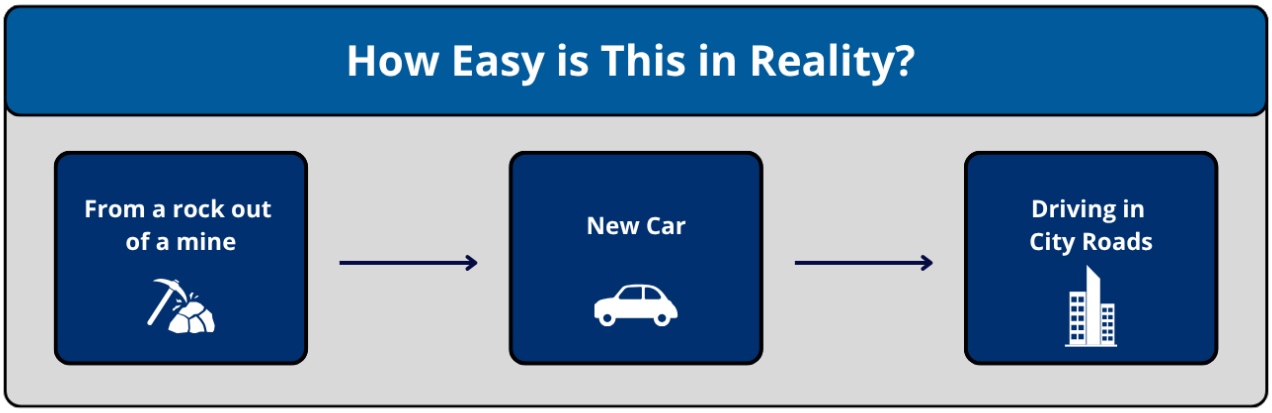
Critical minerals are raw materials that human civilization relies on for technological innovation, economic activity, and national security. Much of modern daily life is made possible by these minerals, which we find all around us in the form of our electronic devices, basic public infrastructure, clean energy equipment, and even our household appliances.

We are mindful that different countries may have certain differences across their official lists of critical minerals and rare earth minerals. For the purposes of this report, we refer to critical minerals in a broad sense, such that the issues we raise for critical minerals are also relevant for rare earth minerals.

Examples of critical minerals include:

Mineral	Primary Uses
Aluminum	Aircraft, transportation, packaging
Cobalt	Battery electrodes (including electric vehicles)
Copper	Electrical wiring (e.g., cars, cities, wind turbines), renewable energy infrastructure, electronics
Graphite	Battery anodes (including electric vehicle batteries)
Iron	Steel production (buildings, infrastructure)
Lithium	Batteries (including electric vehicle batteries)
Nickel	Batteries (including electric vehicle batteries), stainless steel
Rare earth elements (REE)	Electronics, magnets, defense systems
Silicon	Solar panels, semiconductors, computer chips

The supply chain of critical minerals – from initial extraction, to processing, refinement, transportation, and final delivery and recycling at the end of use for the item produced using critical minerals – is highly complex and may be vulnerable to supply disruptions.[3] Given these intricacies and challenges, emerging technology – specifically blockchain based tools for data verification - may be the only answer to ensure more robust and resilient critical minerals supply chains.



This report builds on previous GSMI supply chain reports, narrowing down on the specific issues raised by critical minerals supply chains that are an essential component to enable future economic growth. The essence of this is how critical minerals advance the themes introduced in foundational previous GSMI supply chain reports, carving out an especially important case where emerging technologies can provide tools that other traditional approaches have been incapable of delivering.

Critical mineral supply chains are complex and are intertwined with business competitive advantage and national security interests for companies involved at many stages. These challenges are heightened versions of well-known opacity in supply chains, especially beyond Tier 1 suppliers. Traditional supply chains are opaque for many reasons, and as a result, developing full transparency may be inaccessible to deliver the necessary traceability that entities along the supply chain, and stakeholders impacted by it, need to conduct due diligence in their interactions, as well as for those seeking to build resilience of supply chains.

A common misconception equates blockchains solely with public–aka *permissionless*–networks like Bitcoin. In reality, blockchains can also be *permissioned*, where participants are known and access is controlled, making it suitable for most enterprise use cases. And, blockchain itself is just one type of distributed ledger technology (DLT). Other DLTs use different designs–such as directed acyclic graphs (DAGs) or hashgraphs–to achieve similar goals.

Another misconception is that simply setting up a blockchain or distributed ledger gives you a provenance solution. It doesn't. A blockchain or distributed ledger is the safe home where provenance data can live transparently and be trusted. But, a key challenge is capturing, recording, and querying the right provenance information.

This is where provenance becomes central to supply chain visibility. Provenance provides the 'life story' of a critical mineral, making it possible to trace origins, transformations, and movements across complex global networks. Without it, supply chains operate in the dark, leaving blind spots around compliance, risk, and sustainability. With it, visibility becomes actionable: organizations can anticipate disruptions, verify sourcing claims, and build resilience and trust into their supply chains.

PURPOSE

The purpose of this paper is to provide tools to facilitate a desired future of more robust critical minerals supply chains. With a systems design thinking approach, it advocates for a paradigm shift in global critical minerals supply chains, leveraging emerging technologies – particularly blockchain and other distributed ledger technologies (DLTs), in convergence with other emerging or frontier technologies like AI, IoT and Edge computing, and internet connectivity and 5/6G:

- **to establish verifiable trust across supply chain complexities, while protecting sensitive data (e.g., commercial, personal, etc).**
- **to influence effective governance models for critical minerals supply chains**
- **to enhance due diligence and ultimately improve transparency and accountability**

The ultimate benefit: trust in global commerce.

Overall, this report is a response to a widespread observation by key stakeholders that implementation of most due diligence frameworks for critical minerals supply chains fall short of robust risk management objectives.[4] For instance, many key global forums on critical minerals have not yet fully acknowledged the benefits of emerging technologies like blockchain to support a solution-driven approach that can greatly enhance outcomes.

By identifying and addressing due diligence gaps, this report intends to provide a methodology and toolbox (Specified in Annex 2) to enable a level playing field globally for responsible sourcing and end-to-end supply chains of raw materials. In addressing clear needs, this report builds on state-of-the-art advances to enhance robustness of global supply chains for critical minerals through digital tools, (e.g., traceability, transparency, accountability, and decentralized collaboration). It is also consistent with existing global projects to strengthen responsible sourcing agendas, sustainable raw materials, responsible business/governance practices, and responsible financing.

We start with an overview of challenges in critical minerals supply chains, and ways emerging technology can help address them. We particularly highlight the complex landscape of multiple guidelines and requirements for stakeholders, identifying ways to address any barriers in applying innovative tools to facilitate compliance, and providing a blockchain toolkit to consider for facilitating compliance. We then provide a brief overview on the nature of guidelines, providing further detail on how blockchain technology can be deployed to better meet those guidelines and provide proof of compliance for reporting and audits. This report provides insight on current responsible sourcing standards, requirements, and related guidelines, particularly in light of how blockchain technology can help stakeholders throughout critical minerals supply chains comply. This leads to a proposed methodology for compliance, highlighting ways blockchain can enhance each verification.

Finally, the report identifies the needs of key stakeholders across critical minerals supply chains, gaps and challenges in meeting these needs, ways technology can help meet these needs. We conclude by proposing recommendations, conclusions, and open questions.

CRITICAL MINERALS, CRITICAL TRUST: FIXING BROKEN SUPPLY CHAINS WITH TECHNOLOGY

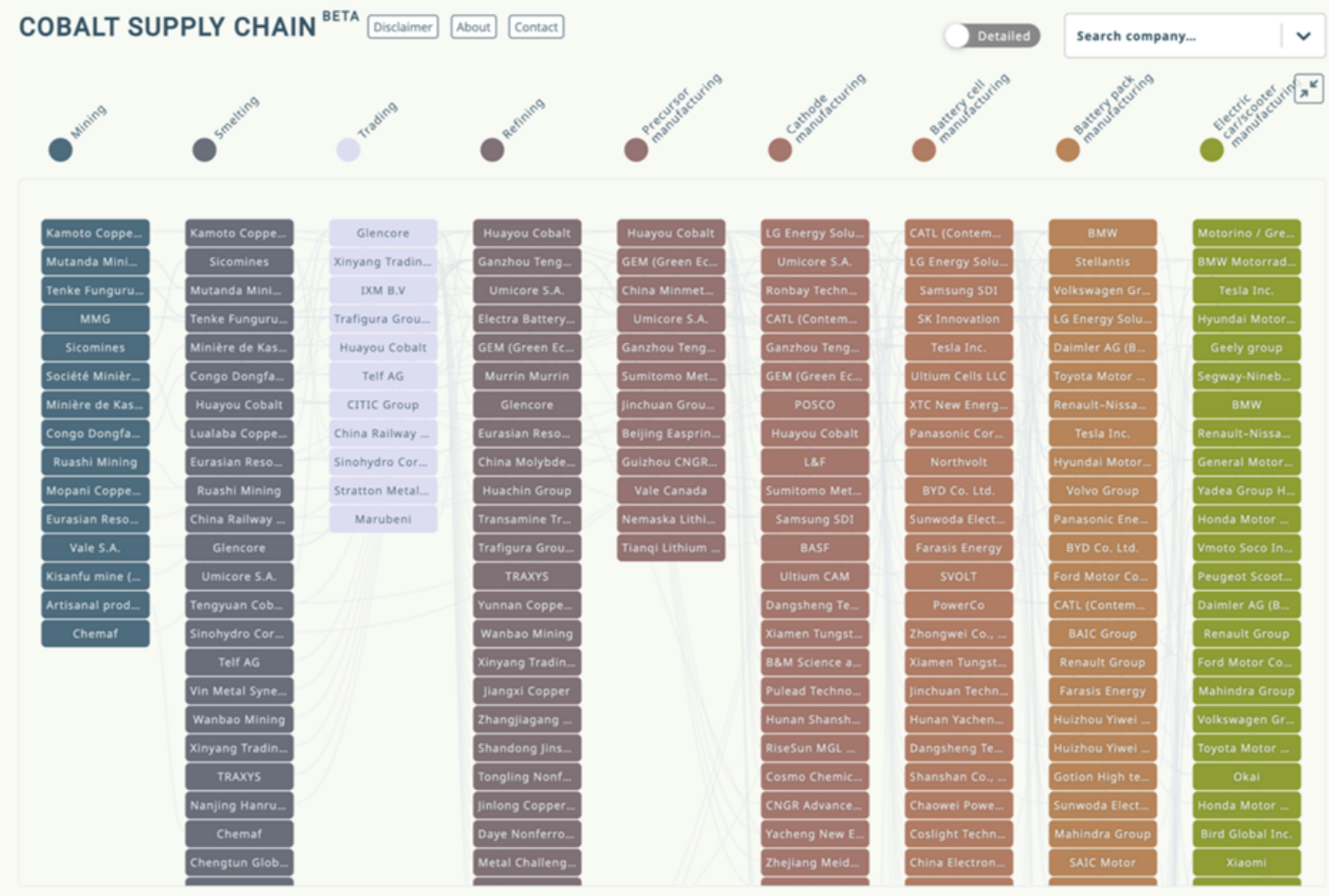
There is immense market value to be gained from improving trust and transparency, even across the most complex of critical minerals supply chains. For instance, major brands are looking to use supply chain data to create new customer experiences that allow users to obtain insights into the labor practices behind their products. Research initiatives like these calls for total visibility of all commercial transactions, prior to the deployment of enhanced commercial solutions. Yet as much as the world would benefit from supply chain transparency for critical minerals, there are complex global challenges that must be addressed:

CHALLENGE: SUPPLY CHAIN COMPLEXITY

Supply chains for critical minerals are highly complex, with multiple jurisdictions and processes involving multiple stages, players, modes of transportation, documentation and data sharing, and regulatory requirements.

These processes also involve an interplay between both physical and digital corridors. The first refers to physical infrastructure like railways and ports, while the second refers to information technology deployed to optimize these supply chains. Digital corridors record extensive logistics networks to track and manage the movement of minerals from their source to global markets, and ultimately to end users. While security and efficiency are fundamental, the inherent complexity of these supply chains poses substantial challenges.

As an example, below is the supply chain for cobalt:



Source: Resource Matters.

OPPORTUNITY WITH EMERGING TECHNOLOGY: BETTER CORRIDOR MANAGEMENT

Facilitating critical trade corridors possesses the potential for eliminating major bottlenecks in trade. As corridors manage goods in transit, corridor efficiency naturally involves improving the transit process of goods across countries and regions. The United Nations Conference on Trade and Development (UNCTAD) report on blockchain and trade facilitation performance[5] states:

"International corridor management is a major component of the global trading system. Given the increasingly interconnected global economy, goods go across many countries and sometimes multiple regions to make it to the target destination. This is not without challenges, especially when the multiple stakeholders within critical corridors do not have a commonly shared digital backbone for trade data and information sharing. The complexity of multinational trade flows makes critical corridors particularly important for ease of trade flows and serve as critical determinants of the time and cost to trade."

Digital corridors in particular can be optimized with emerging technologies, especially in alignment with the Global Digital Compact adopted at the UN Summit of the Future held in September 2024 in New York. Emerging technologies can also improve the effectiveness of implementation of strategies like the World Bank Trade and Transport Corridor Management Toolkit.[6]

CHALLENGE: GEOPOLITICAL RISKS

National and global economies depend on resilient supply chains. Yet ideological conflicts often drive the geopolitical context in which the modern economy and global supply chains operate. If any actor disrupts the supply chain, it can have global implications, bringing disruptions to economic trajectories and power structures, such as competition in the semiconductor industry.

Geopolitical risks in critical minerals supply chains stem from concentration of resources in certain countries, with manufacturing and final consumer demand often located in disparate regions. Resource concentration increases supply vulnerabilities, especially in cases of unwanted events - global conflicts, political instability, and economic sanctions can directly affect supply and lead to volatility in prices. Resource concentration thus also impacts power dynamics between nations, with resource nationalism and export controls arising as mechanisms to gain leverage with trading partner nations.

Ultimately, geopolitical risks arising from critical minerals-driven disputes may threaten national security and destabilize efforts toward economic development and the energy transition. In a context of shifting power dynamics and increasing uncertainty, there is a rising multipolar struggle for resources among powerful nations, where often countries that have those resources retain limited power and are subject to political pressures.

For instance, countries like the United States, China, Japan, and Russia are building corridors globally to strengthen their position with respect to access to critical mineral resources. The United States and China have already demonstrated a rivalry in exerting global political influence, stemming from efforts to access mining resources in places like Latin America. China[7] and Japan[8] are also financing corridors in Africa.[9] Access to critical minerals can be the source of armed conflicts and wars, which disproportionately hurt local communities in those nations where raw materials originate, which are often lower income nations with greater vulnerabilities.[10]

Expected outcomes from these geopolitical dynamics can draw lessons from historical events such as the 1970s oil shock and following US embargo[11], where a higher price of oil created incentivized the US to search for alternative oil resources domestically and increased its bargaining power over the Organization of the Petroleum Exporting Countries (OPEC), which now provides a significantly lower percentage of petroleum resources globally. Similarly, US-China rivalries have created incentives for mining critical minerals on US soil[12], as geopolitical risks have prompted efforts to diversify sourcing overall. Ultimately, the implication in the long-term is to reduce exposure to geopolitical risk by further diversifying supply, but in the short-term, this could it heighten it (especially if suppliers are worried about their sourcing being disrupted by supplier cuts to raise pricing ahead of losing pricing power when supplies come on line).

OPPORTUNITY WITH EMERGING TECHNOLOGY: GLOBAL JUSTICE

In a time of increasing geopolitical complexity and trade wars, emerging technologies can help countries shift the balance of power[13] toward a more equitable global economy, away from extractive models where financial flows disproportionately favor "consumer" nations in the Global North at the expense of resource-rich countries in the Global South.

Is the logic here may be of a 'race to the bottom' via opaque supply chains to conceal activities that violate international obligations. While removing that opacity necessarily leads to investment in downstream production capacity in developing countries to help them move up the value chain, it may also merely reduce one form of harm (conflict minerals) from supply chains while leaving the extractive economic model intact where Global South countries are unable to advance, by being constrained as producers of low-value added commodities.

For instance, there is a need for a global strategy on responsible sourcing, where blockchain technology can be critical in developing a trusted ecosystem for global trade performance, ultimately supporting global peace and prosperity. Innovation can lead to a turning point, as a source of competitiveness that can facilitate "co-opetition" dynamics for win-win outcomes for all stakeholders and local communities.

Blockchain technology, which enables data sharing in ways that benefit all stakeholders, can transition dynamics toward greater convening and collaborating. In working together to build supply chain resilience with greater transparency and trust enabled by technology, trading partners can increase the market opportunity for all, in ways that favorably influence international relations rather than conflict.

As António Guterres, United Nations Secretary General stated at the Launch of the Panel on Critical Energy Transition Minerals, April 26, 2024 "One principle shines from the heart of this initiative – and that principle is justice. Justice for the communities where critical minerals are found… Justice for developing countries in production and trade; and justice in the global energy revolution."

CHALLENGE: SYSTEMIC VULNERABILITIES DUE TO LACK OF TRANSPARENCY/ SECURITY

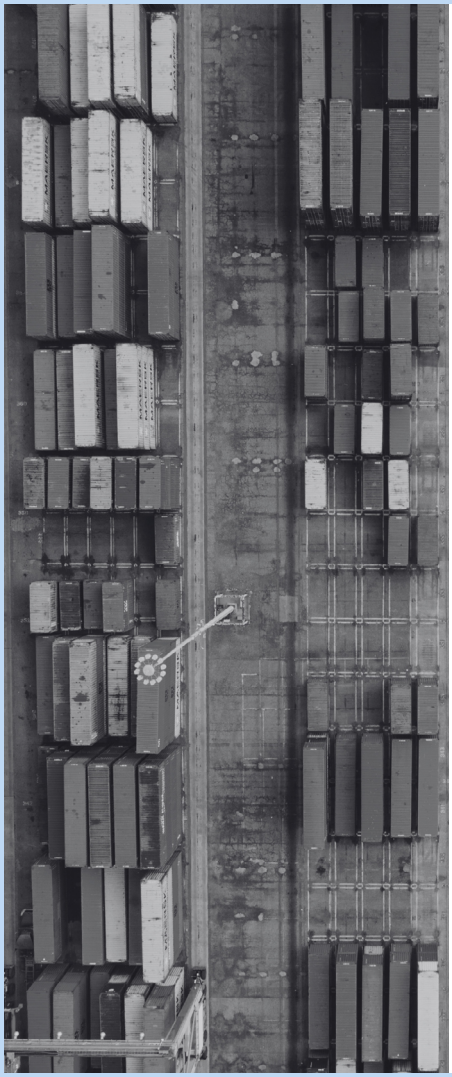
Global reliance on critical minerals and rare earth elements has exposed systemic vulnerabilities: opaque sourcing, geopolitical manipulation, and rampant counterfeiting and forgery, with respect to both critical minerals and the documentation supporting their provenance respectively. Traditional supply chain models, dependent on centralized databases or paper trails, fail to provide the transparency, security, and multi-tier traceability required to mitigate these risks. Often these supply chains are made up of widely spread tasks, managed by analog systems that remain disconnected from each other, with limited data visibility and limited data sharing for stakeholders who need it most. In an analog context, making data available may mean disclosing the full ledger of records, which would require disclosing confidential information – both personal data and trade secrets.

The Pitfalls of Traditional Transparency

Current approaches to traceability often consolidate data into centralized “buckets,” creating vulnerabilities:

- **Honeypot Risks:** Central repositories, storing a high amount of data in one place, attract hackers
- **IP Exposure:** Sharing full production details with auditors or partners risks reverse engineering
- **Oversimplification:** Aggregated data obscures critical nuances across tiers (e.g., unethical subcontractors)

Supply/Demand Imbalances



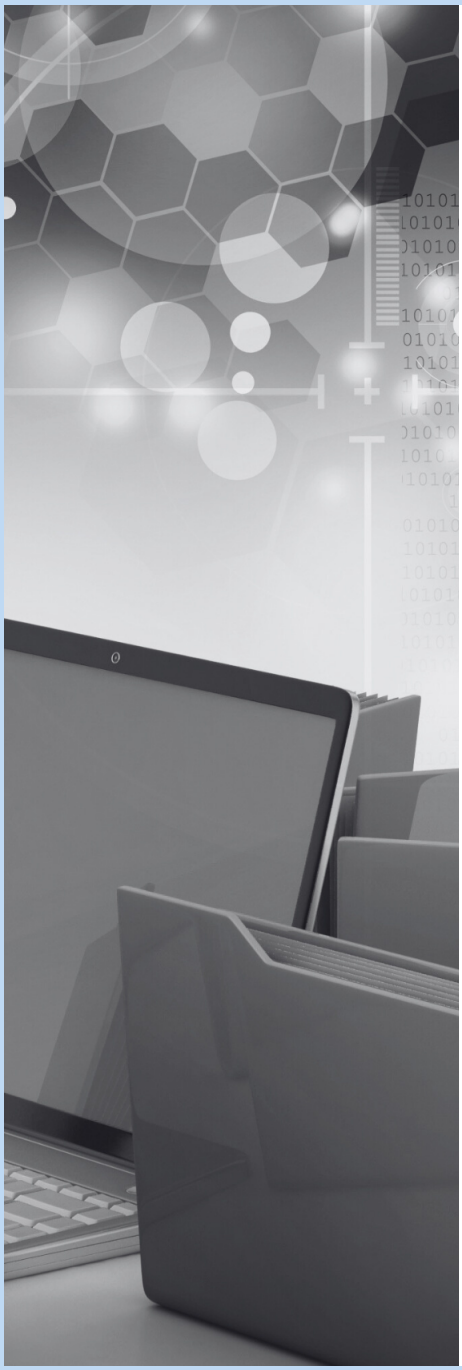
Moreover, lack of transparency can exacerbate supply and demand imbalances. For instance, the energy transition can rapidly increase the demand for certain critical minerals without providing the necessary data for producers to ramp up supply accordingly. This could point to issues where producers want to increase production but are unable to supply due diligence data to purchasers (assuming energy transition is more likely to demand compared to other sources of demand).

For instance, in palm oil biofuels, import restrictions were imposed to cut off imports of specific products related to sustainability risks, and had the unintended consequence of harming producers who had gone through the process of sustainability certification because a large market for their production was closed after the fact. These issues affected modern diplomacy conversations, including Indonesia vs. European Union regarding palm oil and biofuels disputes at WTO Panels. Moreover, the Covid pandemic also highlighted numerous supply chain fragilities and concentrations, with supply chains facing major challenges in the face of rapid shifts in demand, transportation bottlenecks, and shortages in raw materials.

Sustainability Concerns

From a sustainability standpoint, lack of transparency also creates obscurity with respect to environmental impacts in production processes, as well as labor conditions including the presence of slave labor. A recent McKinsey study estimates that the majority of companies globally have no supply chain visibility beyond Tier 1 which means they are effectively flying blind in relation to many material sustainability-related risks buried in their supply chains.[18]

Challenges Arising from the Informal Economy



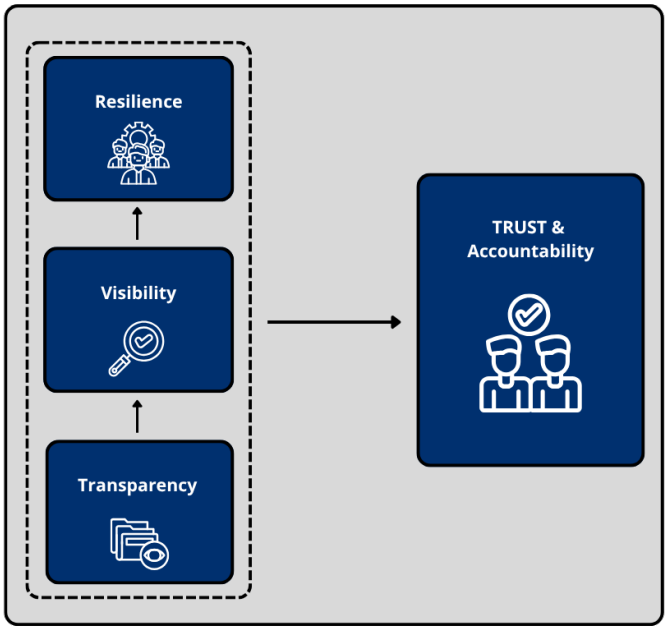
In much of the developing world, the majority of economic activity remains in informality – that is – outside of legally registered and regulated activities. Informal economic activities, including many small enterprises, are not taxed but also cannot access basic services and protections, such as access to financing, training, social security. In the case of critical minerals, this may include the activities of small and artisanal miners and their cooperatives, transportation providers, vendors of supplies and equipment, and other essential labor and supporting services. In some countries, the process to legally register a business, alongside basic activities such as owning property, are so onerous relative to the benefits for average citizens that many prefer to remain in a status of informality. Thus, while there is a massive estimated aggregate wealth in the informal economy, much of it may remain illiquid and tied to lack of visibility, which may increase the risk of corruption and undesired activities.

In addition to the negatives associated with wealth accumulated in the informal economy, it also reduces domestic resource mobilization (e.g., taxes) for infrastructure investment and (e.g., lack of participation in the formal financial sector) increasing financial market depth and local liquidity, which reduces external financing requirements for the formal private sector companies. Both issues contribute to high perceived risk by external investors (leading to high interest rates) at the same time the domestic industry (including downstream production) may be rendered less competitive by Dutch disease (overvalued exchange rate as a result of natural resource wealth).

Challenges Arising from the Informal Economy (cont.)

The conventional view is that moving informal economy to the formal economy is always a net positive, but that may be a perspective that reflects an imposition of a Western attitude towards different forms of economic organization. There could be value produced if emerging technology is employed in a way that allows for interfacing between formal and informal economy without requiring a wholesale change, while still providing visibility in supply chains.

This takes into account the UNCTAD research related to stakeholder capabilities and participation and report recommendation on Policy guidance for stakeholders: *"While blockchains could speed up processes at both local and global levels, stakeholder preparedness, readiness and awareness play a crucial role in the success and sustainability of the technology in a national context. Implementation will require a holistic approach of training, preparing and supporting the broader stakeholder ecosystem to understand and fully engage in the development, design and deployment of the technology. As multi-stakeholder systems by design, blockchains not only need stakeholder acceptance, but also stakeholders' active participation to attain proper function and to achieve the intended purpose."*[14]



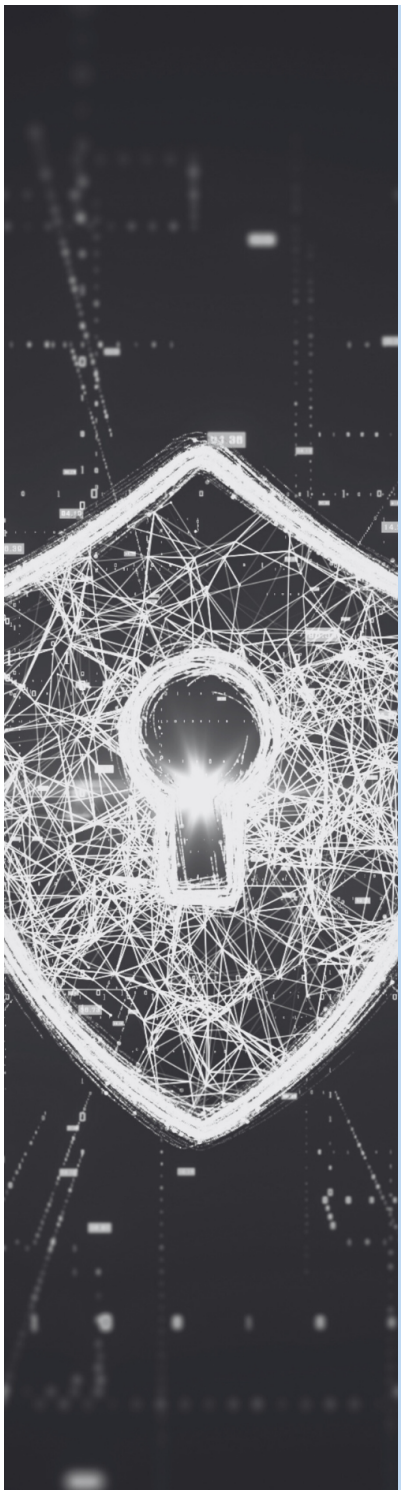
OPPORTUNITY WITH EMERGING TECHNOLOGY: TRANSPARENCY & SECURITY

Supply chain resilience is made possible by greater visibility, which in turn is built on transparency. Blockchain technology can enhance existing initiatives and greatly increase transparency, in ways that improve both traceability alongside security.

Transparency

When it comes to traceability & provenance, blockchain technology can record key interactions following processes to make products (e.g., geo-location date/timestamps of interactions, physical movement), as well as facilitate evaluations (e.g., conduct evaluations, 3rd-party audits, facility inspections, and product test results linked to specific batches). Public protocols provide the benefit of data access for all network participants, allowing companies to build solutions with a shared protocol in ways that increase opportunities for all stakeholders and facilitate coopetition.

Security



As for security, privacy preserving tools are especially useful when it comes to selective disclosure of data and self-sovereign ownership of data, such that the necessary data is made available, when needed, to designated stakeholders. This can point to the right data necessary to balance supply and demand. Transparency is also a fundamental condition for AI-based tools for demand planning and response, which can improve supply chain resilience. For supply chains, permissioning measures and other privacy preserving tools enabled by blockchain technology are critical and enable:

- **Data Property Rights:** Ensuring companies retain ownership of intellectual property (IP), pricing, and proprietary processes.

  - A related element is that companies in EMDEs should benefit from participating in more transparent supply chains, and should not just face 'stick' of loss of market access & financing as the principal reason for producing & supplying this data. Current market ecosystem has intermediaries demanding data on behalf of end-users (investors, financial institutions) and then selling that data back to the companies that supplied it (e.g., for peer benchmarking). The payments ecosystem related to blockchain systems (e.g., stablecoins, CBDC) should enable payment for data on a granular level (data item for particular company) in addition to other important data property rights.

- **Selective Disclosure:** Sharing cryptographic proofs of claims (e.g., mineral provenance) without exposing raw data.

- **Interoperability:** Integrating legacy systems with emerging web3 tools through emerging protocol abstraction layers.

Economic Growth & Formalization

The transparency provided by blockchain technology can shed light on the value of informal economic activities, helping quantify and record essential data. It can also facilitate access to markets and connect important players into integrated records of global critical minerals supply chains.

CHALLENGE: MANY GUIDELINES; MAKING DUE DILIGENCE DIFFICULT

Given the complexity and global importance of critical minerals supply chains, there are a plethora of guidelines, standards, and regulatory requirements intended to address the challenges of these supply chains and improve their resilience. In addition, international convenings, protocols, and trade agreements set commitments to support resilience in critical minerals supply chains. In this context, supply chains for critical minerals are governed by a wide array of government policies, industry standards, and international frameworks. Multiple initiatives and platforms – ranging from responsible raw materials sourcing, mining management, sustainable finance, value chain management, and fair trade – may be useful for stakeholders seeking to adhere to responsible business conduct, but assessing and ensuring due diligence can be extremely difficult.

- **Systems not up to par:** With current systems, there is a wide array of tasks and data to be checked across various stages of the supply chain (e.g., documents, authenticity verifications, use of standards). The data gathered and revised must also be congruent across jurisdictions and platforms. This adds great complexity into due diligence assessments – essentially for the "yes/no" decision on whether an entity meets due diligence requirements whether for financing or other commercial decision-making.

- **Requirements are not harmonized:** When it comes to supply chain resilience, there is currently no widely accepted system definition and parameters, governance model with specifications like data property rights & selective disclosure licensing, or standards for data management.

There is also a need for interoperability across supply chains, similar to internet and computer protocols. In complex supply chains, different supplier groups and other stakeholders may be subject to different standards utilize technology differently. Moreover, different layers of the supply chain may be considered part of different industries, with different considerations and requirements.

The palm oil and biofuels issue mentioned before is also an example from a different context, but illustrates a similar point. Standards that were developed for sustainable palm oil were primarily designed for the food sector (to protect the value chain intermediaries and final manufacturer of consumer goods where validating sustainability back to the individual inputs was important to avoid deforestation-related production).

Where other sustainability concerns arise (e.g., macroeconomic incentives for deforestation related to biofuels), the ban was designed because any use of biofuels with deforestation risk is likely to increase aggregate deforestation to meet both food & energy requirements. However, in imposing an import ban, those who had met the requirements for the consumer food production sector were punished with loss of access, while those that were excluded from the EU's market already faced no incremental harm, penalizing companies for doing the right thing.

OPPORTUNITY WITH EMERGING TECHNOLOGY: BLOCKCHAIN TO ENHANCE DUE DILIGENCE

Blockchain technology can be a promising tool to better assess adherence to ethical best practices, guidelines, and regulatory requirements. Stakeholder priorities can be broadly considered, in ways that take less effort to perform required tasks (e.g., basic traceability tests) to meet minimum standards and maintain a basic level of trust. If a greater portion of the due diligence process becomes automated and transparent, with less resources, it can cover a wider scope of data, tiers, and processes across the supply chain. Ultimately, organizations can move beyond meeting minimum requirements to consider a broader array of stakeholder concerns (e.g., double materiality).

Awareness, education, and engagement are key to align stakeholders toward a coordinated adoption of blockchain technology to enhance due diligence across supply chains, addressing any barriers toward this adoption. For instance, contrary to certain public perceptions that blockchain makes the data it records public (e.g., it would also be a concern if a private blockchain allows all users of that blockchain to view all the on-chain data), there are solutions available to protect IP and data privacy, with sensitive information never shared beyond those specifically granted access.

First, it will be important to address current barriers to implement blockchain to optimize due diligence for critical minerals supply chains, which consist of:

Barriers to adopt blockchain for due diligence	Mitigants
Perception of blockchain making all data public, leading to reluctance to share sensitive data with competitors (e.g., suppliers, volumes, contracts).	• **Awareness & Training** on how to implement shared transparency without full disclosure: Blockchain based privacy tools include solutions to allow validation without exposing trade secrets (e.g., zero-knowledge proofs). • **Permissioned ledgers** also allow companies to share compliance-related proofs (e.g., origin, ESG data, due diligence data) while keeping commercially sensitive data private. • **Best practice**s point to storing sensitive information off-chain, sharing proofs on the blockchain (e.g., as hashes)
System integrations and costs, limiting scalability	• **Stakeholder collaboration** toward shared and open systems (e.g., offer shared industry utilities through consortium blockchains). Layer 2 and permissioned solutions can also improve scalability. • **Subsidies and capacity building**, especially for small organizations, considering low cost mobile solutions over expensive tech.

Barriers to adopt blockchain for due diligence	Mitigants
Desire for opaqueness in parts of the supply chain, to conceal poor practices or informality, contributing to traceability gaps.	• **Incentives toward transparency**, including economic incentives, and sanctions for poor behavior and lack of due diligence. • **Digital identity tools** for artisanal miners and smallholder players & partnerships with NGOs and local cooperatives to digitize transactions, helping informal players integrate into the global system.
Lack of quality data to record (Garbage in, garbage out concept)	• **Investment in infrastructure** (e.g., sensors, satellite monitoring)
Different data formats and measurements, reducing interoperability	• **Data standards** (Development and adoption) • **Multistakeholder initiatives** • **Government-sponsored pilot** projects toward standards adoption
Poor governance practices	• **Develop clear contractual rules**, especially for liability, and embed smart contracts with these responsibilities. • **Develop inclusive governance models** that give voice to upstream suppliers.
Lack of interest in blockchain adoption, due to unclear ROI or comfort with status quo	• **Regulatory sandboxes for blockchain** traceability and acceptance. • **Education, training, and engagement** toward formal recognition of blockchain records as compliance evidence of due diligence requirements. • **Tie blockchain to market access** advantages and highlight efficiency gains
Power and information asymmetries	• **Cost sharing approaches** so downstream buyers, generally with deeper pockets, cover a greater portion of the implementation burden

BLOCKCHAIN TOOLBOX FOR DUE DILIGENCE IN CRITICAL MINERALS SUPPLY CHAINS

Blockchain can provide granular data on inputs, outputs, and changes of title and custody, allowing visibility for an entire product with respect to the origin and destination of critical minerals. Below is a list of blockchain attributes that can be beneficial to enhance the resilience of critical minerals supply chains by strengthening due diligence mechanisms. We offer this toolbox as a reference for stakeholders to consider in performing due diligence to meet requirements:

Tool	Benefit
Shared records	Verified records on supply chain data, compliance with requirements, and certifications facilitate auditability, regulatory compliance, and other due diligence requirements. Auditable data trails reduce reliance on self-reporting
Tokenization	Trace materials as they move across physical boundaries
Digital identities	Interoperable identity systems (e.g., for workers) integrate into supply chain data
Smart Contracts	Automate transactions, compliance, payments, benefit sharing, and reporting, upon meeting key requirements
Immutable records	Prevent corruption and fraud, with no retroactive record changes
Shared ledgers	Enable collaborative practices and standardized digital certifications (e.g., conflict-free minerals, fair trade practices, carbon footprint) and compliance frameworks (e.g., harmonized regulatory requirements)
Incentive mechanisms	Encourage positive behaviors (e.g., tokenization and credits to incentivize metal recycling)
Privacy & Security Tools	Enable selective disclosure of necessary data. Zero knowledge proofs can reveal only necessary data for any given decision, without revealing sensitive information that is better kept private. Cryptographic key management, for instance, ensures data confidentiality and data integrity for greater security. Multisig (multi-signature) validation enables collaboration and security with shared control and improved accountability, in a way that reduces single points of failure.
Real-Time Data records	Facilitate assurances for regulators, manufacturers, investors, etc.
Decentralized governance mechanisms	Enhancing collaboration across key stakeholders, including voices of traditionally underrepresented groups. Decentralized Autonomous Organizations (DAOs), for instance, can implement measures such as voting, project proposals, and automated execution of transactions.
Integration with IoT devices	Real-time access to data captured on the ground by IOT devices, securely recorded on a blockchain
Integration with AI Solutions	Blockchain provides verified data going into AI algorithms, the methods in which data is processed by AI algorithms (foundation models, and the outcomes of AI-driven informed decision making for better monitoring & evaluation of impacts.
Decentralized Finance (DeFi) and Regenerative Finance (ReFi)	DeFi might provide the infrastructure for supporting both payment for licensing of ESG data (to incentivize companies to provide it) and also topics like ReFi to act in ways that are regenerative rather than extractive. ReFi can improve the effectiveness and monitoring of environmental and social protections, such as community engagement, management of water and other resources, and emissions targets

BLOCKCHAIN STRUCTURE

Blockchain technology should ideally be deployed in two dimensions: to capture production data and to capture commercial transactions. This way, each tier in the supply chain can be accurately followed, as raw minerals end up in many different goods. This bifurcation allows companies and consortia to determine the appropriate technology tool to use for each function; enables granular, multi-tier supply chain visibility while safeguarding competitive advantages and sensitive data; and provides the structure to evaluate various standards and assess technology adoption.

TRANSPARENCY: PRODUCTION VS. COMMERCE

1. **Production Data:** Immutably record the journey from inputs to outputs. This includes records of how materials are extracted, refined, and processed (e.g., energy usage, labor conditions).

2. **Commercial Data:** Immutably record commercial events, where transactions indicate change of custody and title, to link the multiple tiers of the global supply chain. This provides verifiable proof of ownership and custody transfers, contracts, and payments across suppliers, without disclosing pricing.

BLOCKCHAIN AS A TOOL FOR DUE DILIGENCE

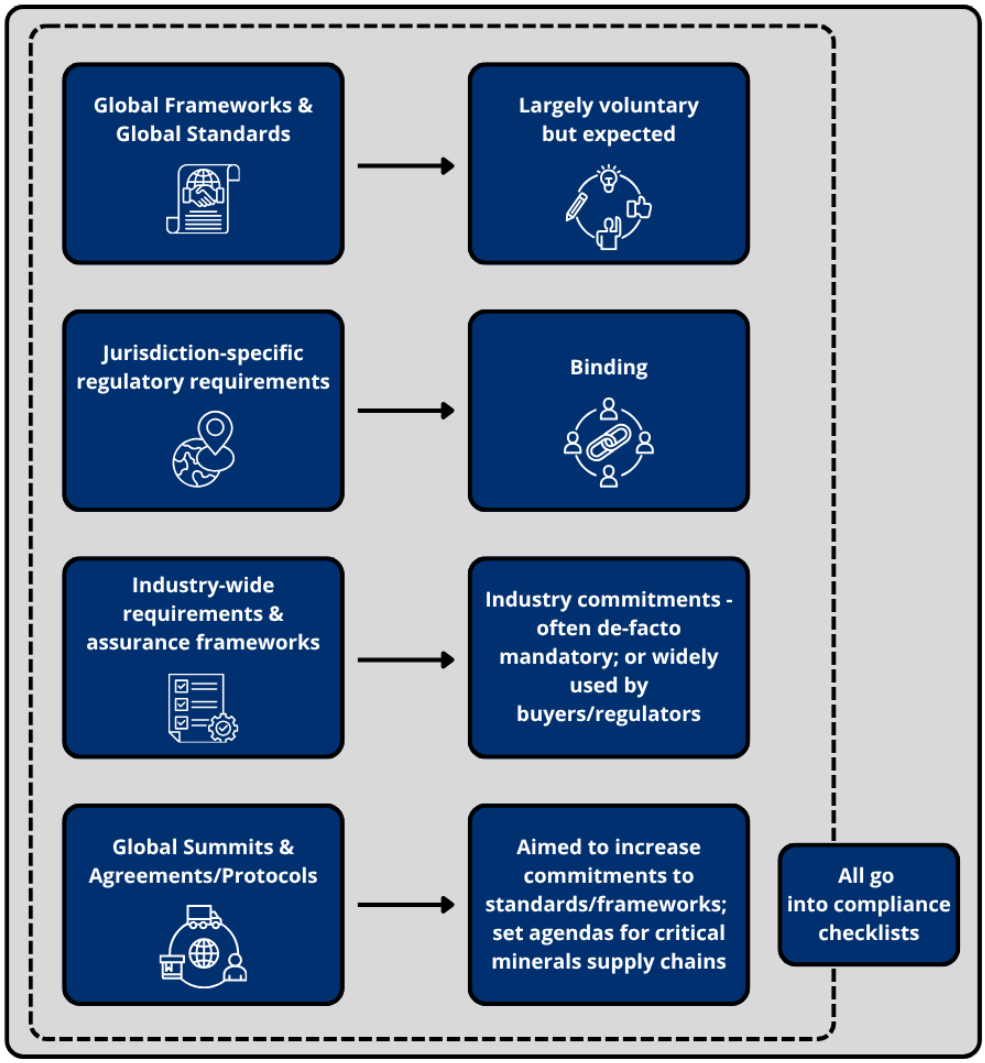
Because of the complexity of due diligence and the various specific requirements, below we identify the main themes covered by due diligence requirements across critical minerals supply chains, followed by ways blockchain technology can help enhance due diligence to meet those requirements.

DUE DILIGENCE PRINCIPLES

Principles drawing from existing international norms, commitments, and legal obligations across critical minerals supply chains can be summarized as the following:

Principle 1	Human rights must be at the core of all critical mineral value chains.
Principle 2	The integrity of the planet, its environment, and biodiversity must be safeguarded.
Principle 3	Justice and equity must underpin critical mineral value chains.
Principle 4	Economic development must be fostered through benefit sharing, value addition, and economic diversification.
Principle 5	Investments, finance, and trade must be responsible and fair.
Principle 6	Transparency, accountability, and anti-corruption measures are necessary to ensure good governance.
Principle 7	Multilateral and international cooperation must underpin global action while promoting peace and security.

A detailed landscape of the various guidelines for critical minerals supply chains can be found in Annex 1, with the main concepts and players illustrated below:



DUE DILIGENCE METHODOLOGY

The landscape of guidelines can be applied into a practical compliance checklist, with the following considerations. The blockchain toolbox referenced above can be referenced to meet the points below. For mineral-specific compliance checklists, see Annex 2:

1. **Governance & Policy:** Adopt policies for responsible sourcing and human rights, aligned with OECD, UNGPs, and IFC.

2. **Traceability & Chain of Custody:** Implement chain of custody controls from mine to smelter/refiner to components to final product, selecting a model defined by ISO 22095. Adopt recognized audit protocols (e.g., RMAP, IRMA, Copper Mark, ASI) as relevant.

3. **Risk Assessment for conflict areas & forced labor:** Screen for exposure to conflict-affected and high-risk areas (CAHRA) and forced labor across the supply chain, and subsequently prioritize risk mitigation measures, according to relevant frameworks like (e.g., US Uyghur Forced Labor Prevention Act (UFLPA), UK Modern Slavery Act)

4. **Corrective Actions & Supplier Engagement:** Implement risk mitigation measures, escalating or disengaging where necessary, in alignment with OECD.

5. **Independent Assurance:** Adopt required and expected assurance and audit mechanisms (e.g., LME assurance, RMAP audits, GISTM facility audits, etc.)

6. **Public Reporting:** File legally required disclosures (SEC Form SD; Canada S-211; EU Battery/CSRD reports) and any voluntary reporting disclosures.

7. **Market-Specific Rules:** Adhere to rules for specific sectors (e.g., for EV/battery supply chains, IRA §30D critical minerals thresholds and FEOC exclusions prior to making claims for tax credits)

EXAMPLES OF BLOCKCHAIN FOR DUE DILIGENCE

The following organizations and initiatives have begun to recognize the role of blockchain to facilitate compliance with relevant regulatory and other requirements:

Frameworks recognizing blockchain's role

United Nations Conference on Trade and Development (UNCTAD): Released Global Report on Blockchain and its Implications on Trade Facilitation Performance, which provides a policy and technical framework, considerations, and recommendations for blockchain deployment in global trade. Blockchain can help advance proposals for UNCTAD blockchain and trade facilitation initiatives, among others.

Responsible Minerals Initiative (RMI): Released RMI Blockchain Guidelines as a voluntary framework to standardize the application of blockchain in critical minerals supply chains, focusing on common principles to improve due diligence and promote interoperability.

Commercial Trust™ Protocol (CTP)[15]: Developed by The Provenance Chain™ Network, facilitating verifiable blockchain-based digital credentials and management of intellectual property. CTP provides a standard framework to verify the claims made of people, parties, places, products, and processes across supply chains. It goes beyond classical web2 and web3 solutions by functioning as an abstraction layer of proprietary and web3 technologies to facilitate component-level data property rights, evaluations, and selective disclosure of requirements, incentives, claims, and evidence (RICE™) in commercial transactions. The CTP captures an immutable record of: production; orders; shipments; settlements; requests; and the results of evaluations of evidence needed to verify claims, without centralizing or disclosing sensitive data, intellectual property, or trade secrets. Companies can be transparent and run their business without giving away sensitive data or trade secrets.

Selected initiatives adopting blockchain

Lobito Corridor: Blockchain technology is enhancing transparency, security, and efficiency for this trade route, consisting in a railway and infrastructure project to transport critical minerals including cobalt and copper from the Democratic Republic of Congo (DRC) and Zambia to the port of Lobito in the Angolan Atlantic. This corridor is strategic for Western nations seeking to diversify their sourcing of critical minerals, and blockchain technology is being used to address critical challenges from complex logistics to illicit trade and corruption. [clarify stage of blockchain implementation or evaluation]

MineHub[16]: Digital trade platform providing open, enterprise-grade solutions for end to end traceability in mining and metals to ensure resilience and responsibility in supply chains. Provides a digitally integrated workflow that connects a vast network of partners and stakeholders and their transactions, as an alternative to paper-based and manual processes. Integrates blockchain technology to track minerals like gold and copper from mine to end user. MineHub recorded the first blockchain-based iron ore trade in 2020.

Auto Makers: Major companies (BMW, Ford, Hyundai/Kia, Mercedes-benz, Tesla, Volvo) are using blockchain technology to trace minerals like cobalt and mica. Industry consortium Responsible Sourcing Blockchain Network (RSBN)[17] was founded in 2019 by Ford, Volkswagen, and Volvo alongside mining and technology companies, with the purpose to track and verify ethical mineral sourcing form mine to market. Blockchain technology is being used to promote environmental and human rights standards, and ensure global traceability for customers.

Jewelry: Blockchain implementations focus on ethical sourcing and authenticity for tracking of diamonds and rare earth minerals. This increases trust with certifications of traceability from mine to consumer, with immutable records of ownership and origin, to address concerns of counterfeiting and illicit practices across the supply chain. Jewelry can be tokenized on a blockchain, provided with a unique identity.

Battery materials: "Battery passport" solutions can track key materials going into electric vehicle batteries, which not only confirm ethical sourcing and prevent counterfeits, but also simplify compliance through real-time audit trails that facilitate adherence to requirements for battery safety, environmental impact, and end of life management. These verifications about battery materials and history also optimize recycling processes, allowing recyclers to recover valuable materials more effectively.

Blockchain Platforms

Circulor, IBM Blockchain Platform (in partnership with MineHub), Minexx, and Re|Source are examples of blockchain solutions and consortia being implemented to track critical minerals from mines to end users.

MAPPING OF GUIDELINE MAIN THEMES AND BENEFITS OF BLOCKCHAIN

Guideline Topic		
Supply Chain Transparency & Traceability		Blockchain Benefits
Objective	Provide visibility on where and how minerals are sourced and processed, as requested by governments and investors	Provides a tamper-proof ledger recording every transaction or movement of critical minerals across the supply chain: • Tracks provenance from mine to market by logging each step (e.g., mining, smelting, refining, shipping, final use). While blockchain is a safe home for provenance data, in itself, it doesn't provide provenance. • Immutable records reduce risk of fraud or misinformation because data can't be altered once entered and validated • Chain of custody provides a clear and secure record of who handled a given critical mineral at each step.
Themes	Blockchain or digital tracking tools Reporting on origin, transit routes, and processing facilities Public disclosures and ESG reporting	
Examples	EU Battery Passport (for lithium, cobalt, etc.) SEC and EU non-financial reporting directives	A company can reference blockchain entries to confirm that a battery's cobalt came from a certified, conflict-free mine in the Democratic Republic of Congo
Ethical & Responsible Sourcing		Blockchain Benefits
Objective	Prevent human rights abuses, child labor, and financing conflict zones	Supports due diligence and human rights compliance by enabling: • Verification of certifications (e.g., child-labor-free, conflict-free) • Community reporting mechanisms (e.g., recording community consent like FPIC) • Audit trails for compliance checks
Themes	Traceability and chain of custody systems Third-party audits Certification schemes (e.g., IRMA, RMI) Community consent and engagement (e.g., FPIC – Free, Prior and Informed Consent)	
Examples	U.S. Dodd-Frank Section 1502 (for conflict minerals) EU Conflict Minerals Regulation	Blockchain integration with OECD Due Diligence Guidance enables all parties to verify sourcing claims and ethical practices.

Guideline Topic		
Sourcing Security & Resilience		Blockchain Benefits
Objective	Ensure supply continuity, reducing dependency on a single source or country	Increases visibility and coordination across the supply chain: • Detect bottlenecks or delays early • Map risks and vulnerabilities in real time • Manage inventory or contracts transparently (e.g., smart contracts)
Themes	Diversification of supply sources (geographic and commercial) Strategic stockpiling Onshoring or nearshoring parts of the supply chain Redundancy and flexibility in logistics and production	
Examples	U.S. Critical Minerals Strategy (DOE, DOI, DOD) EU Critical Raw Materials Act Japan's METI mineral sourcing policies	A battery manufacturer can quickly identify supply chain disruptions from a specific smelter and switch suppliers accordingly.
Sustainability & Environmental Standards		Blockchain Benefits
Objective	Minimize environmental damage from extraction, processing, and transport	Allows stakeholders to audit environmental impact in real time with a verifiable data trails, linking to IoT devices, satellites, or other entries that track data on: • Emissions • Water/energy usage • Waste management or reclamation
Themes	Environmental Impact Assessments (EIA) Lifecycle analysis (LCA) for carbon footprint Water/energy usage regulations Requirements for mine reclamation and closure	
Examples	International Council on Mining and Metals (ICMM) Principles OECD Due Diligence Guidance for Responsible Supply Chains	Data on energy usage captured on IoT devices can be recorded on a blockchain and made available to stakeholders who make assessments and perform audits
Downstream Integration & Recycling (Circular Economy)		Blockchain Benefits
Objective	Support for domestic refining, processing, and recycling to reduce dependence on raw material imports	Provides a log of the entire lifecycle of a mineral, from extraction to end-of-life, which helps identify when and where materials can be recovered, reused, or recycled. • Enables secondary market tracking of materials • Supports tracking and reporting of circular economy targets • Verification of shared value/corporate responsibility claims of supporting local communities and smallholder recyclers
Themes	• Tax incentives and subsidies • Support for R&D in alternative materials and recycling • Circular economy strategies	
Examples	EU Circular Economy Action Plan Japan's Circular Economy Roadmap US Inflation Reduction Act	Track recycled lithium from one EV battery going back into a new one

Guideline Topic		
Cross-Border Regulatory Compliance		Blockchain Benefits
Objective	Comply with rules from various jurisdictions	Facilitates cross-border compliance easier by creating standardized digital records that governments and trading partners can access.Consistent, verified data across jurisdictions.
Themes	• Critical minerals supply chains are complex and span multiple jurisdictions • Requirements across jurisdictions and activities can vary widely • Doing business with certain jurisdictions makes stakeholders subject to their rules (e.g., EU requirements may apply to EU stakeholders and all those doing business with them) • Trade agreements between multiple countries require compliance with requirements from all jurisdictions involved	
Examples	• Bilateral and multilateral agreements (e.g., U.S.-Australia Critical Minerals Partnership, Minerals Security Partnership) • Trade classifications, tariffs, and export controls (e.g., China's rare earth export policies) • WTO rules and bilateral free trade agreements with critical minerals chapters	Alignment with multiple relevant regulatory requirements, such as compliance with both the EU Battery Passport, US-Mexico-Canada Trade Agreement
International Collaboration & Trade Policy		Blockchain Benefits
Objective	Adherence to trade agreements and conditions set by governments on following trade policy	Accountability & monitoring of international agreements and protocols among governments • Connects company level records with requirements for trade policy and international agreements • Connects all interested parties across corridors (e.g., corporates, suppliers, governments, civil society) with consistent and verified data • Combats illicit trade, corruption, and fraud
Themes	Bilateral and multilateral agreements Trade classifications, tariffs, and export controls WTO rules and bilateral free trade agreements with critical minerals chapters Navigating tariff or non-tariff trade barriers	
Examples	Digital Corridors Agenda Agendas and forums through G20, WECD, and development banks U.S.-Australia Critical Minerals Partnership Minerals Security Partnership China's rare earth export policies	Blockchain infrastructure deployment across the Lobito Corridor, connecting critical minerals from the DRC and Zambia to the Angolan port of Lobito

Guideline Topic		
International Collaboration & Trade Policy		Blockchain Benefits
Objective	Adherence to requirements companies must follow to source critical minerals from any particular place	Facilitates compliance with corporate due diligence, including regulatory requirements - Creates standardized digital records - Governments and trading partners can access consistent, verified data across jurisdictions.
Themes	Corporate due diligence requirements Regulatory compliance Reporting on labor and environmental practices Providing data to ensure customers of responsible supply chain practices	
Examples	Global Battery Alliance EU Battery Passport US-Mexico-Canada Trade Agreement (USMCA)	Auto makers have begun using blockchain technology to trace cobalt from mine to electric vehicle

STAKEHOLDER PRIORITIES FOR STRONGER GOVERNANCE

The toolbox and methodology proposed above can connect the entire landscape of stakeholders with shared data and knowledge, with the prospect of a better governance model toward supply chain resilience. Any successful framework toward a just transition in critical minerals supply chain governance must involve all stakeholders: from the public sector, civil society, and the private sector – from large companies to small companies and artisanal miners, and the substantial informal economy in many developing countries. Although some players may not be willing to or incentivized to provide transparent data, in cases of concealing sub-par practices, a broader governance system with stronger visibility would make it more difficult to maintain opaque operations.

Despite their various needs and incentives, all stakeholders benefit from greater visibility and validation on data and claims. Once a full blockchain-based chain of custody is achieved, all other concerns and externalities can be better understood and addressed. For instance, if refinery capacity is outsourced to a jurisdiction with lax regulatory requirements, a better system to measure impact (e.g., satellite-based data oracles on water usage, emissions, and forced labor conditions) can shed light on concerning data and justify relocating business to another region. The value of blockchain therefore points to the capacity to strengthen the governance process.

STAKEHOLDER LANDSCAPE: NEEDS, DUE DILIGENCE GAPS, BLOCKCHAIN OPPORTUNITIES

While due diligence gaps risk stakeholder needs remaining unmet, blockchain directly addresses gaps in traceability, transparency, and trust across all stakeholders. In general, upstream tiers of the supply chain (mining, refining) face higher gaps with traceability and ESG verifications. Midstream tiers of the supply chain (manufacturing, OEMs) face gaps around multi-tier visibility and reliance on supplier self-reporting that may not be verified by a third party. Downstream tiers of the supply chain (end users, investors, governments, NGOs) face gaps around data harmonization and monitoring, alongside technical needs to ensure quality of products.

While blockchain doesn't directly solve physical risks (e.g., water pollution, unsafe mining), the visibility it provides enables verifiable accountability, facilitating enforcement and creating incentives toward greater compliance, which eventually should lead to increased investment and opportunity.

Below is a landscape of key stakeholders, specifying their roles, needs, due diligence gaps, and blockchain based tools to address those gaps. (Note: Main stakeholders are marked in navy blue cells, and the information along those rows applies to all stakeholders of their kind. Some stakeholders have sub-categories, listed below them in white cells. Some of those sub-categories may have particular roles, needs, due diligence gaps, and blockchain benefits, filling their respective rows)

MAPPING OF STAKEHOLDER NEEDS

Stakeholder	Role	Needs	Due Diligence Gaps/Risks	How Blockchain Helps
Companies	Companies play the key roles of extraction, manufacturing, and transportation. All companies along the value chain are expected to be regulated. Actors directly involved in the extraction, transformation, and commercialization of critical minerals across the value chain.	Ethical supply chain proofs, especially ensuring provenance and correctly sourcing Regulatory compliance Optimization to improve profit margins: Cost efficient & resource efficient supply chains, alongside methodologies to build and scale their solutions	Multiple requirements across multiple supply chain stages make end to end traceability difficult	End to end chain of custody
Extraction: Exploration & Mining	Search for and extract ores and minerals from deposits	Access to capital and financing Access to skilled labor, especially in remote areas Access to equipment and infrastructure Secure long term mining rights and permits Regulatory clarity and compliance with regulations (e.g., permits, land access, ESG requirements) Local community acceptance to avoid social conflicts Stable price and demand Long-term offtake agreements to de-risk operations and secure cash flow Basic services (e.g., energy, accommodations, water, digital infrastructure/connectivity, tools)	Limited 3rd party verifications on ESG and safety claims Limited community consultation records Limited subcontractor tracking (e.g., small scale and artisanal miners) Challenges proving compliance with requirements, especially (e.g., anti-corruption, royalty payments, regulations)	Smart contracts and tamper proof records for permits, licenses, royalties paid, reducing corruption Digital identities for subcontractors ensure traceability for artisanal mining and smallholder operations Transparent reporting of compliance with ESG requirements and other requirements, for regulators and investors Trusted impact disclosures help build trust with local communities

Stakeholder	Role	Needs	Due Diligence Gaps/Risks	How Blockchain Helps
Artisanal Miners & SMEs	Small scale mining operations	Access to markets, financing, training, and safety equipment (difficult in informal sector) Access to mineral deposits Reliable sources of water, energy, and inputs to perform job Demand for labor Avenues to facilitate formalization Alternative and supplementary livelihood options Basic services (e.g., energy, accommodations, water, digital infrastructure/connectivity, tools)	May not be legally registered, and as such not subject to legal requirements but may regardless need to provide assurances to downstream partners. While artisanal/SME miners may be formally subject to fewer regulations, they will nonetheless face requirements of downstream buyers. These may not be in the form of hard requirements, but due diligence requirements filter down to them	Digital identities can record essential data for reporting and quantify their economic activities
Processing & Refining	Convert raw ores into usable materials, including intermediate stage products, which they sell (passing along validation of upstream supply chain)	Stable and diversified feedstock supply Advanced technologies for processing (e.g., separation, purification, and value addition) to increase yields and reduce waste Regulatory clarity and compliance (e.g., emissions controls, waste management, water usage, chemical usage) Certifications to ensure responsible sourcing and compliance Affordable inputs Energy security Proximity to downstream customers Data from observers and contributors to support compliance Financing	Limited visibility on origin of ores (e.g., mixing legal & illegal supply) Limited and inconsistent reporting on regulatory requirements, ESG and waste management Unclear methodologies for ESG compliance Data silos across miners, refiners, regulators, etc.	Tokenization of ore batches allows end to end traceability from mine to refinery Shared ledgers facilitate standardized disclosures on compliance with requirements, including ESG and waste management Shared and interoperable blockchain records can integrate miners, refiners, and regulators
Manufacturers & Original Equipment Manufacturers (OEMs)	Manufacture materials into parts, components and finished goods (e.g., EV makers, battery producers, electronics producers)	Price stability and predictability to manage supply chain costs Long-term contracts with suppliers Reliable and diversified sources of processed minerals (e.g., high purity materials for magnets, semiconductors, batteries, etc.) Certifications to ensure compliance with standards, sustainability practices, and regulatory requirements (e.g., traceability from mine to factory where electric batteries are manufactured, no conflict minerals, adequate due diligence) Data from observers and contributors to support compliance Substitution R&D research to reduce reliance on scarce minerals	Challenges verifying traceability, human rights standards, and environmental requirements across various tiers of suppliers Rely on supplier verifications, which often self-report and may be unaudited Unclear methodologies for ESG compliance within procurement processes	End to end traceability from mine to refinery, from mine to processing to final product Smart contracts to ensure suppliers are compliant with ESG and other requirements Blockchain records can integrate into procurement processes, product passports, and certifications
End Users & Industries	Sectors that rely on critical minerals in final products. Utilize final products made from critical minerals (e.g., energy, defense, automotive, electronics, aerospace)	Reliability of critical minerals supply to prevent bottlenecks in production Custom material specifications Long-term contracts and supplier diversification Recycling and circular economy strategies (e.g., policy incentives for alternative materials, recycling, etc.) Access to innovation (e.g., batteries requiring less scarce minerals)	Limited visibility on supply chain dependencies and concentration (e.g., reliance on a single country for resources) Limited risk management for geopolitical disruptions Limited collaboration across industries for shared due diligence standards International regulatory requirements are not harmonized	Real time blockchain data provides insights for risk modeling (e.g., supply chain dashboards) Shared ledgers with privacy tools allow coopetition - collaboration without exposing trade secrets Blockchain-based certifications can help align global standards

Stakeholder	Role	Needs	Due Diligence Gaps/Risks	How Blockchain Helps
Recyclers & Circular Economy Players	Recover minerals from used products (e.g., batteries, electronics) and deliver them for production into new products	Efficient collection systems at products' end of life Regulations to encourage recycling and reuse Innovation for cost effective recovery Access to markets for recycled materials (e.g., OEM acceptance) Validation of quality materials recovered	Limited chain of custody verifications for recycling Lack of certifications and standards on recycled materials Limited collection systems make it difficult to prove responsible sourcing for secondary materials Lack of harmonized reporting frameworks on recovery efficiency	Tokenization of recycled materials improves chain of custody verifiability Blockchain based certifications of recycled content can be approved by OEMs for processing Incentive mechanisms using tokenization and credits can encourage collection and recovery behaviors
Logistics & Distribution Entities	Actors enabling the physical and commercial movement of minerals across borders and between supply chain stages. Ensure physical movement of goods across the stages of the supply chain and across country borders	Assurances of supply chain transparency and compliance with relevant requirements (e.g., documentation, certifications) for goods to be accepted at the next stage of supply chain processing or consumption) Adequate infrastructure	Limited visibility across tiers of the supply chain Limited verifications to support claims and documentation provided	End to end traceability and verifications of compliance
Transportation Providers	Move raw materials, intermediates, and finished products across supply chain stages and borders. Physically move goods to next level of processing across supply chain stages, often mobilizing products across borders	Adequate physical infrastructure (e.g., roads, ports, railways) Collaboration with importers/exporters/ customs authorities when transporting over a border Transportation Documentation to clear customs at borders: Freight documentation (e.g., ProForma Invoice, Commercial Invoice, Packing List, Certificate of Origin, Insurance Certificate, Export License, Import License, Bill of Lading, Dangerous Goods Documents, Safety Data Sheets); additional documents including Letters of Credit, Bank Drafts; Jurisdiction specific requirements (e.g., local labor law compliance, inspection certificates and results, signature stamps)	(same as above)	(same as above)
Importers	Bring raw or processed materials into domestic markets for further processing or final consumption. Import materials and products for further processing domestically, or final products for consumption and use	Reliable supply of raw or unfinished materials, or final products Collaboration with brokers and transportation providers Compliance with multiple standards and requirements for trade and trade financing Transportation Documentation: Freight documentation (e.g., ProForma Invoice, Commercial Invoice, Packing List, Certificate of Origin, Insurance Certificate, Export License, Import License, Bill of Lading, Dangerous Goods Documents, Safety Data Sheets); additional documents including Letters of Credit, Bank Drafts; Jurisdiction specific requirements (e.g., local labor law compliance, inspection certificates and results, signature stamps)	(same as above)	(same as above)

Stakeholder	Role	Needs	Due Diligence Gaps/Risks	How Blockchain Helps
Exporters	Ship raw, refined, or finished products to international markets. Export materials and finished goods to markets abroad	Reliable markets with buyers to purchase goods provided Collaboration with brokers and transportation providers Compliance with multiple standards and requirements for trade and trade financing Transportation Documentation: Freight documentation (e.g., ProForma Invoice, Commercial Invoice, Packing List, Certificate of Origin, Insurance Certificate, Export License, Import License, Bill of Lading, Dangerous Goods Documents, Safety Data Sheets); additional documents including Letters of Credit, Bank Drafts; Jurisdiction specific requirements (e.g., local labor law compliance, inspection certificates and results, signature stamps)	(same as above)	(same as above)
Brokers	Intermediaries connecting buyers and sellers, aggregating volumes, and sometimes handling customs, duties, or VAT. Liason between exporters, importers, and manufacturers, often acting as sourcing agents, distributors, and aggregators that can facilitate volume discounts, and may at times pay duties/ VAT fees	Reliable sources of supply and markets with demand Quality assurances and certifications Supply chain visibility for accountability on sourcing of products they sell (e.g., for duty drawbacks) Transportation Documentation: Freight documentation (e.g., ProForma Invoice, Commercial Invoice, Packing List, Certificate of Origin, Insurance Certificate, Export License, Import License, Bill of Lading, Dangerous Goods Documents, Safety Data Sheets); additional documents including Letters of Credit, Bank Drafts; Jurisdiction specific requirements (e.g., local labor law compliance, inspection certificates and results, signature stamps)	(same as above)	(same as above)

Stakeholder	Role	Needs	Due Diligence Gaps/Risks	How Blockchain Helps
Governments & Regulators (public authorities)	Entities shaping the policy, legal, and trade environment for critical minerals. National governments define and enforce regulatory requirements, trade controls, and policy (e.g., managing tariffs, export controls, and strategic alliances). Governments act on behalf of citizens, negotiating critical minerals agreements with other nations and companies globally. Governments levy taxes or other fees (e.g., portion of sales) in exchange for making land available for extraction and production. For some countries, this is a significant portion of government revenue. Regulatory Agencies monitor industry practices, transparency, and environmental/social standards.	Strategic stockpiles and alternative sources of critical minerals to ensure diversification of supply Investment in domestic production and recycling to support domestic markets Mechanisms to reduce dependence on suppliers from geopolitically sensitive jurisdictions Investment incentives to attract domestic exploration and processing Assurances that national security and energy transition goals are being met Assurances of environmental and labor standards compliance Assurances on provenance and governance, especially regarding ethical sourcing System of monitoring and reporting (e.g., regarding commitments made, permits delivered, etc.) Mineral royalties	Inconsistent regulatory frameworks between jurisdictions Lack of real time monitoring of movement of minerals (including imports & exports) Limited enforcement capabilities for labor, environmental, and anti-corruption requirements especially in mining regions Limited capabilities to audit complex and global supply chains	Real time tracking of imports and exports for customs Immutable records facilitate compliance and enforcement Shared data ledgers facilitate cross-border cooperation and standardization of requirements
Port and Customs authorities	Oversee product flows at borders, ensuring compliance with trade and security rules. Validate products passing through borders and key checkpoints	Proof of certifications and validation (e.g., certificates of origin and provenance, compliance checklists) Data on latest requirements to be verified	(same as above)	(same as above)
Investors & Financial Institutions	Organizations providing capital and risk management for supply chain actors. These include financial institutions, private investors, and development banks. They finance large projects to explore and extract minerals, and also companies throughout processing and other steps of the supply chain.	Risk-adjusted returns, especially long-term project stability for large investments Verifications of project compliance with ESG metrics (e.g., emissions reporting to satisfy green finance requirements) and other disclosure requirements (depend on characteristics of the customer) Understanding of the supply chain involved in their investments Supply chain transparency to reduce any reputational risks Government incentives or guarantees to reduce geopolitical risks Policy stability and investment incentives Scalability and return on investment (ROI)	Multiple guidelines and lack of standardized metrics for supply chain risks, hindering due diligence for de-risking assurances Opacity across multiple stages of the supply chain Reliance on company self-reporting and limited verifications on claims (e.g., greenwashing risks) Limited ESG verifications from mining and processing Difficulty tracking geopolitical exposures in investment portfolios	Verified ESG and regulatory reporting directly from source Blockchain-based risk scoring models integrating geopolitical and supply chain data Auditable data trails reduce reliance on self-reporting

Stakeholder	Role	Needs	Due Diligence Gaps/Risks	How Blockchain Helps
Project Finance Entities & Development Banks	Finance large-scale extraction and infrastructure projects, often through syndicated loans. Focus on large and complex investments, often involving negotiations among various financiers for syndicated loans, etc.	Project de-risking and transparency Clear ESG (Environmental, Social, Governance) metrics	(same as above)	(same as above)
Trade Finance Entities	Facilitate global transactions with risk mitigation tools for importers and exporters. Provide financial solutions and risk mitigation services to importers and exporters, to facilitate trade	Understanding of the supply chain involved in their investments, to prevent goods from being seized by customs Derisking measures Assurances on disclosure requirements (depends on characteristics of the investment)	(same as above)	(same as above)
Insurance Companies	Manage operational and political risk exposure in exchange for premiums.De-risking projects by assuming financial risk of projects in exchange for regular payments	Accurate data and understanding of the supply chain, to price the risk accurately	(same as above)	(same as above)
Indigenous Groups & Local Communities	Stewards of ancestral lands and potential partners in agreements toward equitable development (as opposed to companies, especially foreign, extracting and depleting their lands for their own profit maximization at their expense). Rightsholders and land stewards directly impacted by mining and processing activities. Indigenous Groups are custodians of ancestral territories; potential partners in equitable development agreements. Local Communities are populations affected by extraction and production, whose livelihoods and environments must be considered.	Fair compensation and benefit-sharing from mining projects Protections of the environment (e.g., land, water) and cultural heritage Employment, capacity building, and local development opportunities. Transparency and participation in decision making, including free, prior, and informed consent (FPIC) Health protections (e.g., in cases of risks of heightened pollution)	Difficulty accessing transparent data on mining impacts (water use, emissions). Weak mechanisms to verify claims, benefit-sharing agreements, and payments. Limited legal or technical capacity to challenge violations. Lack of participation in formal due diligence frameworks.	Blockchain-based records provide verified data on compliance and environmental and social metrics Smart contracts can automate direct benefit sharing payments

Stakeholder	Role	Needs	Due Diligence Gaps/Risks	How Blockchain Helps
Civil Society & NGOs/ International Organizations	Advocate for community rights, social and environmental justice, and facilitate engagement with governments and companies regarding accountable resource management and development. and development. NGOs & Advocacy Groups promote social, environmental, and governance standards. International Organizations foster multilateral cooperation on resource governance.	Monitoring and accountability frameworks Verifications of enforcement regarding human rights, labor, and environmental standards Transparency in sourcing (e.g., avoidance of conflict minerals) Global cooperation to ensure fair access to markets and economic opportunity for all	Difficult to verify authenticity of claims Limited access to reliable, verifiable supply chain data Lack of global harmonization of certifications Limited resources for monitoring on the ground, and connecting local impacts with global corporate accountability	Automated and verifiable reporting reduces monitoring burden and adds clarity on compliance with requirements and best practices Blockchain records on supply chain data, compliance, and certifications Standardized digital certifications (e.g., conflict-free minerals, fair trade practices, carbon footprint)
Academia & Research Entities	Generate knowledge, innovation, and technical expertise for industry and policy. Expertise and investigations on research on key themes and solutions for the industry use	Funding for innovation in extraction, processing, and recycling Data access and industry collaboration Policy engagement Skills development programs	(same as above)	(same as above)
Workers	Provide basic labor, including miners. This includes the labor force powering the sector, from mine sites to manufacturing plants. Miners provide extraction and on-site labor. Industrial Workers provide operatives in processing, refining, and manufacturing stages.	Considerations: risks they take; health problems faced; wages they may/may not receive	May not know their rights or how to enforce them	Digital identities to better access essential services and make informed decisions Smart contracts to automate direct payments
Other (Data, Standards & Assurance Bodies)	Actors ensuring transparency, accountability, and quality across the supply chain. This includes data providers that are key for decision making.	Assurances of data accuracy	Limited assurances on accuracy of data	Verified data on immutable records, directly from source

Stakeholder	Role	Needs	Due Diligence Gaps/Risks	How Blockchain Helps
Observers	Independent organizations (e.g., trade associations, watchdogs, government observers) that provide risk, compliance, and sustainability data. They provide objective data to help manage risks, without taking part in transactions as direct stakeholders (e.g., lack of compliance with standards/ requirements, geopolitical concentration, volatility). Focus on transparency, accountability, and long term sustainability of critical minerals supply chains.	Accurate data from supply chain stakeholders, used to make decisions Assurances of data accuracy across the supply chain Assurances that data is not tampered with across mine, to OEMs & manufacturers, to consumers, to recyclers, to new production cycles	(same as above)	(same as above)
Contributors	Key stakeholders involved in physical and commercial flows of critical minerals, with a more involved role than observers. Provide data to help make decisions, driving drive production and processing to support critical minerals' use in high tech applications (e.g., scores for raw materials for use in specific industries).). Entities directly shaping standards and practices (e.g., testing labs, certification bodies, standards setters).	Accurate data from supply chain stakeholders, used to make decisions Assurances of data accuracy across the supply chain Assurances that data is not tampered with across mine, to OEMs & manufacturers, to consumers, to recyclers, to new production cycles	(same as above)	(same as above)
Auditors	Independent third parties verifying compliance with regulations and sustainability frameworks.	Accurate data and requirements for verifications	Data silos and lack of accurate data along entire supply chain	Verified data on immutable records, directly from source

COOPETITION IS THE NAME OF THE GAME

Blockchain technology can be a source of competitiveness for all stakeholders, while better promoting peace and prosperity, especially for an industry that is inherently global. While critical minerals supply chains are deeply embedded into the interests of multiple nations, with various players and competing agendas that have historically resulted in multiple conflicts, technological solutions that improve visibility can lead to win-win situations among stakeholders toward a better governance framework that benefits all.

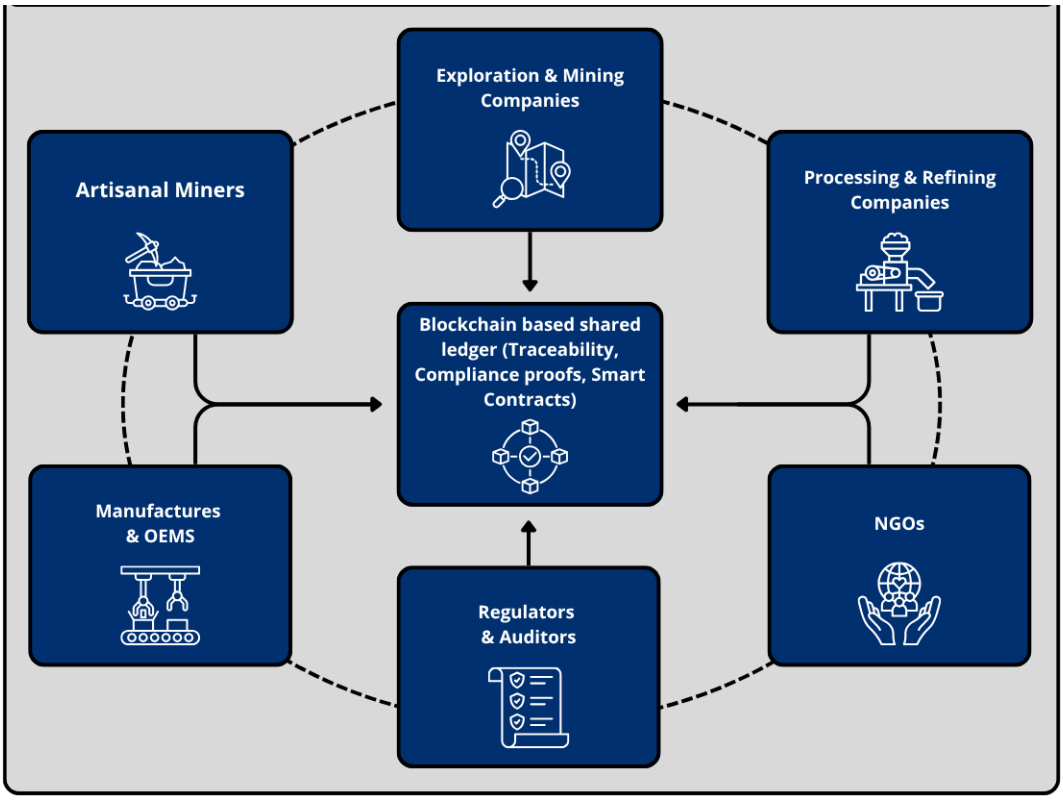
By facilitating compliance with requirements and strengthening due diligence, blockchain technology can be a tool to support alignment of interests, with numerous resulting benefits that broaden economic opportunities for all, including:

- **Minimizing data silos to better address any supply chain vulnerabilities**
- **Better coordination to attract investment and direct financial aid more effectively**
- **Optimized technical support**
- **Technology transfer to support the needs of low-income nations**
- **Enhanced international cooperation to harmonize standards and requirements**
- **More effective risk mitigation initiatives**

For instance, mining entities derive the greatest value from blockchain-based traceability, auditability, and smart contracts. Recycling entities would greatly benefit from incentives toward collection and recovery. Governments, investors, and NGOs can lean on standardization, auditability, and transparent records.

"Coopetition," a concept of cooperative competition, is particularly promising for critical minerals supply chains where both nations and companies compete for access to limited resources, as well as the rights to extract them upon meeting regulatory, environmental, and other ethical requirements. Blockchain facilitates coopetition by providing a neutral and trusted shared infrastructure that allows competitors to collaborate toward shared goals of compliance, traceability, and risk management, while still seeking competitive advantage based on other factors such as price, efficiency, and customer loyalty.

Innovation can lead to a turning point, as a source of competitiveness that can facilitate "co-opetition" dynamics for win-win outcomes for all stakeholders and local communities. In collaborating toward greater transparency and trust, trading partners can increase the market opportunity for all, in ways that favorably influence international relations.



PROPOSED AFRICAN PILOT: DIGITAL STRATEGY FOR MONITORING CRITICAL MINERAL VALUE CHAINS, MINING AGREEMENTS, PROTOCOLS AND LICENSES AND DIGITAL CORRIDORS

INTRODUCTION

Enhanced international collaboration is crucial for a sustainable global raw material governance, including technical support, financial aid and technology transfer to support the needs of low-income nations. There are a number of initiatives and platforms in the field of responsible mining management and responsible value chain management in DRC. The project intends to offer three added value to the several initiatives in place, as well as companies, development banks and private investors from China, Europe, USA, willing to *Improve responsible sourcing of raw materials and responsible business conduct initiatives with regard to raw materials* in DRC:

i. The project is designed to offer a meeting place to address responsible sourcing governance, responsible business, impact financing and “regional” development under the leadership of the DRC authorities.
ii. There are a number of regulations, standards, etc. in the mining sector. Without funding to implement them we will not progress. The project Is designed to develop a collaborative process between investors and donors to finance a responsible sourcing blockchain eco-system to improve the implementation of existing rules.

iii. This blockchain strategy should aim to have a strong market structuring power while China controls 80% of the cobalt production in DRC and the EU as well as the USA and Zambia have signed 'batteries protocols' with DRC while the EU is announcing a "*blockchain batteries passport*".

This project, based observations that *most due diligence framework fall far short of robust risk management*[19] and based *on the experience of existing responsible sourcing initiatives supported by the EU and USA*, intends to be the kind of pilot *needed to enable a level playing field for responsible sourcing of raw materials, Identify and address gaps in the raw materials supply chains due diligence in close cooperation with the* Digital Development Agency (ADN) within the Cabinet of the President of the Democratic Republic of COngo which supports this project and has identified 3 main challenges: (i) Management in the context of an ongoing armed conflict in Eastern DRC (ii) Multiple Legislations at national, regional and local levels in the DRC and at the EU level (iii) Financial resources. As demanded by ADN this project aims to:

- A cooperation agreement between countries of the Region leading to a regional standard
- Consistency between multiple legislative provisions by creating a place for joint review
- An intelligent border control system
- Sharing and pooling of IT infrastructures

Batteries will be the first product category to be legally required to comply with DPP, sometime in 2026. To be impactful, digital product passport technology needs to be based on open standards, be open source, permissionless and decentralized. This *project* will *build on the state of the art in sustainable raw materials traceability, transparency, accountability and decentralized collaboration organization. It will link with existing EU projects related to international* ***responsible sourcing, responsible business, digital tools*** *to contribute to strengthening responsible sourcing agenda from a geopolitical, technological, governance and financial standpoint*.

Promoting knowledge exchange among countries and regions plays a pivotal role in enhancing governance standards. To ensure effectiveness, measures and initiatives should be tailored to local conditions and aligned with national capacities and frameworks. Only a collaborative and coordinated approach can avoid redundancies among existing instruments and initiatives, and enable a cohesive response to the diverse challenges of resource management.

This proposed pilot aligns with current and upcoming African leadership of key global bodies including South Africa, hosting the G20, Angola and Burundi chairing the African Union in 2025 and 2026 respectively, and the Democratic Republic of Congo (DRC) sitting as member of the Security Council in 2026. This digital strategy could benefit from being highlighted both within the framework of processes under the aegis of both the African Union and the American Administration, as well as at the level of the United Nations and during the 7th Africa-Europe Summit.

The implementation of a strategic partnership between the Democratic Republic of Congo (DRC), Rwanda and the United States of America (USA) and its Companies (KOBOLD METALS) relating to critical minerals, is one of these agreements that should have a digital strategy.[20] A digital strategy is an essential element of governance in the age of the digital revolution in order to ensure African countries a decisive and fair place in the global chain of transition minerals (green economy, digital and energy transition). The developments towards peace between the DRC and Rwanda would expand opportunities underlying development of the Lobito Corridor (Angola, Zambia, DRC) as well as other critical minerals value chains across southern Africa.

The digital strategy, which we define as "*a driving force for strategic change and transformation of economic, financial, social and cultural models*", should have the following components:

1. **Integrated digital corridor for strategic and critical minerals:** development of an "*Integrated Development & Value*" approach intended to ensuring that maximum value remains in Africa for the economic growth and socio-cultural development of local populations.

2. **Creation of a digital ecosystem** for "*Monitoring, reporting, verification, accountability, trust*" intended to cover the expectations of States, Investors, Rating Agencies and Companies (having an exploitation or exploration permit or being involved downstream in the value chain) to ensure traceability, verification of commitments made (critical minerals passport, taxation system) and thus facilitate international trade.

3. **Creation of an international forum** on strategic and critical minerals (in line with the dynamics of the ongoing partnership discussed above): bring everyone around the table to have governance that leads to "stimulating excellence". This would also constitute a means of "balancing pressures" emanating from multiple actors, gathered in "hubs" each covering a specific ecosystem in view of the lessons learned from the OECD 2025 Forum on *Responsible Mineral Supply Chains* (5-7 May 2025). These would be the following hubs:

    iv. the African ecosystem, including government, civil socierty and business;
    v. the US ecosystem, including government, financial institutions, businesses including those involved in exploration & extraction as well as end-users, and civil society (NGOs, networks and foundations including the (GBBC);
    vi. the Chinese ecosystem, which includes, in addition to the Government, the Chamber of Commerce for Metals and Minerals (CCCMC), networks, and the 500 companies involved in an "Africa-China Alliance for the Protection of Human Rights";
    vii. the European ecosystem in all its diversity;
    viii. ecosystem of emerging actors: Saudi Arabia, Australia, Canada, United Arab Emirates, India, Qatar, Turkey, present or negotiating with the DRC and/or partner countries in the region (Zambia) for critical minerals.

This digital strategy prepared with the BC100+ and GBBC organizations would define a strategy to use technology to:

i. Establish a robust traceability framework that would build on the United Nations call for a "*Global Traceability System for Transition Minerals*," by jointly establishing a framework among trading partners, with technical support, to prevent social and environmental harms along supply chains;
ii. Cover the entire transition minerals value chain and its actors, including in importing countries, monitoring revenue distribution while eliminating illicit flows of resources and funds;
iii. Be integrated to provide transparency into fiscal operations to ensure that all minerals are accounted for and taxes are collected appropriately;
iv. Provide support for agreements with neighboring countries to facilitate cross-border traceability, especially for regionally processed minerals.

Blockchain for the UN Charter Values and the SDGs (BC100+), of which GBBC is a signatory, could collaborate together with the organizations responsible for digitalization issues in the African countries affected by the Lobito Corridor (Angola, Zambia, DRC) and provide expertise relevant to:

i. The implementation of blockchain technologies and artificial intelligence (AI) to support transition mineral value chains, the search for alternative investments, permits, industrialization in Africa, and digital trade;
ii. A digital strategy to support existing and complementary initiatives for regional peace, those of the United States, the African Union, and the United Nations;
iii. Building the confidence of investors and rating agencies;
iv. The USA-DRC-Rwanda Agreement,
v. The Africa-Europe Partnership and related protocols.

To ensure the relevance, consistency, and added value of this strategy, an **Observatory and Forum on digital related developments** could be established to provide all stakeholders with the necessary information and report on progress, which constitutes a confidence-building factor and a starting point for further progress.

We remain available to assist authorities and businesses in developing this digital strategy, identifying desirable ecosystem members and the digital infrastructure to be put in place to achieve the objectives, and, as an integrator, ensuring an integrated systems approach utilizing all the tools offered by the digital revolution, including AI.

CONCLUSION

In light of the complexity of critical minerals supply chains, this report offers a 'methodology' and a 'tool box' for global supply chains that can enable greater supply chain resilience through a stronger governance framework that is by definition trans frontier.

Accountability and trust processes are necessary for sustainable and ongoing projects across critical minerals supply chains. Stakeholders are expected to require increasing transparency assurances (e.g., requirements for purity of materials, assurances of no conflict minerals or forced labor), and compliance can be accelerated with the use of blockchain technology for the benefit of all.

Many of the recommendations below apply to today's particular geopolitical context: with a global tariff environment, global political ideological competition, and a regulatory environment that demands provenance, as indicated by increasing international agreements and protocols. Ensuring access to markets for goods produced with critical minerals requires taking measures to prevent shipments from getting blocked at a border or sent back due to lack of import/export requirements, or lawsuits around lack of compliance (e.g., tech companies being sued due to conflict minerals, trade related issues in rubber glove manufacturing).

By adopting the proposed approach, stakeholders across the critical minerals supply chain ecosystem can achieve unprecedented visibility without sacrificing security – turning trust from a vulnerability into a strategic asset, while ensuring the financial benefits of the value chain are realized locally.

RECOMMENDATIONS

1. A blockchain-based governance framework for critical minerals supply chains should:

- Initially focus on high-level themes to address (e.g., structure of the project and logic of the solutions), and at later stages focus on technical aspects
- build on the experience of existing responsible sourcing initiatives and international discussions (e.g., OECD program on critical minerals)
- Take steps to disrupt and dismantle any illegal infrastructure used by bad actors to distribute and operate unauthorized versions of data

2. Engage diverse blockchain players (from blockchain consortia, DAG-based IoT platforms, etc.) alongside critical minerals supply chain stakeholders to address supply chain challenges holistically

- Conduct initial assessments, including implementation of penetration & security testing tools to identify cyber-attacks and other supply chain vulnerabilities

3. Pursue agreements with key stakeholders toward a global blockchain strategy that is integrated with their common concerns and considers their various needs.

- Engage key stakeholders for a global strategy on responsible sourcing, where blockchain technology can be critical in developing a trusted ecosystem for global trade performance.
- Identify a designated entity to enforce conformance to a single framework/standard
- Unitize DLT Innovations: Recognizing hashgraphs, Directed Acyclic Graphs (DAGs), public ledgers, and permissioned blockchains as equally valid tools for supply chain resilience.
- Split Traceability & Provenance: Align solutions with specific use cases rather than forcing one-size-fits-all systems.

4. Define common global standards for transparency and security of data

- Education, training and awareness to address public perception is that blockchain makes sensitive data public, and instead focus on privacy preserving tools and best practices
- Define who should own and be entitled to access what data on shared ledgers, and what data should remain private vs. made public
- Define requirements around data property, drawing on lessons from other open data frameworks (e.g., open banking)
- Ensure interoperability and data sharing parameters across supply chains and across blockchains, drawing on lessons from internet and computer protocols
- Consider when and how it would be beneficial to classify data as property, to shift focus from data privacy to data property rights. Draw on W3CI verifiable credentials standards for selective disclosure.
- Prioritize Data Ownership: Ensure participants control what is shared, with whom, and under what terms.

ANNEX

ANNEX 1: TAXONOMY

- **CAHRA:** conflict-affected & high-risk areas
- **CoC:** chain-of-custody;
- **RMAP:** Responsible Minerals Assurance Process (RMI)
- **Upstream:** processes and network of suppliers and raw material providers that are located before a company's main manufacturing or production stage
- **Downstream:** activities that occur after a product is manufactured, which are focused on delivering it to the final consumer
- **Tiers:** Categorize suppliers based on their relationship to the final product, creating a hierarchical structure that moves from direct suppliers to raw material providers (e.g., Tier 1 suppliers are direct partners who provide goods or services to a company, Tier 2 suppliers are the companies that supply Tier 1 suppliers, and Tier 3 suppliers supply the Tier 2 suppliers, etc.)
- **Conflict Minerals:** mined in conflict-affected regions, whose sale provides funding for armed groups, human rights abuses, and violence

ANNEX 2: STANDARDS & FRAMEWORKS FOR CRITICAL MINERALS

GLOBAL FRAMEWORKS

- OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected High-Risk Areas – Due Diligence and guidance, with a 5-step framework for risk-based due diligence (strong management systems, identify and assess risk, strategy to respond to risks, due diligence audits, due diligence report), model policy, and suggested measures for risk mitigation. This provides a template that many laws and exchanges reference.

- UN Guiding Principles on Business & Human Rights (UNGPs) — Due diligence framework for human rights that many regulators and standards align with.

- IFC Performance Standards on Environmental and Social Sustainability — Project-level expectations to identify, avoid, and manage risks, frequently applied to mining and used by lenders. Based on 8 Performance Standards: risk management, labor, resource efficiency, community, land resettlement, biodiversity, indigenous people, cultural heritage.

- Extractive Industries Transparency Initiative (EITI) Standard (2023) — Global benchmark for transparency and accountability in the oil, gas, and mining sectors, often a country-level requirement. Provides a framework for disclosure and multi-stakeholder oversight for transparency in extractive industry practices (e.g.., revenues, contracts, beneficial ownership).

- Global Industry Standard on Tailings Management (GISTM) — Principles for tailings safety and disclosures, which key stakeholders including the International Council on Mining and Metals (ICMM) targets conformance with.

- United Nations Conference on Trade and Development (UNCTAD) Global Report on Blockchain and its Implications on Trade Facilitation Performance — Provides a policy and technical framework, considerations, and recommendations for blockchain deployment in global trade.

- UN Secretary-General's Panel on Critical Energy Transition Minerals — Intended to guide a just and sustainable transition for critical minerals, producing 7 Guiding Principles and a subsequent UN Guidance for Action emphasizing environmental and social standards, community benefits, and responsible governance across the lifecycle of critical minerals.

- International Labor Organization (ILO) Skills and Lifelong Learning Strategy and related initiatives – Focus on to creating equitable and resilient skills systems strengthening policies, governance, and financing with specific pillars.

MAJOR REGULATORY REQUIREMENTS

European Union

- Conflict Minerals Regulation 2017/821 — OECD-aligned due diligence for EU importers of tin, tantalum, tungsten, and gold (3TG).
- Battery Regulation 2023/1542 — Due diligence on raw materials (e.g., cobalt, lithium, nickel) used in batteries, in addition to traceability, data, and public reporting.
- Corporate Sustainability Reporting Directive (CSRD) — Requires large companies to disclose supply chain impacts under the European Sustainability Reporting Standards (ESRS), impacting mineral sourcing disclosures.
- Corporate Sustainability Due Diligence Directive (CSDDD) — Human-rights and environmental due diligence across value chains.
- Critical Raw Materials Act (CRMA) — Sets 2030 benchmarks for EU extraction, processing, recycling capacity, faster permits, and risk monitoring for listed "strategic/critical" materials.
- Carbon Border Adjustment Mechanism (CBAM) – trade policy tools to ensure competitiveness for domestic industries, with measures to prevent carbon leakage (moving carbon-intensive production outside of a jurisdiction with stricter climate policies). CBAM places a carbon cost on imported goods, based on their embedded greenhouse gas emissions. This largely applies to high-carbon industries (e.g., cement, steel, and fertilizers).
- EU Digital Product Passport (DPP) for Electric Batteries– Implementation of the EU Digital Product Passport (DPP) for Electric Batteries supports the collection and sharing of product-related data among supply chain actors, addressing information gaps for products and components and enabling circularity.

United States

- SEC Conflict Minerals Rule **(pursuant to Dodd-Frank - section 1502 and Code for Federal Regulations)** — Form and rule requiring annual disclosures of critical minerals originating from certain jurisdictions (in and around Democratic Republic of Congo) and due diligence measures on source and chain of custody.
- Uyghur Forced Labor Prevention Act (UFLPA) — Establishes rebuttable presumption of forced labor for goods mined, produced wholly or in part to the Xinjiang Uyghur Autonomous Region (XUAR) of China, or by an entity on the UFLPA Entity List, requiring intense scrutiny upstream inputs such as polysilicon.
- Inflation Reduction Act (IRA) and Treasury final rules/IRS regulations — Provisions under federal income tax credits for the purchase of qualifying new and previously-owned clean vehicles, requiring a tracing methodology. Guidance for Advanced Manufacturing Production Credit clarify that vehicles only qualify if critical minerals for batteries and components meet sourcing thresholds and do not originate from a Foreign Entity of Concern (FEOC). Department of Energy issued final Guidance on Definition of Foreign Entity of Concern in parallel.

Other Jurisdictions

- Fighting Against Forced Labour and Child Labour in Supply Chains Act (Canada) — Requires annual reporting on steps to prevent and mitigate forced labor and child labor in supply chains.
- UK Modern Slavery Act (UK) – Criminalizes slavery and human trafficking, requiring transparency statements on modern slavery risks in supply chains and responses.
- Modern Slavery Act (Australia) — Requires large Australian businesses to report on their measures to combat modern slavery in their operations and across their supply chains.

GLOBAL STANDARDS FOR MANAGEMENT & MEASUREMENT

- ISO 22095:2020 **(Chain of Custody — terminology & models)** — Defines a framework for accepted design, implementation, and management of chain of custody (e.g., segregation, mass-balance, etc.) in mining schemes.
- ISO 14001 (Environmental Management Systems (EMS) & 2024 Climate Action Amendment — Framework for organizations to design and implement site and corporate EMS, and continually improve their environmental performance, integrating readily with mining standards
- **ISO 14040/14044 Life Cycle Assessments (LCA)** — Framework to evaluating environmental impacts of a product or service throughout its lifecycle, with ISO 14040 defining the principles and ISO 14044 providing detailed requirements for each phase.

INDUSTRY INITIATIVES & FRAMEWORKS

- London Metal Exchange (LME) Responsible Sourcing — Metal brands listed for trading on LME must meet human rights and responsible sourcing standards, aligned with OECD Guidance. Non-conformance risks suspension.
- Responsible Minerals Initiative (RMI) – Responsible Minerals Assurance Process (RMAP) – Audit program for smelters and refiners across multiple minerals, aligned with OECD Guidance. RMI Blockchain Guidelines also establish a voluntary framework to standardize the application of blockchain in critical minerals supply chains, focusing on common principles to improve due diligence and promote interoperability.
- Initiative for Responsible Mining Assurance (IRMA) — Comprehensive site-level mining standard referencing ISO 22095, with chain of custody models (e.g., segregated, controlled blending, mass balance).
- Copper Mark — Site-level responsible production and chain of custody requirements for product claims, in addition to climate, circularity, and other supply-chain considerations. Also provides Nickel, Molybdenum, Zinc Marks for those respective mineral supply chains.
- Aluminum Stewardship Initiative (ASI) — Performance standard and chain of custody requirements for bauxite-to-aluminum supply chains.

GLOBAL SUMMITS & CONVENING INITIATIVES

- G20: Includes agenda to harness critical minerals for inclusive growth and sustainable development
- OECD Forum on responsible mineral supply chains: Addresses key topics related to responsible business conduct and due diligence of minerals through plenaries, partner sessions and deep-dives
- European Commission Raw Materials Week: High-level sessions, policy discussions, and networking opportunities focused on the sustainable and secure supply of raw materials in Europe.

- Global Batteries Alliance: convening actors across the value chain to align on sustainability performance expectations for batteries around principles of transparency, traceability, accountability and circularity.
- Just Transition: principles, processes, and practices that build economic and political power to shift from an extractive economy to a regenerative economy

ANNEX 2: CONSIDERATIONS FOR BLOCKCHAIN TOOL BOX

SECTION 1: SECTOR CRITICAL MINERALS SUPPLY CHAIN, TRADE PERFORMANCE AND COMPANIES' PRIORITIES AROUND ETHICS, SAFETY, ANTI-CORRUPTION, COMMUNITY SUPPORT, ENVIRONMENTAL PROTECTION, ANTI-DISCRIMINATION, AND INTEGRITY.

- The digital product passport and mineral exports in a cradle-to-grave value chain (see with EU), supply chain transparency and value chain traceability
- Intelligent Border System and cross border clearance
- Stakeholder coordination
- Payment processing and trade finance
- Trade risk management
- Trade reporting
- Sharing and pooling of IT infrastructures, training.
- Traceability platform for mining and raw materials tracking systems (e.g., active in DRC, Kenya or Rwanda)
- Responsible sourcing of cobalt through an OECD-compliant blockchain certification platform (e.g., as in DRC)
- Enhance the traceability of tantalum, (e.g., Rwanda)
- Tax transparency (e.g., Roadmap protocol EU/DRC)
- Tax revenues collected and redistributed
- Workers' safety
- Workers' revenues
- Child Labor

SECTION 2: STAKEHOLDER CO-DEVELOPMENT ACTIONS

Digital tools so that no one is left behind, in line with globally-identified targets.
The 'digital corridors' will not be limited to sectoral aspects, minerals in this case. They will cover all aspects of the lives of local populations that can be improved (access to finance, loans, education, health, trade, insurance, etc.) including consideration of stakeholder priorities such as:

- Diploma Certification (as in Ethiopia and Congo)
- Digital identity and payment solutions for the unbanked and underserved across Africa
- Certify Land Ownership in Agricultural and Forestry Areas
- Cryptocurrencies serving the poorest (e.g., Kenya, Niger, South Africa, and Uganda)
- Fintech apps fighting against financial exclusion (e.g., Cameroon)
- Micro-jobs (e.g., with the World Food Program)
- Micro-insurance (e.g., Kenya)
- Health aid through the diaspora (e.g., Cameroon)
- Enhanced transparency, security, and efficiency in African healthcare (e.g., Nigeria)
- Affordable home financing (e.g., Mozambique, Zambia and other African countries)

- Education (e.g., with UNICEF in Rwanda, Niger, and Kenya)
- Renewable Energy DRE solutions provider (e.g., Nigeria)
- Training in blockchain technologies

SECTION 3. ACTIONS THAT FALL UNDER THE SOLE JURISDICTION OF GOVERNMENT

- Digital identity (e.g., Kenya)
- Management of public funds (e.g., Burkina Faso and Ethiopia)
- Monitoring of judicial decisions and the protection of children

ANNEX 3: COMPARATIVE REVIEW | CTP ENHANCEMENTS ACROSS 12 MINERAL SUPPLY CHAIN STANDARDS

View the Comparative Review here.

ANNEX 4: EXCERPTS FROM THE WORLD RESOURCES FORUM ANNUAL REPORT 2023[21]

'Rethinking Value – Resources for Planetary Wellbeing' has focused on three key transitions with the potential to make resources a driver for shared wellbeing within planetary boundaries. Here is a snapshot of some of the main takeaways highlighted in the conference report.

GOVERNANCE OF RAW MATERIALS KEY TO ACHIEVING THE SDGS

There is a pressing need to institutionalise resource governance in the global agenda, while simultaneously redefining resource utilisation strategies. Raw materials governance needs to be better integrated with the Sustainable Development Goals, beyond a mere association with sustainable production and consumption patterns (SDG12). Institutionalising resource governance is crucial because it acknowledges the pivotal role of resource use in achieving sustainability across multiple facets of development, such as ending poverty, advancing health and wellbeing and protecting terrestrial and marine ecosystems.

NO ALTERNATIVE TO RESPONSIBLE SOURCING

The rapid growth of the critical raw materials market has given rise to environmental and social concerns related to their extraction. A comprehensive approach to responsible sourcing is required, one that is grounded in collaborative multi-stakeholder cooperation involving businesses, governments, financiers, workers, communities and civil society representatives. Monitoring and reporting mechanisms for responsible sourcing should be developed and implemented across global supply chains. Expectations for responsible extraction have moved ahead of legal compliance, requiring companies to demonstrate social performance beyond what is regulated. Shifting from risk management to value creation is essential for sustainable supply chains.

WE NEED TO HARNESS THE INFLUENCE OF THE FINANCIAL SECTOR

The finance sector has an important role in demanding best practices from companies across various industries, particularly in an environment where reporting standards are predominantly voluntary and diverse. Strengthening sustainability requirements for financing and enhancing the

availability of robust data for informed financial decision-making are critical.

Finance can also play a key role in enabling nature-positive funding, such as for the restoration of healthy natural ecosystems. Public and private finance should also be strategically leveraged to phase out environmentally damaging activities

A MORE EQUITABLE VALUE DISTRIBUTION IS NEEDED

Currently, the distribution of value created is highly unequal and concentrated at the top. This calls for strong democratic institutions that actively promote the engagement of local communities. Policy-makers should set in place policies and processes that empower individuals to assert their rights and partake in decision making, ensuring a more equitable distribution of value throughout society (p14)

ENABLE TRANSPARENCY THROUGH OPEN, TRUSTWORTHY AND DECENTRALISED DATA EXCHANGE

Digital product passports have a huge potential to enable businesses and consumers to access comprehensive information about a product's origins, materials, and lifecycle. Transparency promotes the circular economy by facilitating repurposing, remanufacturing and recycling, and encourages companies to design products with sustainability in mind from the outset. It also acts against green-washing attempts, as it proves that products are coming from sustainable sources and that the ESG criteria are met. To be impactful, digital product passport technology needs to be based on open standards, be open source, permissionless and decentralized

STRENGTHEN GLOBAL COLLABORATION ON RAW MATERIALS GOVERNANCE

Enhanced international collaboration is crucial for a sustainable global raw material governance, including technical support, financial aid and technology transfer to support the needs of low-income nations. Promoting knowledge exchange among countries and regions plays a pivotal role in enhancing governance standards. To ensure effectiveness, measures and initiatives should be tailored to local conditions and aligned with national capacities and frameworks. Only a collaborative and coordinated approach can avoid redundancies among existing instruments and initiatives, and enable a cohesive response to the diverse challenges of resource management

RESTORING CONFIDENCE IN THE MINING SECTOR THROUGH ACCOUNTABILITY AND TRANSPARENCY

The mining sector faces a notable crisis in trust and confidence, particularly among local communities, civil society organisations, and consumers. Given its pivotal role in enabling the trasition to clean energy, it is of paramount importance that the mining industry regains the trust of these key stakeholders. Accountability and transparency play a central role in rebuilding this trust. To achieve this, the mining sector must provide accessible and comprehensive data sharing and transparent information regarding its social, environmental and economic performance.

HARMONISING STANDARDS FOR RESPONSIBLE MINING

As mineral value chains are global in nature, varying standards can lead to inconsistencies and challenges in assessing environmental and social impacts. By harmonising these standards, we can create a unified and globally recognised set of guidelines that not only streamline compliance, but also enhance transparency, accountability and the overall sustainability of mining activities. The convergence of standards fosters a shared commitments to responsible mining practices, benefitting not only the environment but also the wellbeing of local communities and the industry as a whole (p19)

Materials-as-a-Service (MaaS) are new potential approaches to resource governance and business models for metal and mineral value chains. The model is based on the idea that resource rich countries/communities retain the ownership of metals and minerals mined on their territory and market. the materials as a service (i.e. leasing). This means instead of selling the materials themselves only the usufruct (the right to use these materials and gain a benefit from their use) would be sold along the value chain. The sale of the usufruct would be combined h the contractual obligation to guarantee the recoverability of materials at any point in time (p21)

Innovative Partnerships for Responsible Resource Use in Africa

In the context of a general decreasing trendline for Africa's natural capital, it should be re-minded that African land is critical to resilience and the urgent need for sustainable management to move from natural reliance to natural resilience. The move from 'natural resources' to 'natural capital' could cause a shift in the understanding of value and materiality.

- There is still an imbalance in the relationship between the African continent and the global north, with Africa bearing the ecological and social costs of high-income country's resource use. Systematic transitions could transform natural resources and capital into social wellbeing.

- Effective governance is the first step to overcome the challenges Africa is facing today with natural resources management. Among those challenges, are illicit financial flows, political instabilities, a lack of transparency and accountability, the absence of clear legal and policy frameworks for natural resources management, and also the asymmetry of power between global north and global south. A framework which integrates human rights and responsive business practices is needed to ensure both the protection of the environment and symmetric relationships.

The valuation of natural resources should not only be looked at from a global lens, but also from the perspective of local communities. Especially, innovative partnerships are important tools to empower local communities and ensure that they share in the benefits of resource use. Three critical levers need to be activated. First, we should look beyond the private and public sector to move toward integrated finance and thus make available new resources.

Second, an improved financial literacy to translate knowledge into action but also to foster synergies and cooperation between finance and other stakeholders of biodiversity cooperation. Third, local and national discussions along the ones at global scale are needed to enable a responsible use for Africa (p37)

ADDITIONAL RESOURCES

- https://www.congress.gov/crs-product/R47982
- https://www.wrforum.org/wp-content/uploads/2023/07/ECTR-2023.pdf
- https://www.oecd-events.org/responsible-mineral-supply-chain-2025/en; https://www.oecd.org/en/events/2025/05/oecd-forum-on-responsible-mineral-supply-chains.html
- https://www.sustainablemanufacturingexpo.com/en/articles/digital-traceability-metals.html
- https://www.africaeuropefoundation.org/areas-of-action/new-aef-scoping-paper:-revamping-africa-europe-cooperation-on-transition-minerals/
- https://drive.google.com/file/d/1xsN-_QnX48W9aAcccxy6YYXkXckeFzxw/view

- https://www.peerledger.com/ev-and-critical-minerals
- https://www.responsiblemineralsinitiative.org/news/rmi-releases-new-standard-suite/
- https://www.cobaltinstitute.org/global-cobalt/cobalt-value-chain/
- https://assets.ctfassets.net/so75yocayyva/1rFWV6NOCREBzPgWIyJ0GY/589d2e140aa9d64a70ab31e04637587a/As_of_May_14_-_Just_the_Facts_Supply_Chains.pdf
- https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/battery-2030-resilient-sustainable-and-circular
- https://www.globalbattery.org/media/publications/WEF_A_Vision_for_a_Sustainable_Battery_Value_Chain_in_2030_Report.pdf
- https://www.mckinsey.com/capabilities/operations/our-insights/supply-chain-risk-survey
- https://www.bbc.com/news/articles/cn8g540wz3jo
- https://www.koboldmetals.com
- https://positiveblockchain.io/africa-impact-web3-report

ENDNOTES

SUPPLY CHAINS & CRITICAL MINERALS

1 https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-supply-chain#/
2 https://www.ifrs.org/content/dam/ifrs/supporting-implementation/issb-standards/issb-materiality-education-material.pdf
3 https://www.congress.gov/crs-product/R47982#:~:text=Pursuant%20to%20the%20Energy%20Act,domestic%20resources%20and%20other%20research
4 https://www.wrforum.org/wp-content/uploads/2023/07/ECTR-2023.pdf p8
5 https://unctad.org/system/files/official-document/tcsdtlinf2023d1_en.pdf
6 https://documents1.worldbank.org/curated/en/719971468325781473/pdf/Trade-and-transport-corridor-management-toolkit.pdf
7 USD 50 billion invested
8 JICA
9 https://www.yahoo.com/news/articles/china-us-japan-race-control-093000426.html
10 https://apnews.com/article/congo-rwanda-drc-peace-deal-m23-trump-5e5b52100729ad6587a6f267c6c79ae0
11 https://www.break-down.org/post/on-this-day-opec#:~:text=OPEC%20sought%20to%20challenge%20this,number%20of%20Arab%20oil%20producers
12 WY Multi Trillion find on rare earth mineals; OR & NV Lithium deposits
13 J. Borrell
14 https://unctad.org/system/files/official-document/tcsdtlinf2023d1_en.pdf
15 https://www.c-star.io/commercial-trust-protocol#:~:text=The%20Commercial%20Trust™%20Protocol,throughout%20the%20global%20trade%20ecosystem.
16 https://minehub.com/minehub-ensures-timely-and-accurate-data-sharing-with-blockchain/#:~:text=MineHub%20has%20established%20a%20consortium,component%20to%20driving%20operational%20efficiency
17 https://www.prnewswire.com/news-releases/volvo-cars-joins-responsible-sourcing-blockchain-network-launched-by-ibm-ford-and-volkswagen-group-advancing-ethical-sourcing-of-minerals-continues-to-scale-with-this-network-300952585.html
18 https://www.mckinsey.com/capabilities/operations/our-insights/supply-chain-risk-survey
19 https://www.wrforum.org/wp-content/uploads/2023/07/ECTR-2023.pdf
20 Peace Agreement Between the Democratic Republic of the Congo and the Republic of Rwanda - United States Department of State
21 ; KoBold Metals and AVZ Agree on Framework for KoBold to Acquire AVZ's Interests in the Manono Lithium Deposit in DRC
22 https://www.wrforum.org/wp-content/uploads/2024/06/WRFA-Annual-Report-2023.pdf