STUDY

Requested by the DEVE committee

European Parliament

Traceability of critical raw materials, with a focus on Africa

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DIRECTORATE-GENERAL FOR EXTERNAL POLICIES
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STUDY

Traceability of critical raw materials with a focus on Africa – Technical and logistical considerations

ABSTRACT

The traceability of critical raw materials along the supply chain is pivotal in meeting wider public demands for corporate sustainability and complying with relevant regulations from the European Union that contain requirements for responsible sourcing and the transparency of supply chains. This paper serves as a technical and logistical primer on traceability mechanisms, focusing on upstream mining in Africa – the part of a mineral supply chain from extraction to transformation. It compares and classifies the industry's existing approaches to traceability based on the minerals targeted, implementation mechanisms, the use of technology and validity. Emphasis is placed on functional mechanisms, benefits and challenges. Particular attention is paid to comparing industrial methods with artisanal and small-scale mining (ASM) approaches. ASM, which forms a significant proportion of the market of specific critical raw materials, is the most exposed to abuse but has high rates of livelihood dependence and developmental potential. This paper makes recommendations on: the complementarity, interoperability and integration of initiatives; the role of state and non-state actors for compliance and enforcement; and the potential for including ASM.

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List of abbreviations

3TG	Tin, Tantalum, Tungsten and Gold
AFP	Analytical Fingerprint
ASI	Aluminium Stewardship Initiative
ASM	Artisanal and Small-Scale Mining
CAHRAs	Conflict-Affected and High-Risk Areas
CoC	Chain of Custody
CRM	Critical Raw Materials
CSRD	Corporate Sustainability Reporting Directive
DEVE	European Parliament's Development Committee
DRC	Democratic Republic of the Congo
EEAS	European External Action Service
ESG	Environmental, Social and Governance
EU	European Union
ICMM	International Council on Mining and Metals
ILO	International Labor Organization
IP	Identity Preservation
IRMA	Initiative for Responsible Mining Assurance
LSM	Large-Scale Mining
MB	Mass Balance
OECD	Organisation for Economic Co-Operation and Development
RCM	Regional Certification Mechanism
RMAP	Responsible Minerals Assurance Process
RMI	Responsible Mining Initiative
UN	United Nations
USA	United States of America

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1 Introduction

Governments and consumers increasingly demand a clearer understanding of where metals, minerals and gemstones originate and how they are sourced. The traceability of Critical Raw Materials (CRM) along the supply chain is pivotal not only in ensuring compliance with European Union (EU) regulations on responsible sourcing and the transparency of supply chains but also in meeting wider public demands for corporate sustainability. The Conflict Minerals Regulation (2017), the Corporate Sustainability Reporting Directive (CSRD) (2024), the Corporate Sustainability Due Diligence Directive (2024) and the EU Battery Regulation (2023) all demand improved knowledge of the origin or source of materials. Understanding provenance in some product markets has a long history, the most famous example being the *Champagne Appellation d'Origine Contrôlée* (also known as 'AOC') introduced in 1935. For the traceability of mined products such as metals, minerals and gemstones, there is a more recent and growing desire to gain a clearer understanding of their sources and how they move along supply chains.

Given that this is a relatively recent ambition, the existing complexity and opacity of mineral supply chains, as well as low political will, have delayed the development of mechanisms for tracing the origins of minerals (Kapoor et al., 2022). However, a large number of government, corporate and third-party tracing frameworks have been emerging, which draw on schemes introduced at the turn of the millennium designed to enforce United Nations (UN) resolutions or national laws prohibiting or restricting trade in certain mined products. These schemes include mandatory disclosures on sourcing – notably conflict diamonds, as well as tantalum, tin, tungsten and gold (3TG).

Traceability, which Section 2 defines in detail below, is essentially the ability to identify and trace the history, distribution, location and application of products, parts and materials. As material moves through a supply chain, it passes through the custody of different entities, such as miners, processors, smelters, traders and logistics providers, all tracking progress and recording distinct information pertaining to their custodianship. Traceability is the ability to discover information about where and how a product was made, either by piecing together tracking information or by assessing a material's unique characteristics that match it to a source. This can be used to ensure the reliability of sustainability claims in human rights, labour (including health and safety), the environment and anti-corruption. Traceability schemes are the organisations that provide these services and traceability mechanisms are the processes that enable them to function.

This paper serves as a technical and logistical 'primer'[1] on traceability schemes and mechanisms, with a focus on upstream mining[2] in Africa. It compares and classifies existing industry approaches to traceability based on the minerals targeted, implementation mechanisms, technology use and overall validity. Emphasis is placed on functional mechanisms, benefits and challenges, with particular attention being paid to comparing large-scale industrial operations with artisanal and small-scale mining (ASM) approaches. ASM makes up a significant and growing proportion of the

[1] It is based on desk research and a limited number of unstructured interviews conducted during the research and writing in January–February 2025.

[2] 'Upstream' refers to the exploration, mining, refining and processing of raw materials; 'downstream' refers to industrial uses and manufacturing.

market of specific metals and minerals. The World Bank has estimated that in the 1990s, ASM contributed 4 % of total global supply and now represents 20 %. In the late 2000s, ASM contributed 5 % of total global supply of cobalt and now represents upward of 12 %. For sapphires and diamonds: the ASM supply makes up 80 % and 20 % of global supply, respectively. ASM-mined tantalum and tin make up 25 % and 26 % of global supply, respectively (World Bank, 2024). ASM is often the most exposed to human rights abuses and environmental degradation, but has high rates of livelihood dependence (Finn et al. 2024) and developmental potential[3]. Artisanal mining supports many of the world's poorest people and communities. The paper highlights trade-offs between certainty of origin, cost and ease of implementation. In terms of common coverage and impact, these compromises often restrict different initiatives' ability to discover which part of any value chain can be said to be reflected across the breadth of different supply chains, leading to the conclusion that there is no single solution for any specific commodity. Furthermore, this paper complements a parallel paper on EU political engagement and policy options for enhancing traceability and responsible sourcing, which looks in greater depth at the actors involved, together with their motivations and desired outcomes at policy and political levels (Vandome and Dideberg, 2025).

Firstly, some political and historical context is offered that illustrates the emergence of traceability schemes and how they fit with other regulations and guidance procedures. The characteristics of key traceability approaches are then mapped out, including how they provide a Chain of Custody (CoC). A discussion of the successes and limitations of these schemes follows before a final section evaluates the impact of emerging technology on accelerating traceability capabilities, such as the use of blockchain, nanotechnology and DNA engineering. The paper concludes with a presentation of policy recommendations.

2 Overview of critical raw materials traceability in the African context

Section 2 defines some of the core concepts and offers a brief context for mineral tracing schemes in Africa[4]. Then are considered interactions with regulations and legislation, including EU acts, as well as academic discussion and debates around the technical and logistical factors of traceability schemes.

Traceability is 'the ability to identify and trace the history, distribution, location and application of products, parts and materials, to ensure the reliability of sustainability claims, in the areas of human rights, labour (including health and safety), the environment and anti-corruption' (United Nations

[3] The 2016 OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from CAHRAs defines ASM as: 'formal or informal mining operations with predominantly simplified forms of exploration, extraction, processing, and transportation. ASM is normally low capital intensive and uses high labour-intensive technology. "ASM" can include men and women working on an individual basis as well as those working in family groups, in partnership, or as members of cooperatives or other types of legal associations and enterprises involving hundreds or even thousands of miners'.

[4] The political role of different actors in this process is covered more substantially in the paper, commissioned by DEVE. C. Vandome and R. Dideberg, 'Traceability of CRM with a focus on Africa – Policy Options', European Parliament's Directorate-General for External Policies, 2025.

Development Programme and Business for Social Responsibility, 2014: 6). It is a process by which users can identify their various suppliers at every stage along supply chains all the way back to extraction sites by tracing or reconstructing the movement of raw material (Debert and Le Billion, 2021). Traceability can be achieved by monitoring material flows through a CoC – the record of entities with temporary charges over minerals moving through a supply chain, including miners, transporters, exporters, processors and manufacturers. The Organisation for Economic Co-operation and Development (OECD) Due Diligence Guidance for Responsible Mineral Supply Chains for Upstream Actors (OECD Minerals Guidance) makes the following distinction: 'chain of custody' refers to the document trail recording the sequence of companies and individuals that have custody of minerals as they move through a supply chain, such as production records, bills of lading and export certificates. 'Traceability' refers to the physical tracking of minerals at all points of the supply chain, from their mine of origin to the refiner or smelter[5]. In other words, traceability is the ability to identify the origin of a product as it moves in time and space, passing between handlers, owners and transporters. A CoC system records this movement, whether it be through paperwork, databases, or the establishment of a 'digital twin', the conveyance of material, details of the custodian and other information. Manufacturers, processors, auditors and other users should be able to trace any material to the start of its recorded value chain – be that the mining company, a specific mine, or the country of origin – through paperwork, such as mine origin certificates, transport documentation, export and import records and factory receipts. The digitalisation of this movement, transitioning from a 'paper trail' to a 'digital footprint', is discussed below. Similarly, increasing ambitions to achieve tracing at a molecular level will also allow origin identification without the need for CoC documentation.

Traceability allows extractive, trading and manufacturing companies, as well as regulators, consumers and others, to access comprehensive information on composition, quality and compliance with Environmental, Social and Governance (ESG) standards. As such, traceability mechanisms can be valuable tools in achieving greater transparency and accountability within complex mineral supply chains (Schöneich et al., 2023: 955). At the forefront of Research & Development in this space is the development of digital traceability systems, allowing the tracking of products through supply chains by way of digital 'passporting' and the advancement in origin verification through 'fingerprinting'. Increasingly, certification on traceability is provided by entities independent of standard setters. Traceability schemes are often industry-led organisations whose purpose is ensuring the sustainability and responsible sourcing of raw materials, for which traceability plays some role (BSR, 2014: p.6). These organisations are generally labelling or certification organisations and industry or commodity-specific, membership-based roundtables. It is important to note that these organisations are at different levels of advancement in terms of implementing traceability.

The ability to implement traceability is hampered by metal and mineral trading structures. Some material moves directly from mines to processers and manufacturers in lineal paths through direct offtake agreements where the manufacturer may have a direct offtake agreement with a mine to

[5] Elsewhere in the literature a distinction may be made between 'tracking' from upstream to downstream and tracing, which is the origin identification of a product.

take material, making a closed pipeline of traceability simpler. However, the trading of material on spot markets and other trading practices means that ownership of material may change hands several times, often with owners not being physically connected to the material, as it is traded on international markets and routed around the global. Most trading structures are outside of the EU, and thus outside of the regions regulatory oversight, However, some trading hubs, such as the London Metals Exchanges, has increased the requirement to adhere to responsible sourcing mechanisms in order to trade on the exchange.

There are two main strands of practitioner discourse on traceability of mined products from Africa. The first is supply chain management, concerned with material movement along a supply chain for operational benefit, allowing a business to be informed about input-output flows, product quality, location, or movement between processes and storage, as well as ensuring product security preventing theft or laundering of illicit minerals into legal supply chains. Company tracking systems are concerned primarily with commercial information. The second is responsible sourcing, which is concerned with ensuring that products comply with set criteria at specific points throughout the whole supply chain to verify sustainability claims, thereby ensuring responsible business conduct and respect for people and the environment. The latter aligns with the objectives of the European Parliament's Development Committee (DEVE), which aims to promote human rights and good governance in developing countries (European Parliament, 2025). Effective supply chain management is critical for responsible sourcing. Responsible producers need to ensure that supply chain vulnerabilities are addressed to prevent the tainting of responsible minerals with, for example, illegal products that are introduced in transit. Traceability is a means to an end – it is the ability to verify claims on responsible sourcing and performance standards. Trust and third-party assurance remain central to end users' concerns.

There is a notable differentiation between verification and certification. Verification is the ability, when tested, to confirm by way of objective, often physical, evidence that a particular claim is accurate. On the other hand, certification is granted by a qualified third party to an entity within the supply chain to confirm that it has met a set standard or originates in a certain place. Hence, this can be applied to any state, company, or process, such as smelting. Certification is an important means of checking compliance and has become a common practice for industrial mining. Certification can be applied to producers, as custodians of mined products as well as to the product itself in some circumstances. For example, Fairmined Gold certifies gold of responsible origin (Alliance for Responsible Mining Foundation and Fairmined, 2014).

Box 1: Why traceability?

- To support provenance claims, distinguishing between industrially mined, ASM and recycled products; to verify origin claims on the geography of production, transformation, transportation and trade of materials; to provide manufacturer and consumer confidence; and to conform or comply with import or retail regulations in end-user countries.
- To support responsible sourcing and supply chain due diligence. To deepen understanding of who, where and how product was mined, transported, traded; and to assess risk and determine the nature of a downstream entity's connection to adverse impacts up- and mid-stream.
- To provide knowledge on supply chains that can identify where additional due diligence is needed, as well as demonstrate where resources should be allocated to reduce or mitigate supply chain risks.
- To prevent fraudulent entry of illicit materials into supply chains.
- To facilitate extended producer responsibility as a means through which greater volumes of materials can be recovered from end-of-life products, and thus as a pathway for driving higher recycling rates.
- To facilitate two-way information sharing along value chains to strengthen trust and relationships as the basis for managing risks optimally. Also, to allow upstream operators and producing country governments to understand the end usage of their materials and better understand point of value addition and end pricing.
- To minimise the costs associated with due diligence through the data management possibilities that arise.

2.1 The growth of responsible sourcing

Mitigating the social, political and conflict risks prevalent in supply chains originating in Africa has been central to the development of responsible sourcing since the 1990s[6]. The 21st century 'wave' of regulation facilitated new voluntary, regional and transnational initiatives, emphasising transparency and accountability by both mining companies and host governments (Campbell, 2019). This was, in part, an effort to fill legislative gaps in mineral governance regimes and a response by companies to criticism about the industry's negative impacts. In 1998, industry executives convened to set up the Global Mining Initiative, which created the Mining, Minerals and Sustainable Development Project to investigate operational responsibilities as well as the International Council on Mining and Metals (ICMM) as an industry-led strategy to support sustainable development[7].

Enforcing and supporting responsible business practice gained further traction through the UN's 2011 adoption of the Guiding Principles on Business and Human Rights, codifying the responsibilities of state and private actors, as well as international standards and guidelines for companies, such as the OECD Minerals Guidance, the International Finance Corporation Performance Standards and child

[6] The 1992 Whitehorse Mining Initiative in Canada is viewed as the first responsible mining scheme.
[7] International Council on Mining and Metals, website.

labour standards from the International Labour Organization (ILO). It is important to note that the development of guidelines to improve outcomes has not been exclusively 'Western'. The China Chamber of Commerce of Metals, Minerals, and Chemicals Importers and Exporters has produced Guidelines for Social Responsibility in Outbound Mining Investment and Chinese Due Diligence Guidelines for Responsible Mineral Supply Chains (CCCMC, 2014 and 2015). Furthermore, guidelines have been developed by African stakeholders, such as the International Conference on the Great Lakes Region's Regional Certification Mechanism (RCM) and the *Initiative de Traçabilité de l'Or d'Exploitation Artisanale*, which is a Congolese-led programme to trace artisanal gold.

Industry self-regulation and international guidelines on responsible sourcing coincided with and in response to state-led initiatives to counter significant conflict risks in African supply chains. Most notably, this concerned diamonds in the wake of UN embargoes imposed on Angolan supplies in 1999, as well as those from Sierra Leone and Liberia in 2000, combined with a general fall in consumer demand by way of response to 'blood diamond' campaign groups. The 2003 Kimberley Process Certification Scheme was one of the first attempts to certify the origin of a mined product for responsible sourcing, which was followed by other state-led schemes to prevent conflict minerals from entering global supply chains, in particular from the eastern Democratic Republic of the Congo (DRC). Section 1502 of the United States of America (USA) Dodd-Frank Act 2010 imposed disclosure requirements on the import of 3TG from the DRC and bordering jurisdictions. This required companies to report annually to the US Securities and Exchange Commission. Whereas the Kimberley Process is sometimes classified as 'voluntary'[8] in the sense that no country is obliged to join (Partnership Africa Canada, 2013), the Dodd-Frank Act's imposition of legal accountability on downstream users for their upstream suppliers was a marked departure from previous initiatives by making necessary both traceability and origin verification.

However, the industry has experienced operational challenges in geographical contexts such as the DRC, where there is a significant overlap between Large-Scale Miners (LSM) and ASM. Legal bodies using geographic targeting for their specific risks raised a central question: whether traceability schemes could show that a mineral, metal, or gemstone has been responsibly sourced even if its origin is in a high-risk jurisdiction. The ensuing uncertainty has resulted in reduced trade and negative impacts on the livelihoods of vulnerable artisanal mining communities (Stoop et al., 2018).

2.2 EU legislation and regulation advancing traceability and responsible sourcing

The EU has not only passed an act looking to secure critical minerals but has also put in place several regulations demanding adherence to strict standards on how these minerals are sourced. However, there is a potential tension here, given that effective traceability schemes can no longer be regarded as luxuries but rather as necessities. The EU's Critical Raw Material Act of 2024 lists 34 CRMs, 17 of

[8] However, one had to be a member of the Kimberley Process to trade with other members, effectively making it compulsory. Furthermore, the Kimberley Process also received a UN mandate and includes the requirement to legislate elements into national law.

which are denoted as particularly strategic to the defence sector and the EU's ambition to become climate-neutral by 2050[9]. This Act is intended to secure resources considered key for the EU's future security and prosperity (Vandome, 2024).

Furthermore, the EU has put in place various regulatory frameworks setting high standards for how these minerals should be sourced. These include: the Conflict Minerals Regulation 2017, which covers 3TG imports from conflict-affected and high-risk areas (CAHRAs); the 2024 CSRD, which requires reporting on environmental and human rights standards; and the 2024 Corporate Sustainability Due Diligence Directive, which places a duty on companies to maintain sustainable and responsible corporate behaviour in operations inside and outside Europe. The Electronic Exchange System and Battery passports introduce tracing requirements not only for sourcing but also for circular economy and post-life usage. Battery passports require any battery over 12 kWh that is placed on the EU market to include information relating to its efficiency and durability, as well as emissions data and supply chain information, all of which must be stored digitally and available to the general public, regulatory bodies, as well as battery service and end-of-life processors. The 2023 DEVE Committee report highlighted the need for greater transparency and effective management of extractive industry revenues across large-scale and ASM mining operations for employment, value creation and improved development outcomes (European Parliament, 2023)[10]. Reconciling these requirements with the EU's need to secure critical minerals will make effective traceability increasingly important.

2.3 Academic discussions

The feasibility of current traceability schemes, including those based on affordability and credibility, is the subject of significant academic debate. Studies indicate challenges arising from mineral supply chains, which do not appear in other industries such as textile or forestry, pointing at their comparatively high level of complexity, opacity and fragmentation, stemming from the mixing and blending of materials, the role of informal producers and intermediaries and the various processing stages across countries (Barash-Harman, 2018). Many exploratory studies have mapped out the wide range of existing schemes (Debert and Le Billon, 2021; Young, 2018; van den Brink et al., 2019), deriving the efficacy and limitations of non-state regulatory enforcement (Postma et al., 2021; Partzsch, 2020). Some argue that traceability may encourage better environmental and social standards 'from highly to weakly regulated countries' (Barash-Harman, 2018), while others warn about the risk of 'cosmetic compliance' in human rights due diligence (Postma et al., 2021; Vogel, 2022; International Peace Information Service, 2023; Landau, 2019).

Research into supply chain governance has focused on the drivers of traceability among individual firms, where feasibility is an outcome of affordability and credibility (Timmer and Kaufmann, 2017; Schöneich et al., 2023). Traceability is more easily achievable in commodities that are mined in large-scale industrial complexes, such as copper and platinum, compared with easily smuggled,

[9] European Commission, 'Critical Raw Materials Act', webpage.

[10] An analysis of this and its impacts are covered in greater detail in the paper, commissioned by the DEVE Committee on 'Traceability of CRM with a focus on Africa – Policy Options'.

often high-value, commodities mined in fragmented and artisanal sites, such as gold and diamonds (Schöneich et al., 2021; Finlay, 2020). This is because of greater economies of scale which reduce the cost of traceability as well as resources being less easily looted. Le Billion has argued that more easily 'lootable' resources provide opportunities for non-state armed actors (Le Billion, 2001).

Many empirical case studies look at mining activities, assessing the implementation of specific schemes and their interaction with local governance and socio-economic equilibria (Muller-Kone, 2015; Mancini et al., 2021). A considerable number are critical, exposing the unintended consequences of top-down traceability devices' introduction on local political economies, regional market dynamics and the livelihoods of miners (Gouby, 2024; Vogel, 2022; Radley and Vogel, 2015; Hilson, 2014; Zaragoza and Matthysen, 2013). Other studies have compared the impact of traceability schemes on artisanal mining with large-scale industrial mining (Huggins, 2023; Le Billon and Spiegel, 2021; Deberdt, 2022). Other research has focused on quantifying the Dodd-Frank Act's impact and the *de facto* ban on artisanal 3TG from the eastern DRC and adjoining countries on local socio-economic situations, including levels of primary education enrolment, infant mortality and conflict patterns (Bloem, 2023; Parker and Vadheim, 2017; Parker and Elsea, 2016). The Canadian non-governmental organisation IMPACT, formerly Partnership Africa Canada, has produced various studies on the impact of standards and guidance on mineral exports from the Great Lakes, which *inter alia* highlight the need for purchasers to ensure compliance (Blore, 2015); and the International Peace Information Service has underlined the EU CMR's shortcomings, pointing to the fact that international regulation has not trickled down to changes in operation on the ground; furthermore, there are risks that importer countries over-rely on due diligence schemes against journalist or non-governmental organisations reports or insights provided by affected communities themselves (International Peace Information Service, 2024).

Advances in technology – covered in Section 5 – have given rise to significant expectations that technological fixes such as digitalisation, blockchain, machine-learning and sample-based geochemical analyses may address traceability schemes' shortcomings. Researchers have studied their adoption by industry and their potential for trust-building among supply-chain actors but that achieving traceability not only at the mining site but also throughout the downstream supply chain presents logistical challenges, necessitating industry-wide coordination (Onifade et al., 2024), while others have warned about their marginalising impact on small mining communities (Calvao and Archer, 2021). Geochemical sample analysis solutions are still in their developmental stage and not yet widely adopted on the ground. Hence, the academic debate revolves mainly around the technique's scientific feasibility and challenges to scalability (Melcher et al., 2021; Kaikkonen et al., 2022).

In 2025, the International Energy Agency and OECD produced a comprehensive report on *The Role of Traceability in Critical Mineral Supply Chains.* This report argues that 'careful design and implementation, along with addressing key technological and economic challenges, are essential if traceability systems are to effectively support responsible supply chains' (IEA and OECD, 2025: 7). They note that traceability must be tailored to specific supply chains, accounting for their unique characteristics and risks, and that traceability should not be seen as the goal in and of itself but

rather should be used to support clear policy objectives. A summary of the International Energy Agency and OECD roadmap to traceability is provided in Annex 3.

3 Mapping and classification of traceability initiatives

For illustration, this Section maps some examples of existing initiatives detailing their implementation systems and governance. The chosen examples explain how different mechanisms work and highlight their implementation. A more comprehensive list of initiatives can be found in Annex 1. The CoC approach is first explained, followed by coverage of more specific traceability schemes' development at the forefront of innovation in the sector, which could have the greatest impact on ASM.

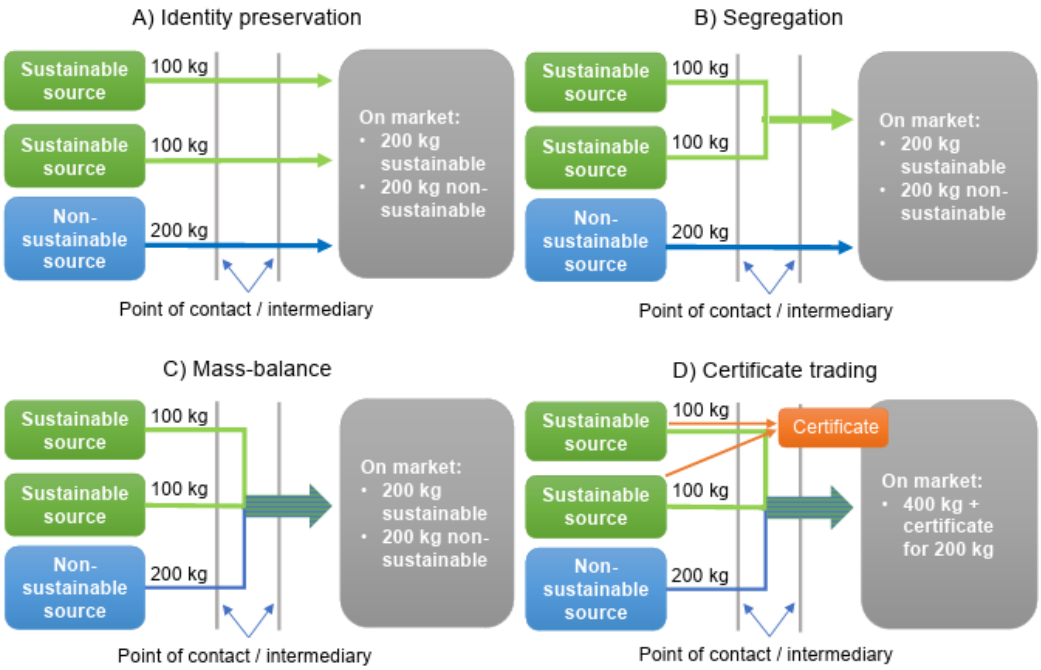
3.1 Chain of custody

The CoC concept broadly relates to the process of evidence documentation. The term is also used in legal proceedings, where CoC is used to authenticate the evidence presented to a court, by documenting the continuity of possession of the evidence from the crime scene to the court (Badiye et al, 2023). Similarly, in mineral supply chains, CoC documents the series of custodians in charge of a mineral 'from the mine through the downstream chain of custody to the end consumer', also documenting their claims of conformity with responsible sourcing standards (Initiative for Responsible Mining Assurance, 2020). The International Social and Environmental Accreditation and Labelling Alliance differentiates between four different conceptual approaches to CoC, articulating exactly how responsibly sourced material should be handled along the supply chain (International Social and Environmental Accreditation and Labelling Alliance, 2016):

- *Identity preservation (IP)* models require that any product from a certified production site be kept separate from other materials throughout the supply chain, providing the end user with confidence about a product's origin and responsible sourcing credentials.
    - Example: The Responsible Jewellery Council (RJC) Chain of Custody Certification for gold and diamonds. Batches of materials are assigned a unique ID. They are tracked through the supply chain to ensure they are not mixed with other materials. The scheme is upheld through a process of regular auditing.
- *Segregation*, also called 'soft IP', permits the blending of materials from different certified sources but prohibits any mixing of materials from non-certified sources. Moreover, the mixing of certified materials must be recorded and documented.
    - Example: The Copper Mark can be used for segregation or mass balance CoC. Copper from certified mines, smelters, or refiners is kept separate from non-certified copper through parallel processes or sequential batch processing. Detailed records are maintained to track the movement of certified copper, a segregation model ensuring that it is not mixed with non-certified materials. Where mixing of Copper Mark material and other sources is conducted by traders or processors, a mass balance approach may be used.

- *Mass Balance (MB)* refers to the range of CoC models that permit mixing certified and non-certified materials at different stages in the supply chain. Manufacturers of the end product can then claim a degree of certification based on the proportions of certified and non-certified materials used.
    - Example: Aluminium Stewardship Initiative CoC standard. Aluminium from certified sustainable sources is tracked through the supply chain by maintaining records of input and output quantities of aluminium, allowing for the mixing of certified and non-certified materials as long as the output claims do not exceed the input quantities of certified materials.
- *Certificate Trading* involves the creation of a certificate for sustainable production at the start of the supply chain that can then be purchased as a credit by end users. This permits the end user to claim that, while the origins of a specific shipment may be unknown, an equal amount of the material has been produced sustainably somewhere in the world.
    - Example: Fair Cobalt Alliance Cobalt Credits. Credits are issued based on the actual production of cobalt at partner mine sites. Each credit represents one tonne of cobalt produced under improved conditions. Companies can buy credits equivalent to their cobalt usage. By purchasing credits, companies can claim that their cobalt use supports responsible production practices, even if they do not physically receive cobalt from those specific mines.
    - Example: The Fairmined System offers 'Fairmined Certificates' for ASM producers that are 'not able to or do not want to sell into the physical Fairmined supply chain and/or for markets that do not aspire to incorporate Fairmined Gold into their supply chain but nevertheless wish to contribute to the development of responsible artisanal miners and their communities. Fairmined Certificates are a 'book and claim' scheme for Fairmined certified gold that has been sold as physically traceable by the ASM[O] to a legal buyer' (Alliance for Responsible Mining and Fairmined, 2024: 42).

Figure 1: Blending of sustainable and non-sustainable product under different CoC approaches



Source: Kaikkonen, H., Kivinen, M., Dehaine, Q., Pokki, J., Eerola, T., Bertelli, M. and Friedrichs, P., 'Traceability methods for cobalt, lithium, and graphite production in battery supply chains Assessing geo-based fingerprinting as a method for battery raw materials' traceability', Research Report, *Geological Survey of Finland*, 2022: 25.

The diagram above visualises how four different CoC models account for the mixing and blending of material and how this is reflected in the sourcing claims of the final product. It demonstrates how a material's sustainability can be claimed on the market. This is based on a 200kg input of sustainably sourced material from 2 suppliers and 200kg of non-sustainably sourced material from 1 supplier being ultimately accounted for.

A key differential between the systems concerns trade-offs between certainty, compatibility within supply chains and cost. The high degree of certainty afforded by the IP system can be costly to implement and thus less frequently adopted. The complex nature of some supply chains, including variations in buyer-seller agreements, including direct offtake agreements, direct or bilateral interactions between entities, or spot markets and auctions, make higher degrees of certainty less possible. Some commodities can pass through the custody of multiple entities at each stage of the supply chain. For some mined products, traders may blend the same mineral, albeit from different sources to meet a client's specific needs. The choice of CoC system can be influenced by the quality of mined material, client needs, or the jurisdiction's location. Actors need to trust those who came before them in the supply chain on their claims of sourcing and origin. Robust CoC mechanisms can facilitate this trust. Many mined goods may be exchanged a number of times between different custodians at each level of the value chain. The traceability starting point for all custodian models is the mining firm, with its use of verification and certification building trust and an assurance that it is complying with the requirements of downstream users.

3.2 Responsible sourcing and custodial verification: Practical but imperfect chain of custody assurance for large scale mining

One of the simplest and most common means of verifying the source and responsible credentials of a mineral or metal is to ensure that all separate entities that have custody of the product through the supply chain each uphold a particular responsible business or ESG performance standard. Such stewardship schemes are built on the principle that mines, smelters, refiners and other supply chain actors, such as semi-fabricators, abide by a set of standards. Some schemes may have an 'add-on' whereby more robust CoC guarantees apply when all entities within the supply chain are participants in the scheme – for instance the Initiative for Responsible Mining Assurance (IRMA) CoC Standard for Responsibly Mined Materials, which can provide for the tracing of material coming from any IRMA-audited mine (IRMA, 2024).

Mining companies in CAHRAs have been motivated to adopt commodity-specific and generalised standards in jurisdictions that have been the subject of international regulation – such as US reporting requirements imposed on material emanating from the DRC and neighbouring states, and the EU's more universal conflict mineral regulation. Such schemes enable the assurance of the verification of LSM projects on responsible business conduct or ESG requirements so that their products can enter supply chains and, most commonly through MB CoC, assure end users of responsible extraction, even if the specific provenance cannot be determined. Such schemes verify that operations conform to a set of standards, such as the UN Guiding Principles on Business and Human Rights and the OECD Mineral Guidance, or an additional set of standards defined by the verifying organisation.

One of the most used industry mechanisms is the Responsible Minerals Initiative (RMI), founded in 2008 and an initiative of the Responsible Business Alliance. Over 500 member companies and associations from 30 mining countries participate in this initiative; its Responsible Minerals Assurance Process offers an independent, third-party assessment that determines which smelters and refiners can be verified as having systems in place to 'source minerals responsibly in line with current global standards' (Global Reporting, 2021: 73). In addition, the RMI provides templates for supply chain due diligence reporting and operational guidance. The RMI is primarily an upstream initiative that works with extractive operations and smelters. In 2021, a consortium that included the RMI was awarded a grant to establish a traceability mechanism for addressing child labour issues (RMI, 2021).

Commodity-specific examples of verification initiatives include the membership-based Copper Mark scheme[11], which in 2019 was incorporated as a company in the United Kingdom and the Aluminium Stewardship Initiative (ASI), established in 2009 as a membership organisation. Both rely on site-specific auditing and verification of standards being upheld as set by the organisation, given that such standards are either derived from or in line with international guidelines and legislation.

[11] The Copper Mark organisation also facilitates the Molybdenum Mark, Nickel Mark, and Zinc mark for associated products. Copper Mark is a partner on the development of the Consolidated Mining Standard Initiative, which when implemented would replace the existing scheme.

Notably, both schemes have established frameworks for the engagement of Indigenous People and communities – the ASI Indigenous Peoples Advisory Forum together with the Copper Mark Peoples and Communities working group – and have also established grievance mechanisms. While a core function of these initiatives is certification of ESG performance, they can additionally provide CoC assurance based on linking certified entities through the supply chain, which contributes to traceability according to the ASI. The Copper Mark and the Mining Association of Canada's Towards Sustainable Mining are working with the UN Centre for Trade Facilitation and Electronic Business (also known as 'UN/CEFACT') CRM Traceability project to create The Copper Mark Digital Credential, which they claim will allow participants to communicate their responsible production credentials along their value chains, taking another step towards increasing transparency. London Bullion Market Association and the World Gold Council are also collaborating to develop and implement an international system of gold bar integrity, chain of custody and provenance, using a blockchain platform for tracking bars (London Bullion Market Association, 2022)

The range and complexity of standards, guidelines and implementation schemes for responsible sourcing have increased, offering more competition and diversity for some processors, foundries, and manufacturers, there has been a simultaneous move towards convergence and simplification of standards, not least to reduce the cost of compliance and avoid duplication of effort. For example, a consolidation project currently under development is the Consolidated Mining Standard Initiative which combines the Copper Mark, Towards Sustainable Mining, the World Gold Council's Responsible Gold Mining Principles and ICMM's mining principles, although at present it doesn't include a chain of custody standard.

As well as the convergence of schemes, there has been a development of single schemes that cover multiple criteria. One example of this is IRMA. IRMA was founded in 2006 and has 96 members, including: Anglo American, mid-tier mining companies such as Albemarle, Arcadium Lithium and Sociedad Química y Minera; processing companies and manufacturers; as well as car makers Ford, General Motors, Tesla and Volkswagen, and investors. Affected communities are given the same weight as mining companies and purchasers in the organisation's governance. that the extent to which IRMA has multi-stakeholder governance and design makes it unique. IRMA scores operations using rigorous reporting and auditing systems; the organisation released a new CoC standard in 2024, detailing how to track material through IRMA-certified sites and custodians. However, its uptake by industrial mining companies has been limited, with only 10 mines in Africa being assessed, 7 of which are in South Africa. Detailed reporting can place a high burden on smaller operators, there being lengthy processes between assessors and operators to agree on conclusions, which can delay trouble shooting.

3.3 Chain of custody tracing schemes: Paper trails to digital logs

Verification of actual materials, as opposed to certifying custodians of those materials, can provide a more comprehensive means of traceability, using digital platforms to log material flows through the supply chain. The first initiatives to follow material through the upstream supply chain were often 'bag 'n tag' systems, where mined material is tagged at the point of extraction with data on its origin. One of the early pioneers of this system was the International Tin Supply Chain Initiative (ITSCI),

which grew from a working group of the International Tin Association established in 2009 and a small pilot in eastern DRC in 2010[12], pre-dating the US Dodd-Frank Act, which subsequently spurred the programme's growth. The initiative verifies that mines operate to an ITSCI standard, defined by the organisation and for which it uses the OECD Due Diligence Guidance as a reference, with accredited agents of participating governments tagging bags on registered mine sites and reporting to a central ITSCI data centre. Tags can then be checked before products leave the smelters, with data then being accessed by downstream users within their due diligence procedures. However, this system's credibility has been challenged due to the free availability of tags, opportunities for corruption in the tagging process and allegations of Congolese minerals being tagged and recorded as being produced in neighbouring countries (Global Witness, 2022). Furthermore, the paper-based and manual entering of data as a source of abuse has been a point of criticism. Studies have argued that not only had the scheme failed to prevent untagged minerals from entering supply chains, but it also led to a stagnation or decreasing of prices in some 'clean' areas (Postma et al, 2021; Vogel, 2022).

Another mechanism, the Better Mining initiative, also developed in DRC and Rwanda, has been more focused on ASM and has also been adopted by industrial mining operators. Better Mining ensures that materials are produced, transported and exported by companies operating in a manner that is aligned with the requirements of the OECD Mineral Guidance, and the RMI Responsible Minerals Assurance Process (RMAP). Consignments are tagged on-site by a Better Mining agent and a digital tracing platform allows the product to be followed from the mine to the smelter. Better Mining agents are located full-time at the sites that use the scheme[13]. They also conduct monthly reviews and produce audit reports, assessing the mine against various criteria, including the OECD Mineral Guidance and IRMA system. While this scheme promotes its application for ASM, it has also been taken up by industrial mining operations, such as Trinity Metals in Rwanda. The physical presence of Better Mining representatives and the enhanced due diligence that is undertaken means that the scheme is more expensive than other mechanisms. Its tracing is also limited up to the point of smelting. However, this process aims to reassure smelters, who can further assure clients through MB CoC. Most significantly, it can be a competitive advantage for companies seeking responsible financing and investment.

The lessons from ITSCI's faults and challenges have informed new entrants into the traceability and verification market. New third-party traceability companies such as Everledger, Circulor, Peer Ledger, Re:Source, iTrace, MineralTrace and Minespider, many of which are European-owned or led, are increasingly digitising tagging systems. These firms often offer a full package of digital solutions, combining blockchain, cloud computing, Web 3.0, Internet of Things and machine learning to compile CoC information and analyse production data and patterns of commodity flows, thereafter summarising traceability information on an easily navigable online platform or a battery passport on the product itself, which can also contain data about the product's carbon footprint and its recycled content.

[12] See ITSCI, 'Our Purpose – Achieving Together', webpage.

[13] Interview with a mining company using Better Mining's services, December 2024.

A market leader in developing supply chains' digitisation is Circulor, a company from the United Kingdom founded in 2017 with offices in Germany and Ireland, that offers clients the ability to track materials through a supply chain and provide details on the point of origin. The scheme functions by pit managers labelling production with tags containing no information before their activation, unlike traditional 'bag 'n tag' schemes, which are often pre-printed. Mobile phone facial recognition is used to verify the authorised tagger's identity. The use of blockchain ensures that information cannot be overwritten and machine learning tools can conduct data analysis to identify anomalies. For instance, if a pit is suddenly overproducing, it could indicate that additional material is being smuggled onto the site. Circulor's emphasis on digitisation is a specific move to combat supply chain threats from human vulnerabilities – especially upstream corruption. Authorised personnel such as pit managers receive payments automatically on a mobile app once the quantities are encoded to erase opportunities for bribery.

Another third-party verification and trace service provider is Minespider. As with Circulor, the company uses a digital platform and parallel digital supply chain to record the journey of material, offering battery and product passports. Several other service providers offer tracking and traceability solutions, with some interviewees suggesting that a market consolidation could be expected[14]. In addition to third-party service providers, top-tier mining firms are also developing digital tracing platforms. For example, Anglo American has developed an internal traceability scheme, Valutrax, which it can offer to customers of specific products – ferronickel, copper concentrates and iron-ore. Similarly, in the ReSource traceability programme was proposed in 2019 by Glencore, the Eurasian Resources Group and CMOC. Such schemes typically rely on similar technology to third party providers. Some major producers favour in-house mechanisms, while others use service providers. However, as yet the industry has not adopted a single model, although this has been suggested by international organisations. It is important to note that mined materials can go through various scanning, testing and analytical processes conducted by the company before being passed on to the next custodian. These processes are for commercial purposes, with limited scope for offering traceability assurance.

3.4 Physical attributes, geo-chemical analysis and molecular origin identification

Another area of development in material traceability is geo-chemical analysis, an example of which is isotope testing to match the make-up of an end material to specific and unique properties of different ore bodies. At the frontier of this research are initiatives that seek to add a traceable marker artificially, for instance, by adding a molecular chemical marker or laser tagging.

The gemstone industry has been leading the development of individual commodity identification and origin verification. The nature of gemstones, such as diamonds, being high-value products mined in relatively low quantity, has made them more suited to such analysis than high-volume, low-cost bulk products. In 2018, Anglo American's diamond subsidiary De Beers invested in developing TracrTM, the world's first fully distributed diamond traceability platform, which has the

[14] Confidential interviews, London, February 2025.

ability to explore the provenance and authenticity of any diamond. Each diamond is scanned at the mine site to create a 'digital-twin', which is followed through the supply chain via successive scanning and protected using an incorruptible blockchain ledger. The programme focuses on gemstone quality rough diamonds and although initially developed for data input to start at its diamonds trading centre where stones from different sites are blended, it is now being further extended to assure point of origin. It has also been applied to the ASM sector through the company's Gemfair programme in Sierra Leone. Similar digital twinning and fingerprinting solutions that rely on digital scanning of physical attributes have been developed by Diabot, Gubelin Gem Lab and others.

An alternative solution being developed in the diamond industry is physically marking stones at the nano and micro levels. For example, Authentia uses nanotechnology to mark stones, whilst Minespider offers laser inscriptions, gemmological fingerprints, radio-frequency identification tags or near-field communication chips as part of its digital diamond passport, developed in response to the discussion on the Group of 7 sanctions against Russian diamond exports. Manipulation of physical and chemical attributes for tracing material through a supply chain is prevalent in other product markets – such as cotton – but has only recently been applied to mining supply chains.

This development parallels processes that seek to use inherent rather than additional properties to trace a product. The EU-supported MaDiTraCe, launched in January 2023, is a 36-month European project coordinated by the French Geological Survey (*Bureau des Recherches Géologiques et Minières*) that aims to reinforce the transparency, traceability and sustainability of complex supply chains relating to CRMs including cobalt, lithium, natural graphite and rare earth elements. It uses mineralogical and geochemical composition identification, first developed by the BATTRACE project, which ran from 2020 to 2023. The key principle behind this project is that mineral ore bodies have unique characteristics which enable end users to track elements back to their mined origin. The project is still in the 'proof of concept' stage but is nevertheless working with various research organisations as well as manufacturers and industrial companies within the EU. Some of the key challenges with technologies underpinning the project are examined below.

4 Successes and limitations of existing schemes

This section highlights some operational challenges faced when implementing traceability schemes from an upstream perspective, focussing on ease of adaption, cost of compliance, mineral-specific issues and the ability to include both LSM and ASM. Operational challenges are listed as bullet points, while the following simple table is provided to summarise certain positives and negatives related to the various initiatives mapped out in Section 3. This is designed to assess the different mechanisms' general effectiveness without singling out specific initiatives for criticism.

4.1 Operational and implementation challenges

- Modern metal and mineral supply chains can be highly complex. Material needs to move through various entities whilst blending and mixing, often with materials from other sources, aggregation, processing and manufacture. MB CoC systems are commonly used due to their flexibility and affordability in this respect. Smelters and traders need to blend material for

many reasons, *inter alia* metallurgical needs or client requirements. Metals and minerals can change weight and composition between stages, making weight-based monitoring problematic and difficult.

- There are often challenges in cross-company or cross-country collaboration to facilitate data mapping, including data collection, storage and sharing protocols as well as the protection of commercially sensitive information. Furthermore, the diversity of downstream and investor due diligence disclosure requirements compounds these challenges.
- Technology can be an important tool, but it raises additional implementation and regulatory issues. Technological solutions often involve data storage and sharing, thus calling for trust between companies, which is difficult when commercially sensitive information is at stake – including orebody analysis, production figures and shipping data. Technological solutions are also more resource and energy-intensive, requiring hardware and energy usage, which can increase costs that can be a barrier for adoption as well as increase the carbon footprint of the schemes.
- Digital traceability solutions rely on access to reliable data-transmission, telecommunications, and energy. Many areas of ASM production, as well as industrial mining, occur in contexts of significant energy and infrastructure deficits.
- There is a need to ensure data integrity, immutability and simple transfer of information across different jurisdictions and across different traceability schemes. Data entry will always involve some human element, which in turn offers opportunities for corruption.
- Many schemes are run by for-profit third-party service providers. This is not unusual for industrial operations working with a range of service providers and contractors; however, it means most schemes are inaccessible to ASM producers. This could lead to higher compliance costs, thereby reducing the finances available for risk mitigation. This problem also arises for industrial mining companies, traders and manufacturers looking to engage in responsible sourcing, with too much of the resources being spent on auditing and der-risking supply chains rather than engaging in risk mitigation.
- It is necessary to build human capital beyond operational roles. There is a need to build internal capacity and understanding of traceability, its objectives, why it matters and what compliance regulation for responsible sourcing means for operators on the ground. This entails developing an understanding amongst workers and producers in LSM and ASM of both the practical requirements for compliance and conformity to standards, as well as an understanding of their requirements and intentions, including the business value of knowing where the product is being used and by whom, and the social value of demonstrating responsible sourcing. Communication and engagement across stakeholders and regulators are important for implementation consistency.
- Traceability mechanisms are often circumvented by agents and entities in the supply chain, including through the parallel market availability of tags for certain 'bag 'n tag' schemes, the addition of illicit material in transportation, the addition of illicit material in processing, where material changes weight, and corruption.

- In some cases, due diligence and traceability costs have fallen disproportionately on upstream actors, affecting local political economies and livelihoods which is inequitable and a barrier to just mineral value chains. This also affects the potential and motivation for upstream suppliers to invest in mitigation, as they already carry a significant cost of implementing schemes that benefit the whole supply chain. Traceability for knowledge generation should also lead to supporting the prevention, minimisation or mitigation of risks and prioritisation of action. Company compliance requirements can impact the potential for local content where providers must also be vetted. This can be a barrier to extending socio-economic improvement and equitable benefit sharing beyond miners to other members of mining communities, including food and service providers.
- Good state-company relations in producing countries are central to the adoption, implementation and enforcement of initiatives. For some schemes, the state is a central interlocutor – as a regulator, enforcer and certification provider – and moreover, the effectiveness of company implementation often depends on state participation. Voluntary enforcement by industry actors is not enough to curb abuse. Major players also have a role in standard setting and communicating the need for best practices for governments wishing to access downstream markets and customers. States could consider a licensing requirement for traceability schemes operating within their jurisdiction to ensure that meet certain criteria such as credibility, feasibility, and interoperability with other systems
- Geography still matters. Schemes targeting conflict-affected areas and jurisdictions where the rule of law is weak, or enforcement capacity is low continue to present challenges to mining companies. The cost of compliance for adhering to multiple schemes can disincentivise investment, where the reputational risks associated with implementation failures are high. Disengagement from mining-dependent communities can negatively impact livelihoods and jeopardise development schemes seeking to build economic resilience in conflict-affected areas.

Table 1: Summary of the positive and negative aspects of each traceability approach

Tracing approach	Examples	Positive Aspects	Negative Aspects
CoC standards	RMAP (previously the Conflict-free Smelters Programme), IRMA, ASI, Copper Mark, and RJC	Ease of adaptation of existing schemes. Ease of adoption. Internationally recognised by industry and stakeholders.	Complexity of compliance due to overlapping initiatives. Cost of implementation and auditing. Costs might disproportionately fall onto upstream users.

Tagging	ITSCI, Better Mining	Accompanies the commodity along its route (often from mining to refining), capturing more of the production line. Operational in fragile and volatile mining areas.	The credibility of certain schemes has been weakened due to fraud and corruption allegations, tag trading. Reliance on unpaid or underpaid state agents which favours corruption. Costs might disproportionately fall onto upstream users. It does not offer a whole-of-supply chain perspective. Some schemes are 'for profit'.
Digital Tagging	Circulor, Tracr, Valutrax, Minespider	Solves some validity and corruption problems through automated data entry automation. Blockchain tamper proofness, reduces corruptibility. Decentralisation and data secrecy of blockchain can improve stakeholder trust.	Human data entries remain points of weakness. Capital intensity potentially marginalises ASM communities and favours LSM. Lack of interoperability of Blockchain technology. Many schemes are 'for profit'.
Physical and chemical sample-based analyses	MaDiTraCe, TraceMet, Metalor, MineSpider, German Federal Institute for Geosciences and Natural Resources, BGR Analytical Fingerprint, Tracr, Provenance Proof	Relies on scientific and objective criteria. Enables end-to-end traceability of complex supply chains from the end of the chain up. Complementary to blockchain and other digital solutions.	Natural fingerprints can be erased or mixed through refining, making them unreadable further downstream. Natural fingerprints are not yet feasible for all commodities. Does not differentiate between legal and illegal actors sourcing from the same site. Industry mistrust in sharing commercially sensitive data and in adding nano tracers to raw material. Challenges with database building, difficult cooperation and data collection across thousands of mining companies and sites. The cost of scaling up is still unclear (still at the pilot stage). Little application to ASM so far.

Source: Authors's own compilation.

5 Evaluating technological innovation opportunities and their limitations

Technology is being applied to supply chains for 'mediation of the human element' to increase transparency and trust along the supply chain and facilitate the exchange of information along the value chain (Clavao and Archer, 2021). Digitalisation can enhance supply chain transparency and minimise opportunities for contamination through the use of embedded sensors, autonomously collected data, as well as cloud-based sharing and analysis (Pincheira et al., 2022). This Section discusses some of the relative merits of technological systems described in the mapping Section above.

5.1 Blockchain

Blockchain is a digital distributed ledger that maintains a continually growing list of ordered records called blocks. Blocks cannot be overwritten and contain information about the block preceding them, thereby forming a chain. Blockchain is a data management tool and is not a means of traceability. However, it can be used as a tool to digitise CoC data securely that would otherwise be stored as a paper trail or in other digital formats. Blockchain can allow companies to compile autonomously collected information from mines to smelters and downstream users in the form of a secure, tamper-proof, distributed digital ledger. Each supply chain's step adds a data block to the decentralised chain available to all actors within the chain – see Annex 3. The appeal of blockchain lies in it being tamper-proof and timestamped (Caplin, 2021), which theoretically eliminates fraud. The decentralised nature of blockchain may also overcome trust issues across supply chain actors through data secrecy.

However, blockchain technology almost always still relies on human-technology interactions and inputs at some point within the chain, as well as correctly encoded data. There is a risk that fake, redundant or useless information can be irreversibly registered on blockchains (Heldt and Pikuleva, 2024). As a response, some start-ups have entirely automated blockchain data entries. Quantities and weights from a singular source are detected and automatically encrypted into the blockchain. Furthermore, the few authorised personnel at mining sites interacting with blockchain entries are validated through facial recognition on mobile applications[15]. Some companies even fully automate excavation and transportation (Clavao and Archer, 2021).

5.2 Geo-chemical sample-based approaches

The geochemical approach consists of a multivariate isotope analysis of mineral samples. The isotopic composition of an element varies according to its origin, which enables scientists further down the supply chain to ascertain the geographical provenance of any given material. Once collected, the chemical data must be statistically analysed against a database of samples from existing mines. Scientists rely on continuing cooperation with private mining companies to share samples from their

[15] Interview with a traceability firm, January 2025.

mining sites for the database. Some mining companies have, though, shown limited openness to collaborating with scientists in populating these databases due to concerns regarding commercially sensitive data. Hence, existing databases have variable data quality, which so far is insufficient for commercial application (Kaikkonen et al., 2022).

Geo-chemical tools, such as the German Federal Institute for Geosciences and Natural Resources (BGR)'s analytical fingerprint (AFP) tool, focusing on tin, tungsten and tantalum in the Great Lakes region since 2006, can be used for dispute resolution. Since its inception, AFP has been envisioned as an 'optional forensic tool' to be utilised in the uppermost segments of 3TG supply chains during third-party audits and risk assessments at smelter and trade hub level to confirm the origin claims on tags, rather than substituting existing schemes. In addition, the AFP's narrower focus on a sub-region makes the database collection challenge more manageable.

However, there are technical limitations to geo-chemical approaches. Fingerprints from mined materials can vary markedly within one mining site or evolve during exploitation. Different sources (deposits and mines) may have overlapping fingerprints, such as isotopic signatures. Most natural fingerprints (including some isotopic versions) are altered during metallurgy and refining making them no longer exploitable, while ores from different sources are often blended at the processing stage (Kaikkonen et al., 2022). Linking a sample to a specific mine is sometimes impossible; in this case, the geochemical analysis can provide only a country of origin, which does not provide the degree of detail needed to capture fast-evolving conflict dynamics. Another limitation is that sample preparation for an analysis can take up to a week[16]. Hence, even if comprehensive databases were collected, geochemical fingerprinting cannot distinguish between responsible and irresponsible actors operating on the same site, which is a widespread issue in African mining sites (Huggins, 2013). The 'natural fingerprint' approach works only for the early stages of the value chain, as 'high pressure and high-temperature processes are involved in the refining of nickel and cobalt that are very likely to alter the original fingerprints, hindering the applicability of the physical traceability method' (Kaikkonen et al., 2022).

[16] Confidential interview with a scientist involved in geochemical fingerprinting, January 2025.

5.3 Artificial tagging

Figure 2: Supply chain penetration of comparative mineralogy-based methodologies

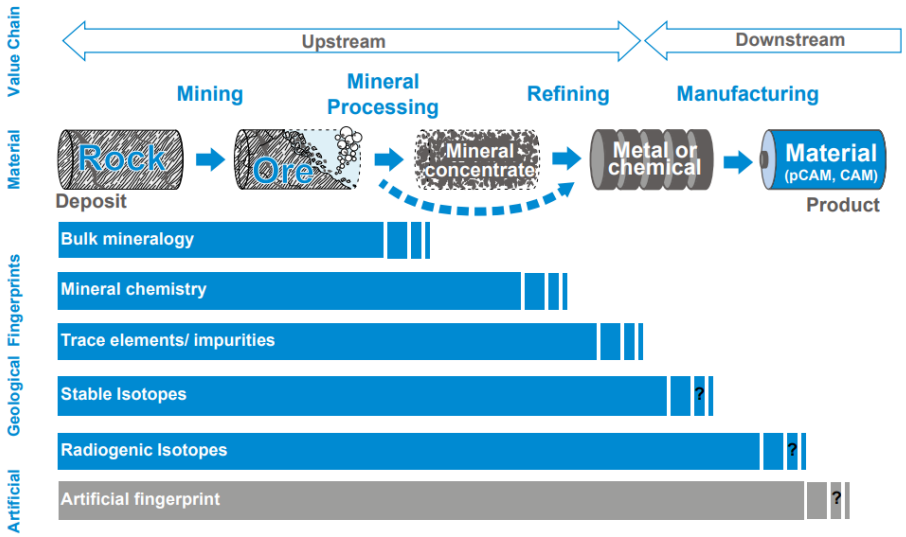


Fig. 11. Principle of the BATTRACE physical fingerprinting approach, modified after Dehaine et al. (2020).

Source: Q. Dehaine, S. P. Michaux, J. Pokki, M. Kivinen and A. R. Butcher, 'Battery minerals from Finland: Improving the supply chain for the EU battery industry using a geometallurgical approach', *European Geologist Journal*, Vol 5, No 11, 2020.

Artificial tagging is seen to have the greatest potential for full supply chain tracing – see Figure 1 above. Artificial tagging of raw materials is thus being explored as an alternative to natural fingerprinting. The technique consists of adding micro-tracers upstream at production sites, which creates a unique artificial fingerprint that can be detected further downstream, forming a signature that resists refining stages. Although this method is widely adopted in other sectors, such as the textile industry, issues of distrust remain in mining from companies sceptical of adding nano-tracers to the material they sell. They are wary of contaminating their materials and of potential penalties from downstream buyers for altering raw material compositions[17]. Whilst this perception can potentially be changed, artificial tagging is likely to work best in already well-controlled supply chains, being less suited to the complex and fragmented mineral supply chains stemming from volatile areas.

[17] Confidential interview with a scientist involved in artificial tagging, January 2025.

Box 2: Limitations to technological solutions

- Reservations in sharing commercially sensitive geological data, as well as geopolitical considerations in storing large volumes of data collected across jurisdictions.
- Capital intensity as well as uncertain costs of adaptation and upscaling are also factors.
- There is a need for a reliable and consistent energy supply, which is not the case in many current African mining areas.
- Remote and isolated artisanal mines in volatile areas present challenges for geochemical data sampling.
- Hardware and software underpinning these technologies are expensive and might lead to the further exclusion of communities engaged in artisanal mining for subsistence, with no access to computing machinery (Onifade et al., 2024: 525; Calvao and Archer, 2021). Greater technological fixes would 'facilitate forms of technocratic environmental governance that potentially alienate or marginalize nonexpert stakeholders' (Calvao and Archer, 2021: 4).

6 Recommendations

This paper has defined traceability as the ability to identify the historic origin of a product via custodianship, from miners to end users. It has demonstrated that this can be achieved by various means, including: CoC models; paper trails and the digitisation of product information using distributed ledger systems; as well as geochemical analysis. It has shown that different mechanisms are currently employed at specific stages throughout the value chain and that there is a persistent need to balance costs, ease of implementation and adoption, as well as certainty and credibility. Traceability schemes are highly dependent upon trust, not only between businesses along the value chain but with all stakeholders, especially regulators, consumers, citizens and communities in producing regions and states. In addition, it has shown that mineral, metal and gemstone traceability is technically possible and currently employed in some specific commodities. However, achieving traceability at scale across many highly complex mineral value chains is a significant challenge. Scalability challenges, especially when implementing systems beyond a 'closed pipeline' from producer to purchaser, include:

- Geographic and technical complexity where mineral supply chains span multiple countries and involve numerous technical processing steps. This can include sometimes conflicting compliance requirements across different jurisdictions and challenges associated with opportunities for corruption.
- Material transformation through processing stages.
- Data reliability and transmission of relevant, accurate and verifiable data across diverse operators with varying technological capabilities.
- Integrating ASM in ways that are cognisant of low-data connectivity environments and energy deficits.
- Standardisation and interoperability challenges between different traceability systems.

- Financial and human capital resource costs of implementing and auditing trackability schemes at scale.

Most importantly, implementing traceability is a necessary, albeit insufficient condition for ensuring that material originates from responsible businesses and operations. Operators must adhere to auditing and verification norms to ensure that they are implementing the standards they espouse. Traceability schemes must be governed and established in ways that respect human rights and deliver value for all stakeholders, where the benefits and costs are equitably distributed along the value chain.

The following recommendations focus on the scaling, adoption and understanding of traceability schemes, ensuring operational feasibility, stakeholder inclusion and equitable cost-sharing while addressing technological, regulatory and socio-economic challenges in implementing traceability schemes. An accompanying paper includes a more comprehensive set of recommendations that considers political realities and offers wider policy solutions.

- **Complementarity, interoperability and integration:** Blockchain should not be envisioned as a stand-alone answer to traceability but as a tool that can strengthen the quality of due diligence. Similarly, ambitions should be tempered regarding the development of a global geo-chemical solution. This should instead be seen as complementary to existing schemes, being used, for instance, either as a dispute-resolution tool when a production anomaly is detected or forensically at specific nodes in the supply chain. Standardising data-sharing protocols across jurisdictions and companies could address collaboration challenges and minimise duplication.
    - **European Commission**: Develop guidelines for standardising data-sharing protocols to minimise duplication and enhance collaboration.
    - **Executive Vice-President for Prosperity and Industrial Strategy:** within the mandate of overseeing the creation of the Critical Raw Materials Platform and implementing the CRMA, and through the strategic coordination role with DG GROW, DG CLIMA, DG ENER, the concerned Executive Vice-President can ensure the integration of traceability solutions into supply chain strategies and facilitate cross-departmental systemic standards for responsible sourcing and traceability requirements for CRMs, including data sharing and interoperability.
    - **European External Action Service (EEAS), 'Team Europe'**: The EEAS can leverage the 'Team Europe' approach to facilitate international cooperation and establish common traceability and data sharing standards. This includes standardisation of methodologies for data generation and setting data parameters to permit cross-comparison. Existing frameworks of international collaboration with key allies, such as the Minerals Security Partnership, as well as forums such as the G20, which transcends geopolitical divisions, can be used to promote and establish frameworks for information sharing and data collaboration.
    - **EU Commission/DG GROW**: Support the development and scaling of European and African traceability solutions that enhance supply chain transparency, focusing on interoperability with existing systems to ensure seamless integration. Leverage the

European Raw Materials Alliance – a DG GROW-supported network of organisations across the value chain, including the Raw Materials Investment Platform – to integrate those pre-requisite mechanisms for traceability. Work with the UN Economic Commission for Europe and OECD for standard setting for interoperability. Work with Horizon Europe R&D mainstream traceability into its research and investment in sustainable mining, materials substitution, recycling technologies and value chain circularity.

  - **Horizon Europe**: Fund research projects focused on developing technology-backed traceability systems adaptable to various supply chains, including those involving artisanal and small-scale mining. This research should emphasise interoperability, compliance and the integration of new technologies with existing systems, as well as being cognisant of energy and technology shortfalls in some international producing areas.
  - **Global Gateway**: drive investment into developing energy and telecommunications infrastructure in ASM mineral hotspots to enable digitisation of ESG performance management and traceability in these areas.

- **Compliance and enforcement:** Traceability schemes need to be flexible enough to accommodate material blending, aggregation and transformation at the smelting and processing stages. However, there is a risk of cosmetic compliance by companies using schemes as a tick-box exercise for responsible sourcing. MB CoC systems that rely on verifying corporate responsibility at origin address the limitations of physical traceability for highly blended supply chains but are built on trust in companies and state implementors, regulators and enforcers to ensure compliance. The involvement of industrial and ASM mining operations' host governments in certification, regulation and enforcement is critical to complement industry-led traceability efforts. There need to be consistent and enforceable legal frameworks in producing countries that establish the conditions for traceability mechanisms to function and ensure compliance, as well as potential licensing requirements. Likewise, governments and regional bodies that are implementing regulations on sourcing need to be consistent and clear in their expectations. This can include intergovernmental collaboration standards and reporting requirements, reducing duplication and easing compliance. Robust data collection and management systems can minimise corruption but they need to be complimented with safeguards to protect commercially sensitive data and establish trust between stakeholders. Similarly, traceability mechanisms should have built-in anti-corruption policies that apply to their initiatives and solutions.
  - **European Parliament**: Advocate for robust legal frameworks that ensure compliance or conformity to responsible business practices and that include traceability requirements, addressing the risk of cosmetic compliance by companies. This includes devising legislation that requires consistent reporting and enforcement standards across member states or defining the criteria for acceptable binding and enforceable voluntary opt-in mechanisms.

- **European Commission**: Develop and enforce regulations that accommodate blending, aggregation and material transformation in supply chains, ensuring that traceability schemes are flexible and effective. Set protocols on the prerequisites of reporting and verification as well as auditing for mass balance schemes and verification of their claims.
- **European Investment Bank**: Provide financial support for traceability projects to support implementation and scaling that enhance compliance and enforcement mechanisms in supply chains, particularly in regions lacking robust legal frameworks.
- **Team Europe, EEAS, European Commission**: Support governments in higher-risk jurisdictions to put in place the regulatory framework that governs traceability in minerals supply chains and work with recognised and credible organisations such as the OECD.

- **ASM Application:** Artisanal mining continues to be an important part of CRM supply chains and a vital aspect of international development efforts to connect important industries for rural employment in Africa to global economic opportunities. Efforts to promote traceability should be supported to proactively include these sectors and international stakeholders should be fully aware of how regulatory requirements might impact beneficiaries of wider developmental ambitions. ASM operators should be consulted to guide how existing solutions could be better adapted to their capacities and be trained on traceability systems, responsible sourcing and compliance regulations. This should include fostering trust and transparency with state agencies. Development partners can assist in identifying traceability schemes that are readily applicable to ASM operations, providing technical and financial support to ASM communities for participation in traceability systems and avoiding exclusionary outcomes.
  - **European Commission and EEAS**: Work with international partners to ensure that regulatory requirements for traceability do not inadvertently exclude artisanal mining operations. This involves fostering trust and transparency between ASM operators, state agencies, standard setters and initiatives and continental bodies such as the African Minerals Development Centre.
  - **Global Gateway**: Support initiatives that provide economic resilience for mining communities, encouraging participation in traceability systems and promoting sustainable development.
  - **European Commission**: Develop programmes to train ASM operators on traceability systems and compliance regulations, ensuring that these operations are integrated into global supply chains without exclusionary outcomes.

7 References

Alliance for Responsible Mining and Fairmined, 'Fairmined Standard for Gold from Artisanal and Small-Scale Mining, Including Associated Precious Metals', Report, 05 April 2024.

Badiye, A., Kapoor, N. and Menezes, R. G., 'Chain of Custody', 13 February 2023, StatPearls, StatPearls Publishing, Treasure Island, 2025.

Barash-Harman, Y., 'Effect of trade and manufacturer traceability on the environmental performance of local companies in emerging economies', *Regulation & Governance*, Vol 14, No 4, 2018, pp. 804-829.

Blore, S., 'Contraband Gold in the Great Lakes Region: In-Region Cross-Border Gold Flows Versus Out-Region Smuggling', *Partnership Africa Canada*, Report, May 2015.

Brink, S. van den, Kleijn, R., Tukker, A. and Huisman, J., 'Approaches to responsible sourcing in mineral supply chains', *Resources, Conservation and Recycling*, Vol 145, 2019, pp. 389-398.

Calvão, F. and Archer, M., 'Digital extraction: Blockchain traceability in mineral supply chains', *Political Geography*, Vol 87, 2021.

Campbell, B. K., *Mining in Africa: Regulation and Development*, London Pluto Press, London, 2009.

Caplin, A., 'Blockchain technology: The future of mining?', *Fasken*, 13 December 2022.

Deberdt, R. and Le Billon, P., 'Conflict minerals and battery materials supply chains: A mapping review of responsible sourcing initiatives', *The Extractive Industries and Society*, Vol 8, No 4, 2021.

Deberdt, R., 'Land access rights in minerals' responsible sourcing. The case of cobalt in the Democratic Republic of the Congo', *Resources Policy*, Vol 75, No 1, 2022.

Dehaine, Q., Michaux, S. P., Pokki, J., Kivinen, M. and Butcher, A. R, 'Battery minerals from Finland: Improving the supply chain for the EU battery industry using a geometallurgical approach', *European Geologist Journal,* Vol 5, No 11, 2020.

European Parliament, 'Report on the role of EU development policy in transforming the extractive industries for sustainable development in developing countries (2023/2031(INI))', PE750.116v02-00, 30 October 2023.

European Parliament, Rules of Procedure of the European Parliament: Annex VI: Powers and Responsibilities of Standing Committees, 10th Parliamentary term, January 2025.

Finn, B. M., Simon, A. and Newell, J., 'Decarbonization and social justice: The case for artisanal and small-scale mining', *Energy Research & Social Science*, Vol 117, 2024.

Global Reporting, Advancing Reporting On Responsible Mineral Sourcing, 2021.

Global Witness, The ITSCI laundromat: How a due diligence scheme appears to launder conflict minerals, Report, 26 April 2022.

Gouby, M., 'Conflict Minerals' in Congo: Do Traceability Schemes Work?', *Foreign Policy*, 22 May 2024.

Heldt, L. and Pikuleva, E., 'When upstream suppliers drive traceability: A process study on blockchain adoption for sustainability', *International Journal of Physical Distribution & Logistics Management*, Vol 1, No 1, 2024.

Hilson, G., ''Constructing' Ethical Mineral Supply Chains in Sub-Saharan Africa: The Case of Malawian Fair Trade Rubies', *Development and Change*, Vol 45, No 1, 2014, pp. 53–78.

Huggins, C., 'Is collaboration possible between the small-scale and large-scale mining sectors? Evidence from 'Conflict-Free Mining' in the Democratic Republic of the Congo (DRC)', *The Extractive Industries and Society*, Vol 13, 2022.

Initiative for Responsible Mining Assurance, IRMA Chain of Custody Standard for Responsibly Mined Materials, Version 1.0, October 2024.

Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development, 'Global Trends in Artisanal and Small-Scale Mining (ASM): A Review of Key Numbers and Issues', Report, January 2018.

International Energy Agency, and Organisation for Economic Co-operation and Development. "The Role of Traceability in Critical Mineral Supply Chains – Analysis - IEA", *IEA*, 28 February 2025.

International Peace Information Service, 'EU Acknowledges Shortcomings of Conflict Mineral Regulation', Policy Paper, 2024.

International Social and Environmental Accreditation and Labelling Alliance, Chain of custody models and definitions: A reference document for sustainability standards systems, and to complement ISEAL's Sustainability Claims Good Practice Guide, Reference Document, 2016.

Kaikkonen, H., Kivinen, M., Dehaine, Q., Pokki, J., Eerola, T., Bertelli, M. and Friedrichs, P., 'Traceability methods for cobalt, lithium, and graphite production in battery supply chains Assessing geo-based fingerprinting as a method for battery raw materials' traceability', Research Report, *Geological Survey of Finland*, 2022.

Kapoor, I., Pratt-Rogers, W. and Kahraman, M. M., 'The problem of conflict minerals: A review of current approaches and a web 3.0 inspired road ahead', *Resources Policy*, Vol 79, 2022.

Kim, Y. H. and Davis, G. F., 'Challenges for Global Supply Chain Sustainability: Evidence from Conflict Minerals Reports', *Academy of Management Journal*, Vol 59, No 6, 2016, pp. 1896–1916.

Landau, I., 'Human rights due diligence and the risk of cosmetic compliance', *Melbourne Journal of International Law*, Vol 20, No 1, 2019, pp. 1-27.

Le Billion, P., 'The political ecology of war: natural resources and armed conflicts', *Political Geography,* Vol 20, No 5, 2003, pp. 561 – 584.

Le Billon, P. and Spiegel, S., 'Cleaning mineral supply chains? Political economies of exploitation and hidden costs of technical fixes', *Review of International Political Economy*, Vol 29, No 3, 2021, pp. 768–791.

Levin, E. and Cook, R., *'Mineral Supply Chain Due Diligence Audits and Risk Assessments in the Great Lakes Region'*, Analysis Report, *International Conference of the Great Lakes Region*, 2013.

Mancini, L., Eslava, N. A., Traverso, M. and Mathieux, F., 'Assessing Impacts of Responsible Sourcing Initiatives for cobalt: Insights from a Case Study', *Resources Policy*, Vol 71, No 1, 2021.

Melcher, F., Dietrich, V. and Gäbler, H. E., 'Analytical Proof of Origin for Raw Materials', *Minerals*, Vol 11, No 5, 2021.

Müller-Koné, M., 'Débrouillardise: certifying 'conflict-free' minerals in a context of regulatory pluralism in South Kivu, DR Congo', *The Journal of Modern African Studies*, Vol 53, No 2, 2015, pp. 145–168.

Onifade, M., Adebisi, J. A. and Zvarivadza, T., 'Recent advances in blockchain technology: prospects, applications and constraints in the minerals industry', *International Journal of Mining, Reclamation and Environment*, Vol 38, No 7, 2024, pp. 497–533.

Partnership Africa Canada, *A Guide to the Kimberley Process*, September 2013.

Partzsch, L., *Alternatives to Multilateralism: New Forms of Social and Environmental Governance*, The MIT Press, Cambridge, 2020.

Pincheira, M., Antonini, M. and Vecchio, M., 'Integrating the IoT and Blockchain Technology for the Next Generation of Mining Inspection Systems', *Sensors*, Vol 22, No 3, 2022.

Postma, H., Geenen, S. and Partzsch, L., 'Digging for due diligence: The case of non-state mineral supply chain regulation by ITSCI in Rwanda', *The Extractive Industries and Society*, Vol 8, No 3, 2021.

Radley, B. and Vogel, C., 'Fighting windmills in Eastern Congo? The ambiguous impact of the 'conflict minerals' movement', *The Extractive Industries and Society,* Vol 2, No 3, 2015, pp. 406–410.

RCS Global, Blockchain for traceability in minerals and metals supply chains: Opportunities and Challenges, 2017.

Responsible Minerals Initiative, 'New Supply Chain Tracing Project to Develop An Industry Protocol and Platform to Increase Downstream Tracing of Goods Made With Child and Forced Labor', Press Release, 2021.

Schöneich, S., Saulich, C. and Müller, M., 'Traceability and foreign corporate accountability in mineral supply chains', *Regulation and Governance*, Vol 17, No 4, 2023, pp. 954–969.

Sirven, J. B., Pailloux, A., M'Baye, Y., Coulon, N., Alpettaz, T. and Gossé, S., 'Towards the determination of the geographical origin of yellow cake samples by laser-induced breakdown spectroscopy and chemometrics', *Journal of Analytical Atomic Spectrometry*, Vol 24, No 4, 2009, pp. 451–459.

Stoop, N., Verpoorten, M. and van der Windt, P., 'More legislation, more violence? The impact of Dodd-Frank in the DRC', *PLOS One*, Vol 13, No 8, 2018.

Timmer, S. and Kaufmann, L., 'Conflict minerals traceability – a fuzzy set analysis', *International Journal of Physical Distribution & Logistics Management*, Vol 47, No 5, 2017, pp. 344–367.

United Nations Development Programme and Business for Social Responsibility, 'A Guide to Traceability A Practical Approach to Advance Sustainability in Global Supply Chains', Report, 2014.

Vandome, C. and Dideberg, R., 'Traceability of CRM with a focus on Africa – Policy Options', European Parliament's Directorate-General for External Policies, 2025.

Vandome, C., 'How can African states benefit from the EU Critical Raw Material Act and the UK Critical Minerals Strategy?', *Africa Policy Research Institute*, APRI Policy Brief, 2024.

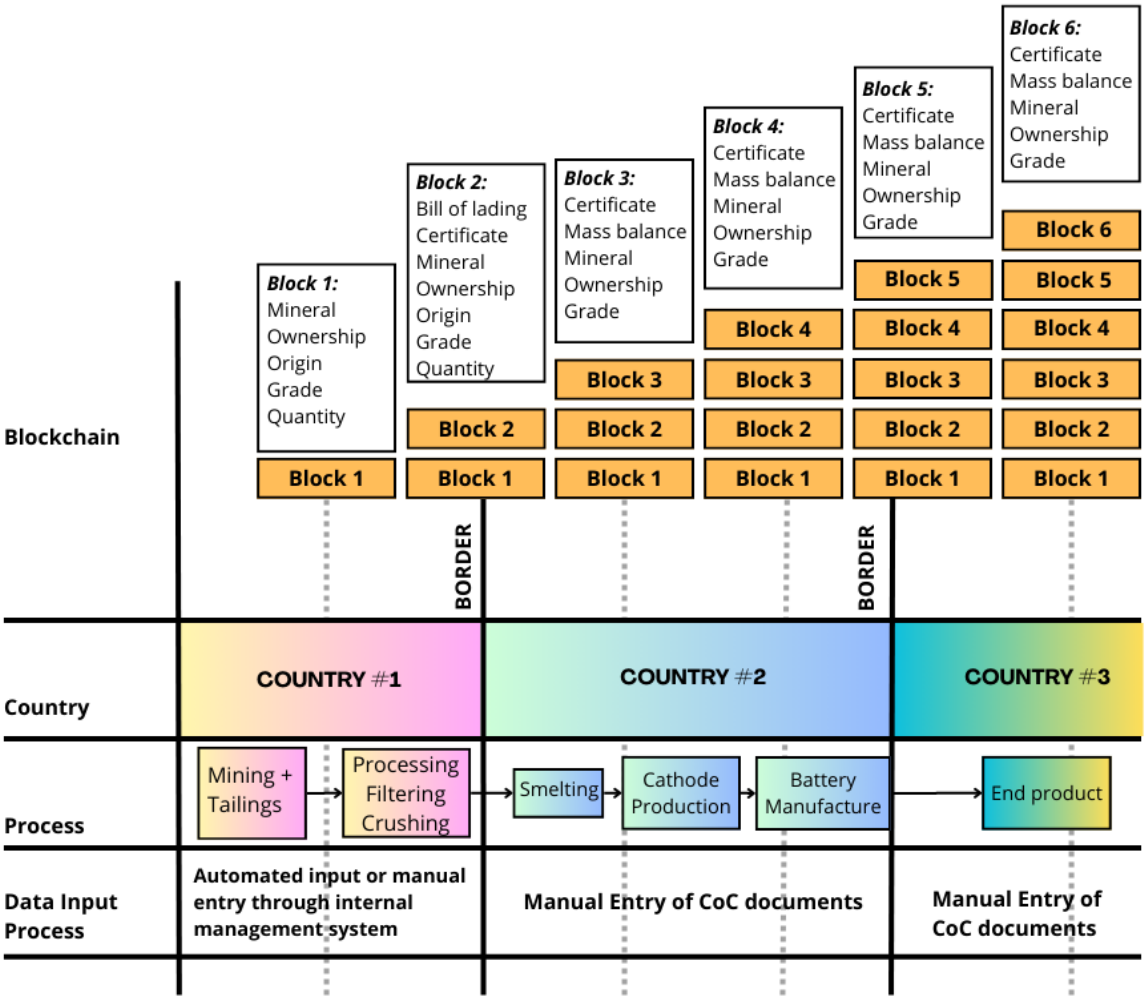
Vogel, C. N., *Conflict Minerals, Inc: War, Profit and White Saviourism in Eastern Congo,* Hurst Publishers, London, 2022.

World Bank. Achieving Sustainable and Inclusive Artisanal and Small-Scale Mining (ASM): A Renewed Framework for World Bank Engagement, World Bank Group, 2024.

Annexes

Annex 1: Visualising blockchain as a tracing tool

This visual depicts the type of information being added as blocks into the blockchain for material as it moves through the supply chain. Once a block has been input, it cannot be overwritten and hence it provides the end user with detailed information on the journey taken by the material.



Source: Author's own, inspired by RCS Global, Blockchain for traceability in minerals and metals supply chains: Opportunities and Challenges, 2017: 5.

Annex 2: Pathways to traceability – summary points from the OECD and the International Energy Agency 2025 report on 'The Role of Traceability in Critical Mineral Supply Chains'

Step 1: Determine policy objectives and understand the supply chain context

- Define clear policy objectives for mineral traceability (for instance, ESG compliance, trade sanctions, supply chain transparency).
- Assess national mineral supply chains, identifying key actors and processes.
- Map the flow of minerals (mined, processed, imported, exported) within the country.
- Align traceability goals with broader due diligence efforts.
- Avoid policies that encourage operators to disengage from high-risk supply chains instead of addressing risks.

Step 2: Choose which products to focus on

- Identify minerals most relevant to the country's economy and policy priorities.
- Mineral-producing countries: focus on domestic production to enable product differentiation and price premiums.
- Midstream/downstream countries: focus on traceability of imported minerals to ensure ESG compliance and regulatory adherence.
- Consider geopolitical factors and trade dependencies when selecting minerals.

Step 3: Determine which information should be collected and shared

- Establish minimum traceability data requirements: origin, geographical path, chain of custody and physical evolution.
- Ensure alignment with international standards (e.g., OECD Due Diligence Guidance, UN Transparency Protocol).
- Define data-sharing protocols to enhance transparency without exposing sensitive commercial information.
- Support integration of ESG performance metrics into traceability systems.

Step 4: Choose which operators to focus on

- Identify key operators responsible for collecting and sharing traceability data (for instance, miners, refiners, traders, manufacturers).
- Upstream-focused approach: engage mining companies and processors to ensure reliable origin data.
- Downstream-focused approach: require midstream/downstream operators to demand traceability from suppliers.

- Tailor traceability responsibilities based on a country's role in the supply chain.

Step 5: Promote the development and use of interoperability protocols

- Establish common standards for traceability data collection and sharing.
- Avoid reliance on single national traceability platforms; instead, promote interoperability among systems.
- Encourage the adoption of flexible, technology-neutral data-sharing protocols.
- Implement data privacy protections to address commercial confidentiality concerns.
- Utilise existing frameworks such as the UN Transparency Protocol to accelerate development.

Step 6: Establish trust mechanisms

- Develop verification systems to ensure data accuracy and prevent fraud.
- Issue government-backed credentials (for instance, business registration numbers, operating licenses) as verifiable documents.
- Establish Authorised Economic Operator programmes to recognise compliant businesses.
- Implement digital origin certification for minerals to enhance credibility in international trade.
- Strengthen oversight mechanisms to prevent corruption and manipulation of traceability data.

Step 7: Create incentives for increasing traceability

- Provide financial support for traceability infrastructure in mineral-producing regions.
- Offer tax incentives or credits to encourage responsible sourcing from designated jurisdictions.
- Establish regulatory requirements that integrate traceability into due diligence obligations.
- Ensure new traceability mandates align with industry capacity and market realities.
- Develop public-private partnerships to share the costs and benefits of traceability implementation.

Step 8: Engage with stakeholders in foreign jurisdictions

- Facilitate international collaboration to address supply chain complexities.
- Engage with foreign regulatory bodies, industry groups and civil society to promote data-sharing.
- Support technical assistance and training programmes for traceability adoption in developing producer countries.
- Provide financial aid for traceability projects in mineral-rich regions.
- Promote best practices and technology transfer to strengthen global traceability systems.

Source: https://www.oecd.org/content/dam/oecd/en/publications/reports/2025/02/the-role-of-traceability-in-critical-mineral-supply-chains_4e5cc44a/edb0a451-en.pdf

Annex 3: Typology of traceability initiatives

Name	Commodity	Description	Notes
EU Conflict Mineral Regulation	3TG	Lays out supply chain due diligence requirements for all EU importers of tin, tantalum, tungsten and gold from CAHRAs.	Adopted in 2017.
EU Directive on Corporate Sustainability Due Diligence	NA	Aims to ensure companies proactively identify, prevent and mitigate adverse human rights and environmental impacts across their operations and value chains.	Adopted in 2024.
EU CSRD	NA	Aims to improve corporate transparency and accountability regarding ESG issues. It applies to non-EU companies generating over EUR 150 million on the EU market.	Entered into effect in 2023.
EU Critical Minerals Act	List of 34 critical minerals (5th update 2023)	Addresses issues of processing and recycling and supply chain challenges.	Adopted in 2024.
EU Battery Regulations	Cobalt, natural graphite, lithium, nickel	Requires battery manufacturers in the EU to 'establish and operate a system of controls and transparency for the supply chain, including a Chain of Custody or traceability system, identifying upstream actors'.	Adopted in July 2023.
Chinese Due Diligence Guidelines for Responsible Mineral Supply Chains	All minerals	Voluntary guidelines designed to align Chinese company due diligence to international standards. Applicable to all Chinese companies which are extracting and/or using mineral resources and their related products and are engaged at any point in the supply chain of minerals.	Adopted in 2015.
China Chamber of Commerce of Metals, Minerals, and Chemicals Importers and Exporters' Guidelines for Social Responsibility in	All minerals	Guidelines structured around ISO 26000 Guidance on Social Responsibility with some exceptions to better reflect the specifics of the mining industry. They take into account the Ten Principles of the United Nations Global Compact and	Adopted in 2014.

Outbound Mining Investment		other international standards and initiatives.	
China Rare Earth Management Regulation	Rare Earth Elements	Establishes traceability requirements for domestic enterprises engaged with rare earth elements (Art14). Establishes a rare earth product traceability information system and emphasises existing export controls regulation	Adopted in October 2024 Part of a wider legislation imposing control on rare earth elements exports.
US Dodd-Frank Act Section 1502	3TG	Part of the Dodd-Frank Wall Street Reform and Consumer Protection Act requires publicly traded companies to ensure that the raw materials they use to make their products are not tied to the conflict in Congo by tracing and auditing their mineral supply chains.	Adopted in 2010
ILO Safety and Health in Mines Convention	All minerals	Advances the right to a safe and healthy working environment for all mineworkers require due diligence and efforts from employers.	1995
ILO Worst Forms of Child Labour Convention	All industries	International convention ratified by 132 countries to end the worst child labour practices including slavery, forced labour, bondage and work that harms children's health, safety, or morals.	1999
ILO Minimum Age Convention	All industries	International conventions setting a minimum age for work at 15 years, for light work 13 years and for dangerous work at 18 years.	1973
Name	**Commodity**	**Description**	**Notes**
Kimberley Process Certification Scheme	Diamonds	UN-backed, state-led multi-stakeholder initiative. 86 countries with an annual rotation of country chairs. Industry and civil society actors are observers. Combines industry certification with government import and export legislation.	Established in 2003.

Extractive Industry Transparency Initiative Standard	Mining in general	Public-private partnership seeking to improve the transparency of extractive industries. Membership is country-based. Issues the Extractive Industries Transparency Initiative standard for the governance of natural resources. The standard consists of seven requirements.	Established in 2003, aims to increase transparency over payments and revenues.
International Conference on the Great Lakes Region Mineral Certification Scheme	3TG	12 Great Lakes and neighbouring countries are members. In 2010, they created the Regional Initiative against the Illegal Exploitation of Natural Resources, which includes six inter-linked tools that the International Conference on the Great Lakes Region member states committed to implementing, namely formalisation of the ASM sector; RCM; the Extractive Industries Transparency Initiative; a database on conflict mineral flows in the region; a whistle-blowing mechanism; and the harmonisation of relevant national legislation across the region Within this remit, the RCM is implemented under the authority of individual member states.	Established in 2010 deemed the main African-led certification scheme in the region.
European Partnership for Responsible Minerals	3TG	Governments, companies and civil society are part of the association. It funds various responsible sourcing projects supporting the social and economic conditions of ASM communities in CAHRAs and assist companies with their due diligence effort.	Established in 2016 by a group of governments (Netherlands, United Kingdom) companies (Intel, Apple, Philips) and civil society organisations (IPIS, Solidaridad).
The Swiss Better Gold Initiative	Gold	A public-private partnership between the Swiss Better Gold Association and the Swiss State Secretariat for Economic Affairs.	In 10 years of activity (2013 – 2023), Swiss Better Gold supported supply chains for a total of 15 tons of gold between ASM producers and Swiss

			Better Gold Members.
BGR Certified Trading Chains	3TG + copper, cobalt, galena, and semi-precious stones	Conceived by the German Geological Institute in collaboration with the DRC and Rwanda national partners, in line with their mining legislation. Certification against five principles schemes, including environmental and human rights considerations on top of conflict-free.	Great Lakes focus, 2009, first pilot project in Rwanda.
Global Investor Commission on Mining 2030	N/A	Investor-led initiative focusing on the role of finance in a socially and environmentally responsible mining sector	Launched in 2022, it includes a working group on traceability.
The UN Secretary-General's Panel on Critical Energy Transition Minerals	N/A	The Panel brings together governments, intergovernmental and international organisations, industry and civil society to develop a set of common and voluntary principles to build trust, guide the transition and accelerate the race to renewables.	Launched in 2024.
Name	**Commodity**	**Description**	**Notes**
OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas	All minerals from CAHRAs	Provides step-by-step management recommendations endorsed by governments for global responsible supply chains of all minerals for companies to respect human rights and avoid contributing to conflict	Last updated in 2016.
Chinese Due Diligence Guidelines for Responsible Mineral Supply Chains	All minerals	The Guidelines are designed to align Chinese company due diligence with international standards and allow for mutual recognition with existing international initiatives and legislations.	Launched in 2015.
International Finance Corporation Performance Standard on Environmental and Social Sustainability	All mining	Eight performance standards directed towards clients, guiding how to identify risks and impacts, and are designed to help avoid, mitigate, and manage risks and impacts as a way of doing business sustainably, including stakeholder engagement and	Established 2012.

		disclosure obligations of the client in relation to project-level activities.	
Dubai Multi Commodities Center Practical Guidance for Market Participants in the Gold and Precious Metals Industry	All minerals	Dubai Multi-Commodities Centre and Government of Dubai, Mandatory for all Centre member refineries on Dubai Good Delivery List (currently 15 refineries).	Established 2012.
UN Guiding Principles on Business and Human Rights	Includes minerals, among others	Global framework outlining the responsibilities of businesses and states to prevent, address, and remedy human rights abuses linked to business activities.	Unanimously endorsed by the UN Human Rights Council in 2011 following a six-year process led by John Ruggie, the then UN Secretary-General's Special Representative for Business and Human Rights.
UN Voluntary Principles on Security and Human Rights	Includes minerals, among others	Guidelines for companies to ensure that their security operations respect human rights, particularly in the extractive sector.	Principles established following multi-stakeholder process in 2000. The Voluntary Principles Initiative established as an international multi-stakeholder forum for the development and implementation of the Voluntary Principles.
IRMA Chain of Custody Standard for Responsibly Mined Materials	All minerals	Multi-stakeholder initiative. Global Standard 'Chain of Custody Standard for Responsibly Mined Materials'. A self-assessment tool for companies which offers independent third-party verification and certification against a comprehensive standard. Based on a mine score instead of a pass/fail approach	IRMA founded 2006. Chain of Custody standard launched in 2024.

Name	Commodity	Description	Notes
Aluminium Stewardship Initiative	Aluminium	Sets performance and CoC standards for the aluminium industry, resulting in certification	Established in 2012.
Cobalt Industry Responsible Assessment Framework	Cobalt	Guidance for companies to demonstrate responsible cobalt sourcing. Five key objectives and seven guiding principles. Cobalt Institute in collaboration with Responsible Compliance Solutions Global (responsible sourcing consultancy). Annual assessment.	Established in 2019.
Copper Mark	Copper, molybdenum, nickel and zinc	Based on due diligence audits at mining sites against the copper mark standard, it delivers a certification.	Established in 2020. Financed through annual fees of participants.
Fairmined	Gold	Alliance for Responsible Mining scheme focused on ASM labour conditions and socio-economic benefits. Involves strict CoC systems and standards for social, labour, environment and trading performance.	Established in 2004. Main focus is Latin America.
International Council on Mining and Metals	All minerals	10 Mining principles for industries, a set of 39 performance expectations.	Industry initiative founded in 2022.
RJC CoC Certification	Gemstones, diamonds, gold, silver, platinum.	RJC Certification requires independent third-party auditing by RJC-accredited auditors to verify that a member's management systems and performance conform to the RJC Code of Practices.	RJC was founded in 2005. CoC certification was established in 2012 and revised in 2017.
RMAP	All minerals from Conflict-Affected and High-Risk Areas	RMI flagship programme tracks company completion annually against RMAP standards, focusing on smelters and refiners' third-party assessment. Participating smelters and refiners are then publicly listed.	RMAP for tin, tantalum, tungsten, and gold was established in 2017. The RMAP for cobalt was established in 2018.
RMI	All minerals	A coalition of industry stakeholders supporting select projects in	Umbrella initiative comporting more

		responsible mining. Includes the RMAP.	initiatives such as RMAP
London Bullion Market Guidance Documents	Gold, silver, platinum, palladium	Based on OECD guidelines, London Bullion Market Association guidance includes Responsible Gold Guidance, the Responsible Silver Guidance, the Responsible Platinum and Palladium Guidance. Mandatory for all Good Delivery refiners wishing to trade with the London Bullion market	Programme of guidance documents began in 2012 with the launch of gold Good Delivery.
ResponsibleSteel	Steel	Responsible steel standards consist of 13 ESG guidelines and a certification system through sites.	Multistakeholder initiative established in 2015.
Tungsten Industry – Conflict Minerals Council	Tungsten	Industry-led framework, working closely with RMI to ensure alignment of the tungsten industry with the existing responsible sourcing requirements. The RMAP tungsten smelter standard has been developed in consultation and collaboration with Tungsten Industry – Conflict Minerals Council to meet the realities of the tungsten supply chain.	Less than 3 % of global tungsten is mined in the DRC, with the bulk of mineral originating and processed in China.
World Gold Council Conflict-free gold standard	Gold	Standard to help companies operationalise OECD due diligence, industry-led coalition to address the challenges of conflict gold.	Established in 2012 by industry membership organisation.
World Gold Council Responsible Gold Mining Principles	Gold	World Gold Council's 10 principles for gold mining companies establishing ESG standards for the gold mining industry Collaboration with the International Council on Mining and Metals is needed to align the standards with wider industry standards.	Framework established in 2019.
Name	**Commodity**	**Description**	**Notes**
Better Mining	3TG	Responsible Compliance Solutions' digitally enabled, ASM upstream assurance and improvement programme involves staff presence in the mines at all times.	It serves around 33 000 ASM miners in the African Great Lakes Region.

Global Battery Alliance	Battery Minerals	A partnership of 170+ businesses, governments, academics, industry actors, as well as international and non-governmental organisations. The battery passport establishes a digital twin of the physical battery that conveys information about all applicable sustainability and lifecycle requirements based on a comprehensive definition of a sustainable battery.	Two rounds of pilots were completed.
Gold Bar Integrity Programme	Gold	The Security Feature is a physical feature that will establish the identity and verify the authenticity of a gold bar, akin to a bar passport, which will link to the Gold Bar Integrity Database. Centralised platform creates an immutable record of what gold has left a mine site: London Bullion Market Association and World Gold Council.	A pilot concluded in 2022.
International Tin Supply Chain Initiative	3TG from Burundi, DRC, Rwanda, and Uganda	Established in 2009 by the International Tin Association, a tin industry coalition run by Congolese state agents from mining sites through to smelters. Tags are sealed on bags of ore at independently audited mines. Traceability data is then encoded and transmitted to downstream users.	Aim to lessen the risk of unfounded disengagement from CAHRAs by businesses.
Responsible Sourcing Blockchain Network	3TG	Collaboration between IBM, Responsible Compliance Solutions Global, Ford Motor Company, Volkswagen Group, LG Chem and Huayou Cobalt. Open industry-wide blockchain platform to trace responsibly produced minerals from source through to end product. Focus on large-scale mining operations, exploring ASM avenues with Better Mining.	2018 pilot, now fully deployed

Analytical Fingerprinting method	Tin, Tantalum and Tungsten	BGR: sample analysis against reference data from the declared mine to test the bag and tag claim of origin.	Developed as a complementary tool to enhance the validity of existing schemes. Not a stand-alone solution.
Authentia	Diamonds	Combination of nano-marking and blockchain.	Platform launched in 2024, claiming 97 contracts with small mines in Africa.
BullionProtect	Gold	Gold authenticity verification device QR code embedded in the seal, readable by smartphone. The seal is very robust and cannot be removed without destroying it.	Developed by the Swiss Metalor and SICPA S.A.
Circularise	Battery materials	Battery passport solution using blockchain technology.	Founded in 2016. Emphasis on circular economy.
Circulor	Battery materials	Blockchain-based traceability solution.	Founded in 2017. Clients include Ford, Volvo, Mercedes and others.
GeoBlock	Gold	Swiss tech start-up focused on traceability of precious metals through spectrometer analysis of gold against a database of mining sites.	
Geoforensic Passport by Metalor	Gold	Scientific collaboration between Metalor Technologies and the University of Lausanne. Multivariate analysis against a database.	
MaDiTraCe	Cobalt, Lithium, Graphite	Develops a portfolio of digital, mineralogical, and geochemical solutions to traceability gaps, including the CERA 4in1 certification scheme and battery passport as well as geochemical fingerprinting and artificial tagging.	Pilot projects.
Mineral Output Statistical Evaluation System	Mainly copper	Designed by the UNCTAD and the Zambian Revenue Authority to detect illicit trade practices that drain billions of dollars each year from the copper-rich nation and its people.	Focus on African governments re-capturing the due taxation rather than

		Spots the under-declaration of exports through statistical tool. Customs automation with ASYCUDA software.	end-user ethical concerns.
Provenance Proof	Gemstones	Offers proof of origin through: - Physical tracers (nanolabels) are applied at the production stage and leave a permanent mark. - Emerald Paternity tests at authorised labs prove the origin of the end user. Also curates a platform and database for approved gems.	
TraceMet	Iron, Copper	Public-private partnership between the Swedish Industry Association for Mines, minerals and metal producers in Sweden, the Swedish Energy Agency and other private companies. Blockchain technology for mass balance accounting.	Pilot projects ended in 2020.
Tracr	Diamonds	DeBeer's diamond traceability platform, digitalisation and tracking of all stages of production from mine to consumer.	Launched in 2018, opened up to the wider diamond industry in 2023.
Valutrax	Ferronickel, copper concentrates and iron ore mined products	Anglo-American's proprietary mineral traceability platform offers a comprehensive overview of a product's tracing information.	A pilot launched in 2022.

DIRECTORATE-GENERAL FOR EXTERNAL POLICIES
EXTERNAL POLICIES ANALYSIS AND SUPPORT UNIT

European Parliament

STUDY

Traceability of critical raw materials with a focus on Africa – Options for Implementation

ABSTRACT

This paper provides policy analyses and recommendations for the European Union on traceability for critical raw materials supply chains, including existing mechanisms and technological advances. It also assesses the effectiveness of both established and innovative pathways for implementing credible traceability systems, considering their implications for the European Union's global positioning and existing regulatory framework. It provides options and analysis for implementation, including political and diplomatic collaboration, that consider African perspectives together with the needs for traceability and broader objectives in their various mineral sectors.

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Executive summary

The development, implementation and enforcement of traceability in Africa require a strong, clear, coherent and consistent demand, signalling the need to comply or conform with regulations and standards to gain market access from the European Commission as a regulator.

Achieving the European Union's (EU) traceability objectives depends on African states' supporting broader legal enforcement and implementation capacities for the sector's stronger institutional governance. Such initiatives should not be externally imposed but rather undertaken *with* African governments and regional bodies.

The EU should continue to support the scientific research and development of technology that has advanced traceability mechanisms, buttressed with increased social science research on the impact and operational feasibility of such technology.

EU diplomatic and economic resources can play a more active role in assisting industrial operators as well as artisanal and small-scale mining producers, not only in implementing and enforcing standards but also in adopting traceability mechanisms strategically targeted towards EU partnership countries and EU-supported transnational development corridors.

International regulations drive responsible sourcing, but clarity is needed on which traceability schemes would be deemed acceptable. Traceability is possible, but costly. Industry-led initiatives can be widespread, but risk placing weak enforcement and compliance burdens on producers. Uneven regulation and minimal enforcement further undermine traceability efforts.

Advances such as artificial intelligence and automation improve monitoring and reduce fraud, yet the benefits mainly apply to vertically integrated supply chains. Digitisation of artisanal and small-scale mining remains experimental and may create barriers to formalisation. African governments lack the capacity for tech-driven traceability, raising concerns over data ownership, cyber risks and unintended socio-economic impacts.

African nations aim to move beyond raw exports by enhancing local beneficiation. While traceability aids market access, concerns persist not only about costs and feasibility, but also the exclusion of small-scale producers by European regulations. Challenges include limited infrastructure and financial constraints, requiring capacity-building, investment in digital literacy and inclusive policymaking.

The race for critical raw materials is shaped by global competition, with the EU facing challenges from China and the United States (US) of America. Vertically integrated Chinese supply chains, instigated by long-term political strategy, have concentrated processing capacity for many critical minerals in China. International collective action to support diffuse supply chains, previously under US leadership and subsidies could be replaced by more mercantilist direct actions under the presidency of Donald Trump. EU activities to promote global production by supporting energy and infrastructure projects via the European Investment Bank, Global Gateway, and other initiatives could offer opportunities to integrate traceability concepts. Regulatory harmonisation and digital trade facilitation are key.

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List of abbreviations

AfCFTA	African Continental Free Trade Agreement
AfDB	African Development Bank
AI	Artificial Intelligence
AMDC	African Minerals Development Centre
AMV	African Mining Vision
ASI	Aluminium Stewardship Initiative
ASM	Artisanal and Small-Scale Mining
BGR	Federal Institute for Geoscience and Natural Resources
BRI	Belt and Road Initiative
CAHRA	Conflict-Affected And High-Risk Area
CBAM	Carbon Border Adjustment Mechanism
CoC	Chain of custody
CRM	Critical Raw Materials
CRMA	Critical Raw Material Act
CSDDD	Corporate Sustainability Due Diligence Directive
CSO	Civil Society Organisation
CSRD	Corporate Sustainability Reporting Directive
DG	Directorate-General
DG INTPA	European Commission's Directorate-General for International Partnerships
DG GROW	European Commission's Directorate-General for Internal Market, Industry, Entrepreneurship and Small and Medium Enterprises
DG TRADE	European Commission's Directorate-General for Trade and Economic Security
DRC	Democratic Republic of Congo
EEAS	European External Action Service
EIB	European Investment Bank
EITI	Extractive Industries Transparency Initiative
ESG	Environmental, Social and Governance

EU	European Union
G20	Group of Twenty
G7	Group 7
GDP	Gross Domestic Product
ICGLR	International Conference on the Great Lakes Region
ICMM	International Council on Mining and Metals
IoT	Internet of Things
IRMA	Initiative for Responsible Mining Assurance
ITOA	Initiative de Traçabilité de l'Or de l'exploitation Artisanale
ITSCI	International Tin Supply Chain Initiative
LME	London Metal Exchange
MoU	Memorandum of Understanding
MSP	Minerals Security Partnership
NGO	Non-Governmental Organisation
OECD	Organisation for Economic Co-operation and Development
RCM	Regional Certification Mechanism
REE	Rare Earth Elements
RINR	Regional Initiative against Illegal Exploitation of Natural Resources
RMAP	Responsible Minerals Assurance Process
RMI	Responsible Minerals Initiative
SADC	Southern African Development Community
SCM	Supply chain management
SME	Small and Medium Enterprise
UAE	United Arab Emirates
UK	United Kingdom
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNECA	United Nations Economic Commission for Africa
UNGP	Guiding Principles on Business and Human Rights
USA	United States of America

USAID	United States Agency for International Development
ZKP	Zero-Knowledge Proof

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1 Introduction

Critical raw materials (CRM) are pivotal to the European Union's (EU) ambitions for climate neutrality, global competitiveness and strategic independence in the context of global green and digital transition. There is wide recognition that strategies to secure sustainable CRM supply chains will require the enhancement of both existing and developing new supply chains external to the EU. Many of the metals and minerals required to achieve future energy security under a green transition exist in resource-rich countries on the African continent. Accessing these materials raises key considerations around transparency and human rights, environmental protection, as well as local development and equitable trading partnerships.

Traceability, with a focus on sustainability and responsible sourcing, is 'the ability to identify and trace the history, distribution, location and application of products, parts and materials, to ensure the reliability of sustainability claims, in the areas of human rights, labour (including health and safety), the environment and anti-corruption' (Business for Social Responsibility, 2014: 6). Any traceability mechanism should allow an end user to identify suppliers back to extraction sites (Debert and Le Billion, 2021). This can be achieved through paper or digital records of material pasting between entities such as mines, processors, smelters, manufacturers, or recycling operations. Alternatively, it can be achieved by analysing mineralogical identity. Traceability also supports recycling rates and the circular use of materials to enhance dematerialisation and reduce the reliance on extraction.

Traceability provides knowledge on supply chains to enable the verification of sustainability claims, thereby supporting transparency and information sharing between business partners. It enables more effective supply chain due diligence, which can help identify, reduce, or mitigate risks and support sustainable development objectives. It can make the circularity of materials more feasible, providing information on materials through the life cycle and supporting the design of products that can be recycled more easily or more efficiently. Claims of circularity, origin, responsible sourcing and supply chain due diligence all rely on some level of traceability. Each requirement has driven the development of different traceability mechanisms across various products and in different countries, with policy implications and choices. At a policy level, there is a need for international regulatory alignment on traceability requirements without undermining the utility of traceability to specific commodities. At an operational level, there is a need for interoperability and data exchange between different mechanisms used by different entities in a supply chain. Traceability is central to the EU's objectives of ensuring that materials entering the market have been responsibly sourced, that resource extraction and material recycling in developing countries can generate broad economic growth, and that materials from conflict-affected and high-risk areas (CAHRAs) are not fuelling insecurity. Achieving these objectives requires cooperation with a broad set of stakeholders and clarity on whether the ambition is to enforce requirements across all actors or to narrow the scope to work with those that provide the bulk of materials.

The EU has an important role in requiring, enforcing and supporting traceability as well as responsible sourcing mechanisms. The proliferation of recent EU regulatory initiatives that mandate greater transparency in sourcing and trade has necessitated a greater focus on

understanding the origin and sourcing of materials. This includes initiatives such as the 2024 CRM Act, 2017 Conflict Minerals Regulation and the 2023 EU Batteries Regulation, in addition to broader Environmental, Social and Governance (ESG) requirements such as 2024's Corporate Sustainability Reporting Directive (CSRD) and Corporate Sustainability Due Diligence Directive (CSDDD). The forthcoming Electronic Exchange System and Battery passports will expedite the implementation of this requirement and intensify business adoption of traceability solutions. To enforce these requirements effectively, the EU can play a greater role in partnering with producer countries, extractive, processing and manufacturing industries and hosting communities to ensure compliance with EU and international norms, thereby supporting delivery. Providing demonstrable benefits to African businesses, governments, and citizens is key to successfully implementing responsible sourcing and traceability schemes, as this will illustrate local value.

The EU has been a key champion and financial supporter of responsible sourcing and traceability initiatives, as have some Member States. It has continued to be an advocate of initiatives that emerged at the turn of the millennium to enhance transparency, accountability and human rights, such as the Extractive Industries Transparency Initiative (EITI), Kimberley Process and the Voluntary Principles on Security and Human Rights. More recently, it has funded significant research into the development of traceability mechanisms. As outlined by the September 2024 Draghi report on EU competitiveness (Draghi, 2024), the ambition is clear: build strategic partnerships with resource-rich countries through value chain investments, including linkages to the EU's Global Gateway initiative; create a common standard for sustainability that aligns with the broader vision of EU-Africa collaboration as a partnership of equals.

The realities and perspectives of African partners are also pivotal to considering implementation options on traceability. Furthermore, it is critical to establish how any new initiative may fit within a complex, broader global landscape of traceability standards and regulations. Cooperating with African partners as well as being mindful of their priorities and concerns, will be fundamental for successfully implementing traceability programmes.

This paper provides an analysis of specific policy options which are available for EU engagement in implementation, exploring the benefits of different implementations of policy options – whether regulatory frameworks, diplomatic forums or industry bodies – at each relevant geographical and institutional level. It also presents an analysis of African perspectives on traceability debates, such as the state's role and the private sector's engagement, as well as the expectations of technological progress in traceability. This analysis builds upon the shorter foundational paper on logistical and technical aspects of traceability schemes in Africa, which lays out an initial assessment of the landscape on traceability, drawing upon desk research and unstructured interviews in January-February 2025.

The conclusion presents specific practical recommendations for the European Parliament's Committee on Development, suggesting potential pathways for traceability implementation, how to consider the interests of African stakeholders and EU Member States, together with how these initiatives should be situated within wider EU diplomatic and development strategies. As such, these recommendations are also intended to complement reflections made by other relevant EU bodies working on CRM supply chains, such as the European External Action Service (EEAS), the European

Commission's Directorate-General (DG) for International Partnerships (DG INTPA), DG for Trade and Economic Security (DG TRADE), DG for Environment, together with the DG for Internal Market, Industry, Entrepreneurship and small and medium enterprises (DG GROW) (as chair of the CRM board).

2 Traceability in Africa: Concepts, mechanisms, and actors

This section outlines the challenges to traceability inherent in the structure of African mineral and metal production and export markets. It outlines the historic engagement of African countries on responsible sourcing – the verification of which is a key necessitating factor for traceability. It then goes on to highlight why traceability is required and what the challenges are before outlining the actors and relationships required along the supply chain, including for existing and experimental traceability schemes. The section focuses on the objectives of regulatory requirements for entities within the supply chain and the wider policy objective of operationalising traceability schemes to support development in producing states. It concludes that traceability is technically possible, but it comes at a cost, and there is a balance to be made between the certainty of origin, the cost of verification, and the scale of adoption and implementation.

2.1 Metal and mineral production in Africa: Structural challenges to traceability

Implementing traceability at scale in Africa is affected by the diverse ways metals and minerals are produced, including industrial mining, artisanal and small-scale mining (ASM), and material recycling. And subsequently, how those materials are processed, blended, traded, and exported[1].

Mining on the continent is highly diverse, involving a range of actors and affecting communities and countries in different ways. Industrial mining accounts for most production and export values. There are certain hotspots of concentrated production volumes, such as South Africa's diversified mining sector and the Central African Copperbelt – see Figure 1 below. However, out of the 54 countries in Africa, 24 rely on relatively few mineral products to generate more than 75 % of their export earnings.

Table 1: Framework for categorisation of ASM

Legal	**Formal**	**Legitimate**
• No explicit prohibition • In accordance with the law	• Process of fulfilling all requirements • Having obtained permission	• Consistent with the law, or 'good faith efforts' (as per the OECD Minerals Guidance)
Informal	**Illegal**	**Criminal / Illicit**
• Not having obtained all requirements (yet) • An infraction of the law	• Prohibited explicitly by law	• ASM benefitting crime, money laundering, criminal networks etc.

[1] See C. Vandome and R. Dideberg, 'Traceability of CRM with a focus on Africa – Logistical and Technical Aspects', European Parliament's Directorate-General for External Policies, 2025.

Source: A. Jorns and E. Levin-Nally, 'Are they all illegal? A more nuanced view to guide LSM engagement with ASM', Levin Sources, 2020.

China is an important partner for developing full supply chain traceability, as processing capacity for many materials is located there. In 2020, it imported about a third of Africa's minerals and metals exports worth USD 16.6 billion (EUR 15 billion). This was an increase of 28 % from 2018, highlighting China's increasing reliance on African minerals and an opportunity for African players to leverage these resources for greater benefits (Benabdallah, 2024). In recent years, Chinese mining and battery companies have invested USD 4.5 billion (EUR 4 billion) in lithium mines, driving many lithium projects in countries such as Namibia, Zimbabwe, and Mali. China's investments in 15 out of 17 cobalt mining operations of the Democratic Republic of Congo (DRC) (Benabdallah, 2024). The refining of cobalt, graphite and rare earth elements (REE) is highly concentrated in China, as is their mining. It is also the largest refiner of copper, but with a greater level of imports, including those from the DRC. China's dominance in processing has been achieved off the back of a reliable source of raw materials, a reliable supply of component parts, a skilled workforce, dependable infrastructure and the scale of the sales market of manufacturers needing inputs. There is also significant vertical integration of firms and close geographic proximity of supply chain custodians that lead to economies of scale and could support increased traceability. In 2025, the Chinese Ministry of Industry and Information Technology released a proposal for a traceability system for the REE sector to provide the government with additional information regarding the origin, supply chain, and export of materials. Currently, the industry is dominated by two firms, partly due to government-driven consolidation. Increasing traceability provides further government control over the industry, including tracking minerals to provide knowledge over downstream utilisation, partly to enforce targeted export restrictions.

China's Battery ID System and Rare Earth Management Regulation are conducive to traceability, data privacy laws and inconsistent implementation of systems, which are a challenge to interoperability with international due diligence and traceability systems. Significant amounts of bulk material produced by Chinese industrial mines are exported directly to China for onward processing, while other industrial mining products are sold at spot prices on the open market.

In addition to primary extraction, a nascent recycling industry has been developing in Africa, including a fast-growing scrap metal recycling sector, which is set to grow further[2]. The effort is largely led by small and medium enterprises (SMEs) across the continent, with a limited number of metal recycling facilities operating at scale in aluminium and copper, predominantly in South Africa, Nigeria and Egypt. The illegal trade in waste electrical and electronic equipment that has occurred over decades has led to opportunities in the recycling of e-waste from developed countries (Moyen Massa and Archodoulaki, 2023: 10). The development of traceability mechanisms in Africa needs to acknowledge and include this industry, especially as it offers mineral opportunities for countries with limited natural endowments and helps meet international resource needs without harmful extraction.

[2] Global Recycling, 'Opportunities in Africa', archived webpage 2024.

The trading of material on spot markets and other trading practices means that ownership of material may change hands many times, often with owners not being physically connected to the material, as it is traded on international markets and routed around the globe. Most trading structures are outside the EU and thus outside the region's regulatory oversight; however, some trading hubs, such as the London Metal Exchange (LME), have increased the requirement to adhere to responsible sourcing mechanisms to trade on the exchange. Minerals and metals trading can be fast-paced, with commercial information such as quality prioritised over detailed identification of origin, transit routes, and blending or mixing processes (International Energy Agency and OECD, 2025: 48). Some manufacturers have direct off-take agreements from producers, making a closed pipeline of traceability simpler. Smuggling is also a key challenge. Up to USD 30 billion of primarily ASM-produced material is estimated to be smuggled out of Africa in 2022 (Swissaid, 2024).

There are also important geological or financial relationships at play between complementary materials, as well as other economic activities that impact traceability. These include the mining of poly-metallurgical deposits and the economic importance of bulk materials for infrastructure, where revenues from one bulk product are uses used to finance infrastructure that supports the development of other minerals; the use of shared energy and water systems for processing multiple metals found together such as cobalt, copper and nickel; or the pricing relationship between different materials that affect choices made by ASM producers who switch between mineral categories according to profit potential driven by fluctuations in metal prices. ASM often entails a mix of settled communities and migratory workers. Many producers emanate from vulnerable communities and, hence, as a livelihood strategy, combine mining with other natural resource-based livelihoods such as agriculture to manage risk or generate capital for cross-investment. Detailed traceability for ASM production requires data on entities, people, geography, and mode of production.

Box 2: Artisanal and small-scale mining

ASM and how it is dealt with in national mining codes and legislation varies considerably across African jurisdictions.

ASM has no fixed definition, but the OECD guidance defines the sector as comprising 'formal or informal mining operations with predominantly simplified forms of exploration, extraction, processing, and transportation. ASM is normally low capital intensive and uses high labour-intensive technology. "ASM" can include men and women working on an individual basis as well as those working in family groups' (OECD, 2018). This includes labour-intensive practices and capital-, mechanisation- and technology-poor'. Artisanal mining is often associated with adverse environmental, health and social impacts, but provides a vital livelihood activity. The World Bank estimates that over 13.2 million people in Sub-Saharan Africa work directly in ASM with potentially 40-80 million people reliant on the sector for some form of livelihood (World Bank Group, 2018). The EU-supported AfricaMaVal project notes that while 'for certain commodities, artisanal and small-scale mining (ASM) activities contribute significantly to Africa's ECRM production, there is commonly a lack of easily accessible information regarding the ASM sector' (Girard, Molina-Millán and Vic, 2024). Another factor in ASM is the role of pricing in the interchangeability of commodities mined – for example, switching between gold and cassiterite depending on the price offered by traders and the accessibility of ore bodies – as well as between ASM and other subsistence activities such as agriculture, which is the custom amongst subsistence farmers that mine lithium only when the price is high, or might mine gold in the agricultural down season, as part of diversifying livelihood activities to manage risks.

In most countries, the ASM sector is legal and regulated under certain conditions; however, in other countries, such as South Africa, the licencing regime does not permit ASM; elsewhere, it may be outlawed in certain protected areas. In the DRC, the *Entreprise Générale du Cobalt*, a subsidiary of Gécamines that was launched in 2019, holds a *de jure* monopsony on the purchase, processing and marketing of artisanal mined cobalt in the DRC (Le Bec, 2021). Illegal forms of ASM can include illegal site incursions onto industrial sites or into ecologically or culturally protected areas.

2.2 African engagement in responsible sourcing

Despite some negative perceptions from African stakeholders of externally imposed regulation, the continent's leaders have been increasingly engaged in international initiatives mandating responsible sourcing and requiring some degree of traceability for its verification. Experiences of regulations and responsible sourcing in Africa are often viewed in a post-colonial context. Since inception, institutional structures to govern mining, including traceability, have faced challenges over sovereignty and the 'ownership' of initiatives (Campbell, 2011) driven by frustration and perceptions of imposition from African governments who rightly claim sovereignty over their extractive sectors and who became frustrated over the shortcomings of the industry to stimulate wider economic growth (Oshionebo, 2020; Campbell, 2009; Besada and Martin, 2014)[3].

[3] The UN General Assembly resolution 1803 (XVII) of 14 December 1962, the Declaration on Permanent Sovereignty over Natural Resources, declared that nations and peoples have ownership of their natural resources. Ownership rights over natural resources were thereby formally granted to African states, albeit ever since they have often failed to protect their

A rise in governance initiatives at the turn of the century sought to fill gaps in industry regulation and improve social performance. Industrial mining companies faced criticism for not consistently managing, mitigating, or avoiding harm to local communities and environments, with a disproportionate impact of those harms experienced by the weakest groups, thereby deepening their vulnerability. A mining Initiative response was provided through the Mining, Minerals and Sustainable Development Project, which was designed to investigate operational responsibilities (International Council of Minerals and Mining and Metals, 2024). The project ran between 2000 and 2002 and led to the creation of the International Council on Mining and Metals (ICMM) as an industry-led initiative to support the Sustainable Development Goal 16 'Peace, Justice and Strong Institutions' of the United Nations (UN) 2030 Agenda for Sustainable Development. Other initiatives emerging at this time included the Extractive Industry and Transparency Initiative, which has 23 African nations as implementing countries, and the Voluntary Principles on Security and Human Rights Initiative, which is broadening its reach in Africa.

Enforcing and supporting responsible business practice gained further traction through the 2011 UN adoption of the UN Guiding Principles on Business and Human Rights (UNGPs), which codified the responsibilities of the state and private actors towards human rights protection. The Principles were unanimously endorsed by the UN Human Rights Council in 2011, which at the time included 13 African council members[4]. The Principles include the duty of the state to protect against human rights abuse by third parties, including business enterprises, although critics argue that its referral to corporate responsibilities rather than obligations softens its impact on enforcing responsible behaviour. Ten African countries have developed or are in the process of developing National Action Plans as mandated by the Principles, whilst many European and American downstream companies are adopting human rights due diligence in alignment with the UNGPs, their primary approach to supply chain due diligence, and the EU is advancing the adoption of these principles in the CSRD and CSDDD.

African states have further been involved in creating responsible sourcing initiatives and guidance used by traceability schemes and companies to demonstrate responsible business conduct. In particular, the Organisation for Economic Co-operation and Development (OECD) Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas (OECD Minerals Guidance, 2018) was developed through a multi-stakeholder process with in-depth engagement by 11 countries of the International Conference on the Great Lakes Region (ICGLR) – Angola, Burundi, Central African Republic, Republic of Congo, DRC, Kenya, Rwanda, Sudan, Tanzania, Uganda and Zambia – as well as representatives from industry, civil society and the UN (OECD, 2025). This Guidance was endorsed by the 11 countries in the Lusaka Declaration, adopted on 15 December 2010 and domesticated into national law in a range of ICGLR countries under the Regional Initiative against Illegal Exploitation of Natural Resources (RINR), endorsed by the heads of state in the same

citizens. See United Nations General Assembly, 'Permanent sovereignty over natural resources', Resolutions adopted by the General Assembly during its 17th session, A/5217, 18 September-20 December 1962, 1962.

[4] Angola, Burkina Faso, Cameroon, Djibouti, Gabon, Ghana, Libya, Mauritania, Mauritius, Nigeria, Senegal, Uganda and Zambia.

year and which includes a Regional Certification Mechanism (RCM), which is an important example of an African originating responsible sourcing framework.

African states are also members of international organisations that have developed guidelines and responsibility standards, including the International Finance Corporation's Performance Standards (2006 and 2012) and the multiple labour standards of the International Labour Organisation. These have been buttressed by other initiatives from investors and African countries, including: *Exporters Guidelines for Social Responsibility in Outbound Mining Investment* devised by the China Chamber of Commerce of Metals, Minerals & Chemicals Importers & Exporters; the Chinese Due Diligence Guidelines for Responsible Mineral Supply Chains (CCMC, 2014 and 2015); the ICGLR RCM discussed below in the DRC case study; and the *Initiative de Traçabilité de l'Or d'Exploitation Artisanale*, which is a Congolese-led programme to trace artisanal gold.

Demonstrating responsible sourcing is more feasible in simpler supply chains with fewer suppliers, but this can lead to market reconfigurations that benefit certain manufacturers while neglecting broader development goals. In contrast, achieving wider development impact, especially including ASM, may require trade-offs on traceability certainty to ensure broader participation and lower implementation costs. Verification and auditing of operations are paramount in ensuring responsible business practice, but this can miss longer-term social challenges and impacts from the extractive industry – including those arising at the exploration phase or after mine closure, including community resettlement, changes in formal and informal land rights as well as access and environmental impacts (Owen and Kemp, 2015). Operators may inherit legacy issues when they take over a site, especially disputes over land and labour rights and access.

The EU has played a vital role important role in driving the development of mineral governance in Africa: firstly, through the development of legislation and regulation on responsible sourcing of material imported into the EU; secondly, through engaging with other key players to set norms, standards and promote wider regulation in the industry, including engagement with the governing organisations of performance standards in collaboration with other global actors such as Japan and the USA to be a 'solutions provider'; and thirdly through diplomatic efforts, including economic diplomacy, to engage with African nations in raising awareness and support for the implementation of governance initiatives. The EU has itself as a strategic actor regarding extractive governance and is well placed to continue to advocate for developing traceability as a means to verify and further ensure adherence to responsible sourcing standards (Amoah Awuah, 2019).

2.3 Traceability requirements and trade-offs

Traceability systems in Africa have largely been adopted as a requirement for verifying sourcing claims, for instance, in responsible production and origin, which is a requirement for some national and international legislation. Numerous industry bodies, governance schemes, regulations and international organisations have advocated for certification schemes to increase product traceability.

Traceability at some level is required not only to make responsible sourcing possible but also to appropriately identify supply chain risks. Conformity with the OECD Minerals Guidance and the OECD Responsible Business Conduct Guidance requires companies to establish a 'system of

controls and transparency', which includes a chain of custody (CoC) or a traceability system or the identification of upstream actors in the supply chain and may be delivered by an industry programme. At present, partial traceability and transparency have become standard for companies conducting environmental and human rights due diligence, with technical, structural and financial barriers existing to achieving high-certainty full traceability. In some markets, such as gemstones, provenance is part of the marketing value of a stone, and it can use higher-cost lab testing and stone scanning. Traceability is not an enforcement mechanism; rather, it is a transparency and risk management mechanism through which actionable knowledge is generated. It must be used in conjunction with responsibility standards, as well as market participation governing schemes, such as the Kimberly Process for diamonds, to improve sector performance and development outcomes.

Traceability is necessary to conform to international legislation on sourcing from specific jurisdictions and CAHRAs – in particular, conflict minerals legislation in the United States of America (USA) and the EU. In 2010, the USA passed the Dodd-Frank Act on financial reform and consumer protection (US Congress, 2010). Section 1502 required companies to conduct due diligence checks on their supply chains of 3TG metals (i.e., tin, tungsten, tantalum and gold) from the DRC and adjoining countries to determine whether they had benefited armed groups, as well as checking for links to other human rights violations. Although Dodd-Frank did not imply a ban, the US Securities and Exchange Commission gave little clear guidance on company compliance. Indeed, the enhanced due diligence and disclosure requirements created a disincentive for companies and consequently, many cut the DRC and neighbouring countries from their supply chains. The EU's Conflict Minerals Regulation 2021 requires that EU importers of 3TG meet international responsible sourcing standards and that EU smelters and refiners of 3TG source responsibly. Whereas the Dodd-Frank Act section 1502 had specified 3TG from DRC and neighbouring states, the EU CRM specified minerals but not any specific geographic location, broadening its scope. Subsequent Securities and Exchange Commission interpretations of Dodd-Frank 1502 have necessitated that all supplies of 3TG be verified as DRC conflict-free.

Exporting material from eastern DRC remains a highly contentious issue, with demands for confidence in traceability. A return to conflict in the region and the M23 (March 23 Movement) expansion of territory in 2024 and early 2025 has heavily impacted the supply chains of coltan. The conflict carries risks for downstream users. In December 2024, the DRC government filed a lawsuit against Apple in France and Belgium, alleging the inclusion of conflict materials in its supply chains, as a result of which the company has incurred damage to property by protesters.

Definitions of a conflict mineral or product are contested, which has an impact on what criteria traceability mechanisms are seeking to prove. The Dodd-Frank definition includes specific minerals – columbite-tantalite (coltan), cassiterite, gold, wolframite, or their derivatives. Also covered was any material mined under the control of armed groups without differentiating between state, non-state, or private security. This included the Secretary of State's discretion in designating certain materials as 'conflict'. This broad definition contrasts with that of a 'conflict diamond', which is limited to non-state armed groups or their allies as designated by the UN Security Council or United Nations General Assembly. Such a narrow definition has been criticised for limiting the Kimberley Process's effectiveness against State military control of diamonds in Zimbabwe or the Russian

company Alrosa's links to funding the conflict in Ukraine. However, it was a political compromise on a process that African countries pursued. Finally, companies boycotting countries that require increased due diligence, at a cost to the company, can be counterproductive both for their own operations and the intended objectives of international regulators. Some countries that boycotted DRC have experienced different, but equally challenging issues elsewhere, albeit with lower compliance risk and less media scrutiny. Furthermore, the developmental intention of international regulation is to support continued constructive engagement and trade as the basis for responsible economic activity that is necessary for lasting peace in CAHRAs.

Implementation trade-offs and complications

Traceability can be achieved, *inter alia*, by using CoC models, paper trails and the digitisation of product information, for example, through distributed ledger systems and geochemical analysis. Various mechanisms are currently employed at different stages of the value chain. There is a persistent need to balance between cost, ease of implementation and adoption, as well as certainty and credibility. The determination of this trade-off varies for different commodities and different jurisdictions. In many cases, the traceability needs of a trader or manufacturer may be satisfied by CoC schemes used to verify or assure that material has passed only through actors whose responsible standards have been verified by the scheme. In other cases, users may require a much higher degree of certainty, which comes at an additional cost. Mineral, metal and gemstone traceability is technically possible and currently employed in some specific commodities or specific jurisdictions. However, achieving traceability at scale across multiple highly complex mineral value chains is beset by many challenges:

- Weak understanding of complicated technology and how to apply it to practical implementation at an operational level.
- Lack of data standardisation means that data is not aggregable or comparable, including for accounting methodologies, exacerbated by a lack of clear guidance on the required levels and conditions of data-sharing in ways consistent with privacy regulations.
- Lack of clarity on the purpose of traceability amongst users and policymakers.
- Uncertainty for investors on how and when participation in traceability will lead to a return on investment.
- Non-aligned incentives for doing traceability for entities across the supply chain and inadequate cooperation and alignment between supply chain partners.
- Complex supply chains include the movement, processing, refining and manufacturing of material in different geographies and processes.
- Infrastructure deficits in energy and telecommunications in remote areas where mining takes place.
- Circumvention of traceability mechanisms by agents and entities in the supply chain, including through corruption.
- Inconsistent application of the rule of law in CAHRAs.

One key challenge with traceability is how far back up the supply chain we want to be able to trace material. Whereas tracking follows material from start to finish, traceability is the ability to enquire about a product's history, seeing who handled it where and when. It is important to identify the

first custodian that can be verified as conforming to standards and input data on materials into a traceability scheme, beginning with processors and smelters, before moving up the value chain to industrial producers, recyclers, and ASM. The trade-offs between cost and certainty are also highlighted below.

The implementation of CoC-based traceability approaches varies depending on which part of the supply chain they cover and which entity is viewed as the first 'trusted' custodian who initiates the onward record of movement and processing of material. There is significant variation across different metals, minerals and gemstones in not only how they are mined and processed, but also which part of the supply chain has the highest ESG risk profile. For supply chains that emanate from industrial mines, the mining companies themselves are often taken as first custodians, either a specific mine site being listed as the origin or the company bringing the product to market. For example, a company may mix materials from multiple sites and carry out initial processing or smelting before bringing the product to market. Hence, while a specific site of origin might not be recorded, the company would be regarded as the start of the supply chain. Provided that all its sites have been verified as conforming to a given responsible performance standard, then the material would be viewed as conforming.

The point at which a CoC-based scheme begins has two important implications and challenges that frame some of the debates in this section: firstly, it determines where the initial point of compliance or conformity is, raising criticism from some producers that they carry the cost of compliance that downstream entities benefit from for free. For many African producers, traceability and verification of standards and responsible performance are seen as a transaction cost. It is a cost of doing business to gain access to specific markets or a necessity for transactions with some traders or smelters. There is a need for a more comprehensive and better-communicated business case for how traceability and responsible sourcing deliver value beyond market access. This is not least because there exist alternative routes to market that do not carry the same transaction cost. Secondly, where traceability does not begin at the point of extraction, such initiatives may have a diminished impact on improving standards, especially when material sources can be highly diffused from multiple industrial, semi-industrial and ASM providers.

2.4 Implementing actors, approaches, and 'pinch points'

Achieving traceability to understand the history, distribution, location and application of products, parts and materials using a CoC model or via geochemical analysis requires the cooperation and trust of many actors. It relies upon the input of data and information trusted and verifiable by other entities in the supply chain, involving significant data sharing amongst actors. This section provides an actor-centric analysis of key traceability schemes, pilot projects and research programmes, highlighting their advantages and disadvantages, reporting mechanisms and potential for scalability.

Traceability can start within an institution where there is an internal control system over product stewardship or once any material is traded, and there is a transaction record. This can be at a mine, where there is a CoC system for record-keeping or the implementation of tracing solutions, or at a smelter or processor, where large amounts of materials pass through a relatively smaller number of

handling entities. It is often the case that traceability is happening in different parts of the supply chain, but different systems or mechanisms do not link up. For example, end-product assemblers may not be able to view information from component manufacturers to identify the smelters or refiners, even where those entities are part of a separate CoC scheme. Achieving full traceability requires an internal control system within each participating entity and a trading control system once a product passes from one entity to another through ownership or handling.

The OECD Minerals Guidance states the importance of supply chain 'pinch points', where fewer entities with a higher volume of material go through them. This gives actors greater control over upstream activities. For metals and minerals, this means traceability can start at the point of processing, refining and smelting. In other words, manufacturers and end users can trace their material inputs back as far as the entity that had custodianship of the material at a point where the metals and minerals were processed, refined, or smelted. These entities can be the starting point for inputting information into traceability systems on the origin and production of the material they receive from suppliers. They can be audited to verify their compliance with international standards and local legislation. This places the responsibility on manufacturers and end users to ensure that they conduct due diligence on suppliers.

Manufacturers

Manufacturers have been instrumental in supporting developments in traceability, especially technology companies such as Hitachi or Intel, car manufacturers including Volkswagen, Volvo and Tesla, together with industrial manufacturing firms. For example, Volvo partnered with Circulor to produce battery passports for their XC90, launched in 2024. Wolfram Bergbau & Hütten AG, the vertically integrated manufacturer of tungsten carbide and tungsten metal powders based in Austria, is committed to sourcing responsibly from ASM operations in CAHRAs (European Partnership for Responsible Minerals Secretariat, 2022). Wolfram Bergbau & Hütten AG worked with other industry representatives to establish the Tungsten Industry – Conflict Minerals Council. EU-based manufacturing companies have been instrumental in supporting traceability, often through contracting third-party traceability providers.

Trading companies and hubs

Trading companies and hubs play a pivotal role in mineral supply chains. To some extent and in some supply chains, these can be seen as 'choke points', where large amounts of material pass through a relatively small number of entities, theoretically increasing the ability to implement traceability; however, there are significant practical challenges. The international commodity trade is largely decentralised and typically opaque. Significant variations in the types of contracts and relationships determine this trade, including long-term supply contracts often run by vertically integrated companies linking multiple operations and smelters, direct off-take agreements and spot market trading. There are various practical challenges in supporting traceability through trading materials related to their physical movement, washing, processing, smelting and manufacture – see complementary briefing note on logistical considerations. There are also certain challenges to information sharing and knowledge distribution across this web of actors, especially when traders and other entities have to respect commercial confidentiality conditions. This is made

more complex by the heterogeneity of standards, allowing choice for companies, but leading to a contradiction in the standards set by buyers against producers. There are additional challenges connected with the cost of compliance and conformity across the supply chain – producers pay the cost of compliance or conformity that traders and manufacturers benefit from, but then manufacturers or product retailers carry the risk if their products become linked to irresponsible sourcing. Finally, there is no price premium for responsibly sourced material. This has been a point of contention in the industry, with, for example, French miner Eramet calling for a pricing tool to incentivise responsible nickel production in the context of low prices due to a glut of nickel production in Indonesia (Dempsey and White, 2024). Others have argued that such a pricing mechanism would be inflationary, also pointing at a 'disconnect between sustainability efforts and market valuations' (Stibbs et al., 2024).

Commodity trading hubs are an important interlocutor for enforcing standards which support traceability. They can impose requirements for participation in exchanges, but face a risk that any such imposition that most market participants cannot meet could lead to trading occurring elsewhere and undermine their strategic centrality. As such, there has been a lag in the uptake of standard implementation. For example, in 2019, the LME published sustainability guidance oriented to the OECD Guidance, making conformity obligatory for participants from 2023[5]. Furthermore, it created the LME passport in 2021, a form of traceability that allows producers to provide information about the sustainability of their products, albeit voluntarily (Müller et al., 2024). Müller takes up certain criticisms of the passport scheme, highlighting that 'instruments are not necessarily binding, violations are not consistently followed up, and complaints from supply chain actors are not published' (Müller et al, 2024: 21). The introduction of obligatory Responsible Sourcing by the London Platinum and Palladium Market in 2023 was an important mechanism for bringing about the rapid exclusion of Russian refiners in the wake of Russia's war of aggression against Ukraine (Müller et al., 2024).

Processors

Processing centres are a widely accepted first entity in traceability. The Responsible Minerals Initiative's (RMI) Responsible Minerals Assurance Process (RMAP) is one of the most used industry mechanisms. RMI was founded in 2008 and is now an initiative of the Responsible Business Alliance. Over 500 member companies and associations from 30 mining countries participate in this initiative; RMAP offers an independent, third-party assessment that determines which smelters and refiners can be verified as having systems in place to source minerals responsibly in line with current global standards. In addition, the RMI provides templates for due diligence and operational guidance for miners and has worked with projects that support ASM.

The RMI is primarily an upstream initiative, working with extractive operations, smelters and mineral processors. In 2021, a consortium that included the RMI was awarded a grant for establishing a traceability mechanism to address child labour issues (RMI, 2021). The RMI provides a list of country-of-origin information for the mined material of conformant smelters and refiners in the

[5] London Metal Exchange, Responsible Sourcing, webpage, 2019.

RMAP, together with gold refiners that have successfully completed a cross-recognised assessment through the London Bullion Market Association or the Responsible Jewellery Council. This initiative claims to have the most detailed information currently available about the origins of responsibly sourced minerals in 3TG supply chains. These demonstrate conformance with the OECD's Minerals Guidance for Responsible Supply Chains of Minerals from CAHRAs or compliance with the US Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010, as well as the EU Responsible Minerals Regulation. The RMI list of active and conformant facilities includes 64 entities in Africa – 29 in South Africa and 25 in the DRC – and its list of 3TG standard smelters includes 15 entities –5 in South Africa and 3 in Rwanda. For many buyers and users of mined products, the ability to trace the source to a verified processing entity is enough for their own reporting or assurance needs. Nevertheless, 'if companies involved fail to disclose the origin of primary material and the conditions of its production, it is impossible for downstream actors to trace the material back to specific mines' (Müller, et al., 2023). There is often a need to trace minerals as far back as their point of origin.

Requirements for knowledge go beyond the point of processing, not just to locate the geological origin, but also to ensure that the material was mined responsibly. Certification or verification can be applied to producers, as custodians of mined products, as well as to the product itself in some circumstances, for example, where there is consumer demand or there is a benefit for the retailer in being able to disclose such information.

The gold industry provides further examples of the smelter verification programme. The London Bullion Market Association holds a Good Delivery List (GDL) for gold and silver refiners, who are required to implement LBMA's Responsible Sourcing Guidance (the Guidance), which comprises the Responsible Gold Guidance (RGG) and Responsible Silver Guidance (RSG), and obtain annual independent assurance on their publicly available compliance reporting. The LBMA has also piloted a Gold Bar Integrity programme (GBI) where a physical security feature is added to bars, and then a parallel digital database is used to track bars through the supply chain.

Commodity-specific responsible sourcing and CoC schemes

Responsible sourcing and custodial verification initiatives can provide a practical CoC assurance for industrial miners, processors and export facilities in Africa, supporting traceability and satisfying the needs of many downstream actors. However, participation in such initiatives is often limited to a few industrial mining firms. For example, commodity-specific industry membership-based initiatives such as the Copper Mark and the Aluminium Stewardship Initiative (ASI) provide verification of custodial entities, which can support traceability by verifying that all custodians within a chain uphold a particular responsible business guidance or an ESG performance standard. The ASI CoC Standard sets out requirements for the flow of CoC Material, including ASI Aluminium, 'through the value chain (from mining or recycling through to final products), with assurance of responsible production at each link in the chain' (ASI, 2023). To support traceability, the standard requires that entities involved in casting have systems in place 'to ensure that unique identification numbers, either physically stamped and/or printed on or with ASI Aluminium by the Entity, correspond to the Input Quantities of CoC Material' (ASI, 2023: 16). Casting involves converting aluminium into solid metal forms for subsequent material conversion and/or manufacturing. There

are 11 ASI-certified entities in Africa: 5 in Guinea, including processing and port facilities; 2 in Nigeria; 1 in Cameroon; and 2 in South Africa, including Port Elizabeth's port facility and the Mozal smelter is the 1 in Mozambique. At present, the Copper Mark has three independently assessed mining facilities in Africa: the Tenke Fungurume Mining in DRC, operated by Chinese firm CMOC, accredited in June 2024, as well as Glencore's Kamoto and Mutanda, which received accreditation in April 2025. Both companies are also members of the Fair Cobalt Alliance. Eurasian Resources submitted a letter of commitment to Coper Mark in September 2024, and THL Zinc has submitted a letter of commencement for the Zinc Mark for its operation in South Africa.

A unified approach to a tungsten-specific audit protocol was agreed upon between the RMI and the above-mentioned Conflict Minerals Council. The joint framework provides tungsten smelters and refiners with the opportunity to demonstrate their compliance with OECD Minerals Guidance provisions through third-party assessment and listing as RMI's RMAP-compliant facility (RMI). This also results in validation as a DRC conflict-free smelter. To incentivise adoption, the company claimed it would provide technical support and training to ASM producers. The company has worked with both the International Tin Supply Chain Initiative (ITSCI) and RCS Global's Better Mining. It conducts additional mine site visits to further increase the validity of responsible sourcing claims and introduce high-level fingerprinting of concentrates. As Gouby writes (2024), 'In 2011, together with Motorola and the Washington-based Non-Governmental Organisation (NGO) Resolve, what was then AVX launched Solutions for Hope, a pilot project in Congo's Katanga (now Tanganyika) province' (Gouby, 2024). This project segregated the CoC supply chain, sourcing from artisanal mines through a company that sold directly to a Chinese smelter and then onward to AVX, which manufactured components for Motorola and Hewlett-Packard. The project also included ITSCI as a verification and traceability mechanism. One of the points of success was that the integrated supply chain bypassed traders and brought end-user companies closer to the miners (Gouby, 2024). However, William Millman, a former technical director at Kyocera AVX, a leading manufacturer of electronic components and major coltan buyer, was quoted by Gouby as noting that 'suddenly, with ITSCI, there was a way for their CEOs and CFOs, to sign off on their Securities and Exchange Commission statements [...] And so, everyone piled in, and it became the easy option.'

Multi-criteria CoC schemes

The same principles for a CoC standard supporting traceability have been employed by the Initiative for Responsible Mining Assurance (IRMA) CoC Standard for Responsibly Mined Materials, designed to provide baseline requirements for tracing material from any IRMA-audited mine. The IRMA scheme was founded in 2006 and is regarded as an important development for the industry in two ways. Firstly, it is an inclusive multi-stakeholder initiative focused on industrial mining that includes requirements for consultations and engagement with ASM and their treatment as stakeholders, where industrial mining is taking place in the vicinity of ASM. Secondly, IRMA sought to consolidate the plethora of standards and expectations being placed on the mining industry into one global standard, with a conformance grading system out of 100. IRMA currently has 96 members, including Anglo American plc; mid-tier mining companies such as Albemarle, Arcadium Lithium and Sociedad Química y Minera; processing companies and manufacturers; as well as car makers Ford, General Motors, Tesla and Volkswagen; and investors such as Stewart investors.

While civil society has lauded the scheme for this multi-stakeholder approach, uptake by the mining industry in Africa has been limited. There are only 10 independently assessed sites on the continent – 7 in South Africa, 1 each in Senegal, Mozambique and Zimbabwe – and this is largely driven by the scheme's usage by Anglo American. In addition, there are 9 self-assessed sites on the continent, including in South Africa and the others in Gabon, Liberia, Namibia, Mozambique, Zambia and Zimbabwe. Mining companies have noted that detailed reporting can place high burdens on smaller operators with more than 100 pages of reporting required. Consequently, this leads to lengthy processes between assessors and operators to agree on conclusions, which can delay troubleshooting. Furthermore, with only two board members from mining companies – diversified miner Anglo American plc and vertically-integrated steel company ArcelorMittal – some mining companies feel that the voice of the industry that ultimately pays the cost of compliance is inadequately heard.

The ICMM, Copper Mark, Mining Association of Canada's Towards Sustainable Mining initiative and World Gold Council have collaborated on establishing an alternative consolidated standard, the Consolidated Mining Standards Initiative, seeking to simplify standards, thereby broadening uptake by companies. A draft standard was circulated with a deadline of December 2024 for submissions of consultations, with a second round of consultations due to take place later in 2025.

'Bag 'n tag' material tracing

Initiatives that follow material through the upstream supply chain often use 'bag 'n tag' systems, where mined material is tagged at the point of extraction with data on its origin. One of the early pioneers of this system was established by the International Tin Association, a London-based industry body established in 1932 that now represents more than two-thirds of global tin production. The Association's ITSCI, grew from a working group established in 2009 and a small pilot in eastern DRC during 2016, pre-dating the US Dodd-Frank Act, which subsequently spurred the programme's growth. ITSCI itself notes that in the years between 2011 and 2016, ITSCI recorded and monitored 3 063 individual incidents across four countries. It has provided information for 380 companies and works on sourcing across 1 800 mining sites throughout Burundi, DRC, Rwanda and Uganda[7].

This system's credibility has been challenged due to the free availability of tags, opportunities for corruption in the tagging process and allegations of Congolese minerals being tagged and recorded as being produced in neighbouring countries (Global Witness, 2022). Furthermore, the paper-based and manual data entry as a source of abuse has been a point of criticism. A study by Radley and Vogel argued that not only had the scheme failed to prevent untagged minerals from entering supply chains, but it had also led to a stagnation or decrease of prices in some 'clean' areas (Radley and Vogel, 2015). Investigative journalist Mélanie Gouby wrote in Foreign Policy that 'in a cruel twist, the cost of the due diligence programme has been shouldered by Congolese miners themselves, effectively asking the world's poorest workers to pay for the right to sell their own resources to

[7] ITSCI, 'Our Purpose', webpage, 28 August 2024.

Western companies' (2024). She identifies various weak points, notably: arbitrage between implementation costs in Rwanda and DRC that incentivise smuggling; wide availability of tags; introduction of non-verified material during the washing stages[8]; and the opportunities for corruption that exist due to tagging being conducted by Congolese agents who are often paid less than the miners themselves. One of the key challenges faced by the initiative is that the expectations placed on it to deliver outcomes often exceed its mandate and scope.

Third-party providers

Third-party traceability service providers have become important actors in developing platforms that assist both commercial and NGO-led schemes and have worked across multiple sectors. Many service providers often apply emergent blockchain technology as a digital ledger system to enhance access, verification and record keeping of traceability information. They sometimes complement this by using their own agents for data inputting. For example, the RCS Global Better Mining initiative, which some ASM and industrial mining operators use in the DRC, Rwanda and Burundi, uses onsite Better Mining agents for tagging bags rather than a government agent and is complemented by monthly audits. Circulor, a UK company founded in 2017, offers clients the ability to track materials through a supply chain and provide details on the point of origin. Where the digital traceability provider has worked in Africa, they have developed pre-printed digital tags and facial recognition safeguards for data input. Machine learning tools can conduct data analysis for identifying anomalies – for instance, if a pit is suddenly overproducing, it could indicate that additional material is being smuggled onto the site. Circulor 'has been involved in traceability for other minerals, such as conflict mineral tantalum, in a project involving the Rwandan government, mining company PRG Resources, which supplies Apple and a refiner' (Ledger Insights, 2020). Another third-party service provider of verification and trace services is Minespider, which has worked with both industrial miners, including Woodcross in Uganda, and participated in donor-led consortium work on ASM. As with Circulor, the company uses a digital platform and parallel digital supply chain to record the journey of material, offering battery and product passports. Circulor worked with Trafigura on a pilot project for cobalt mining at Mutoshi in the DRC. Section 3, below, extends the discussion of how technology contributes to traceability.

There are various other service providers offering tracking and traceability solutions. Hence, some interviewees suggested that market consolidation could be expected.[9] Industrial actors have used third-party providers who have partnered on NGO/Civil Society Organisation (CSO)-led initiatives. However, their higher degree of certainty comes at a cost which puts the schemes out of reach for many producers.

ASM traceability projects

Verification of material from a point of origin as opposed to an initial custodian relies on a range of state and non-state actors, especially when addressing challenges in the ASM sector. There is an expectation of certainty, which often comes at a cost that can fall on miners themselves and which

[8] When material is removed from bags and loses weight due to washing allowing additional material to be added before it is re-tagged, which, provided the new weight is still below the initial weight, is not picked up.

[9] Confidential interviews with various mining companies and third-party traceability providers, London, February 2025.

can undermine the feasibility and scalability of solutions. However, the importance of ASM for development and local livelihoods, in addition to mineral supply, means that this is a particular area of focus for non-governmental organisations (NGOs) and donors seeking to support responsible performance and development outcomes. Various pilot schemes have offered important lessons, and existing schemes highlight the challenges involved together with potential solutions. Many pilot schemes have focused on 3TG due to the economic importance of gold across the continent and the nature of mining in eastern DRC, which has gained particular global attention. The basic principles of traceability remain the same – who is the first custodian, how and where are materials logged and who has access afterwards. Furthermore, for these stages, does a scheme provide monitoring, and how trustworthy are the actors involved? Four different types of actors have developed and promoted these initiatives, with some important overlaps – states, industry initiatives, civil society and NGOs, as well as third-party traceability service providers. For example, Fairmined Gold certifies gold of responsible origin and was one of the first attempts to achieve traceability from ASM production (Alliance for Responsible Mining Foundation and Fairmined, 2014). National governments are critical interlocutors in responsible performance and have been involved in ASM traceability initiatives.

Case study: Evolution of traceability in the Great Lakes

Given the economic risks faced by the Great Lakes governments due to increased reporting on material emanating from the region, as well as commercial avoidance by businesses seeking to avoid reputational risks, regional governments have cooperated to create reporting standards and regional schemes for origin verification, including to work with downstream companies in ways that would support their due diligence requirements and keep them engaged with the region. This regional approach resulted in an RCM framework in 2010, consisting of a government-led framework spearheaded by the ICGLR. Producers' conformance to the scheme is enabled through industry-led initiatives such as ITSCI and the Conflict-Free Smelter Programme. The RCM followed pilots in Rwanda and the DRC conducted by the Federal Institute for Geosciences and Natural Resources (BGR) under the Certified Trading Chains (CTC), started in 2009. The RCM was then incorporated as one of six pillars in the ' RINR by the regional heads of state in 2010. Regional governments signed the RINR as a collaborative and common approach to the rampant illegal smuggling of resources across the region. In the DRC, the CTC project pilot was incorporated within the Congolese Ministry of Mines in 2011, with continued support from the BGR.

In 2015, the Congolese government developed its own traceability scheme for artisanal gold, the Traceability Initiative for Artisanal Gold (*Initiative de Traçabilité de l'Or de l'exploitation Artisanale* – ITOA), run under the authority of the Congolese governmental certification authority (Certification, Expertise and Evaluation Centre). The ITOA scheme consists of physical envelopes tagged onto artisanal gold production by agents on the greenlighted sites. The scheme is deployed to mining sites by agents of the Congolese public service SAEMAPE, 'Service d'Assistance et d'Encadrement de l'Exploitation Minière Artisanale et à petite Echelle', created to support ASM cooperatives across the Congolese territory.

More recently, BGR and its local partners completed a seven-month pilot project to establish and incentivise responsible gold supply chains at Kampene in the Maniema Province, DRC (Neumann et

al., 2019). The implementation used digital traceability tools and was accompanied by, and incentivised 'through technical support for artisanal mining cooperatives, capacity building as well as mine site inspections, monitoring missions and audits forming part of the Certified Trading Chains certification scheme' (Neumann et al., 2019: i). An assessment of this initiative concluded that the 'electronic traceability scheme demonstrated the technical feasibility of operating the scheme under rough field conditions, including technical challenges in network coverage. Along with other systems supported by different partners, the scheme could thus provide impetus for discussions on improving ASM gold traceability in the DRC at a larger scale' (Neumann et al., 2019).

Various actors have conducted other ASM-focused pilots in the DRC: in 2021, GiZ (the German Development Agency) and BetterMining in Kolwezi 'conduct[ed] self-monitoring of risks and incidents on ASM cobalt sites', RCS also ran the Better Cobalt pilot, with the aim of 'deliver[ing] up to 5 supply chains originating from ASM or semi-mechanised mine sites'. On the industrial side, private companies have also run pilot schemes in the DRC. Eurasian Resources Group released its Clean Cobalt Framework in 2018, which includes an emphasis on traceability (Metalkol took part in pilot projects with the Global Battery Alliance and ReSource). The group's Metalkol cobalt facility in Kolwezi also claims to have run a pilot to engage with ASM communities living in the vicinity of its tailing-processing plants in Kingamyambo and Musonoi Rivers. Working with an unnamed NGO, Kingamyambo tailings facility and the Musonoi River tailings, the pilot's goal is to 'better understand the challenges of ASM cooperatives (around their facilities) and support them in identifying possible socio-economic solutions'.

Generally, the Congolese government has broadly been supportive of and taken part in the creation of traceability schemes. Its involvement has added value to some of the pilot projects through the involvement of its specialised agencies with deeper knowledge and experience in upstream aspects of supply chains, but failure in implementation and enforcement has undermined their feasibility or effectiveness. For instance, the chronic failure to pay state agents responsible for tagging production and verifications at the mine level has opened corruption avenues, seriously undermining the validity of the certification. This points to the impossibility of sustaining any robust and valid ASM traceability systems without tackling local socio-economic realities upfront.

The Congolese Mining Code of 2018 and then 2022 aims to 'enhance transparency, localise downstream mining industries, and enhance royalties on mining' (Kulkarni, 2024). In 2019, the government created the *Entreprise Générale du Cobalt* as a subsidiary of the state-owned mining company Gécamines, with a mandate to formalise the artisanal mining sector and a monopsony (sole buyer) on all artisanal cobalt. The EGC has been in operation since 2021. Despite these legal provisions, most ASMs in the country remain outside the law and outside the provisions due to difficulties with compliance as well as state incapacity in key ASM areas. However, regulation and implementation remain weak, with political instability exacerbating conflicts and limited resource capacity (Kulkarni, 2024). Little evidence is available regarding further large-scale operationalisation of the pilots in eastern DRC, including the ICGLR, which remains at a capacity-building stage (EU Delegation to Burundi). Despite these laudable efforts in Eastern DRC and the wider Great Lakes region, structural limitations persist. The regional mineral smuggling ecosystem continues to thrive, as the April 2024 M23 seizure of the Rubaya mine illustrates. The UN panel of

experts on Eastern DRC provided evidence in January 2025 that the Rubaya coltan is smuggled to Rwanda, then mixed with national production, calling it 'the greatest contamination ever recorded of mineral supply chains in the Great Lakes region' (Toulemonde, 2025).

State capacity concerns

Government and industry-led initiatives across the continent suffer from wider national governance challenges that undermine the effectiveness of responsible sourcing efforts. These include the ASM sector's complexity and huge network, with mines often operating in remote areas where state structures are weak, have an inconsistent presence and are underfunded. There are significant challenges in implementing national mining regulation and legislation, with miners often operating in a context of local power dynamics governed by non-state actors – sometimes in the form of non-state armed groups. In such circumstances, actors in the supply chain operate across legal and illegal spheres where governments struggle to implement the country's mining legislation and regulate ASM, including small-scale and semi-industrial operators. There are also challenges relating to the technical services of ministries and national regulatory bodies, including agents' skill capacities, the scale as well as the quality of national due diligence systems and personnel, together with opportunities for corruption where agents are not paid regularly – especially in jurisdictions like the DRC where the state has a role in traceability solutions, but also elsewhere with regards to the enforcement of legal requirements. While the links between minerals and conflict actors gain headlines, more widespread challenges of legal non-compliance include: underreporting of production; misreporting of ore grades and qualities; trans-national smuggling to benefit from access to different tax and royalty regimes; avoidance of export duties; price arbitrage; or access to smelting and processing facilities. A central challenge to improving implementation is citizens' general mistrust of the state.

Initiatives for mineral traceability face a challenge relating to state effectiveness. Some are designed to complement national legislation and requirements, while others exist in parallel or because state functions are not working. However, all require state support and depend on cooperation with the government for their implementation in some form or other. Countries with weak governance and/or authoritarian structures present challenges to sustainability standard-setting and traceability (Müler et al., 2024). This is exacerbated by a lack of resources and a scarcity of appropriate skills, both of which can lead to unreliable reporting and due diligence. Authoritarian states also pose a risk where data can be used against citizens and businesses where there are no adequate safeguards. There may also be conflicts of interest where politically exposed persons and officials connected to a ruling party, government, or military have ownership or vested interests in the mining industry. Furthermore, there are issues around transparency and representation, beyond financial disclosures or individual connections, that inhibit sector accountability, *inter alia*: limits to parliamentary oversight of mining; agreements between the government and operators; or jurisdictional overlap between traditional authorities and national governments.

International support and lessons from Gold

International development agencies and donors have supported pilot projects in their desire to link mineral production and development in high-risk areas. For example, the United States Agency for International Development (USAID)'s Zahabu Safi (Clean Gold) Project received USD 11.9 million in funding for a pilot scheme between 2018 and 2023 in the DRC, with Global Communities as the lead partner (USAID, 2021). The purpose of the scheme was primarily to build commercially viable and conflict-free gold value chains, increase refiners' confidence in purchasing from artisanal producers, and thereby increase downstream actors' confidence, for instance, jewellers, through feasible and credible traceability, due diligence systems and tackling barriers to responsible trade. They achieved this through extensive supply chain evaluation of mines, flows of material, finance, political and socio-economic and environmental risks, as well as through financing third-party audits. Partnerships with local banks sought to pre-finance exports as well as ongoing education to miners and processors of responsible sourcing, sought to improve performance (European Partnership for Responsible Minerals Secretariat, 2022; Global Communities, 2021).

NGO and CSO initiatives have also focused more on pursuing development outcomes and providing a higher degree of certainty. However, the higher cost of implementation and reach has limited such schemes' ability to expand beyond distinct projects. For example, Canadian NGO IMPACT, formerly Partnership Africa Canada, developed the first artisanal gold programme in the DRC, later named Just Gold. The project has successfully created some traceable gold exports from DRC and Côte d'Ivoire, with 2 171 miners participating in the DRC. This project received financial support from various international actors, most significantly Global Affairs Canada, with additional funding previously provided by USAID through their Capacity Building for Responsible Minerals Trade project and the International Organisation for Migration (Just Gold Project, 2022). Apple and Humanity United also provided some funding. This project created an identity preservation supply chain model to take gold from ASM producers to purchasers; most notably, it was the first scheme to verify conflict-free gold exports to Canada. An assessment of the project concluded that 'The future of conflict-free, traceable, responsible DRC gold is unpromising unless there are major shifts in incentives and market expectations. […] Market driven solutions have a role to play, but traditional international aid is still desperately needed to create the conditions that may eventually enable the market to play its role. […] In high-risk areas, responsible sourcing must bolster, not lead, development efforts, which themselves must be carried out using a conflict-sensitive approach' (Katho et al., 2021).

Similar conclusions have been derived from other projects in other jurisdictions. The United Kingdom (UK) launched Fairtrade and Fairmined Gold in February 2011, with a focus on mines in South America. Though this gold scheme ran for two years, the project partners piloted separate models afterwards, and its successor programmes have persisted. Reviews of the initial programme revealed similar challenges to other high-certainty-high-cost ASM-targeted interventions on physical and monetary constraints and developmental impact (Bi, 2022). There were difficulties in achieving certification, such as remote and hard-to-access sites and critics pointing to very high standards that often misrepresented or misinterpreted realities on the ground (Oakley, 2022). A mine in Uganda was online for only six weeks when it was decertified sometime around 2017. One identified problem was that the programme structure never eliminated the

potential opt-out of selling on the open market (Oakley, 2022). The incentive-based solution sought to encourage as many additional licensees as possible to join and reach a 'critical mass of stability' (Oakley, 2022: 106). Overcoming these challenges relies on the principle of continual improvement enshrined in the Code for Risk Assessment for ASM Code – a set of sourcing standards based on the OECD Minerals Guidance – that the Alliance for Responsible Mining developed.

In 2023, the EU-funded EIT Raw Materials supported the Raw Materials Radar Consortium to enhance artisanal small-scale mining practices in Liberia. The objective was to 'develop a software and hardware solution that would use blockchain together with the Internet of Things (IoT) technologies to trace the origin, ownership and provenance of raw materials' (Anyadike, 2023). The IoT kits include 'digitally-connected weighing scales and tracking devices for material shipments. The system will also enable the automatic weighing and recording of material ownership by suppliers on-site' (Anyadike, 2023). Blockchain and digital data analysis enable onward monitoring and further data analysis. The project partnered with four organisations: Fondazione Bruno Kessler's OpenIoT Research Unit; mining consultancy company ECTerra; non-profit Fondazione Hub Innovazione Trentino managed the Internet Protocol; and Minespider contributed its expertise in developing blockchain-based platforms for tracking mineral supply chain data.

Box 3: Conclusions: Traceability schemes, actors, relationships and African mining governance

- **International regulations and legislation have been important drivers for the creation of responsible sourcing and traceability schemes**. However, international regulators need greater clarity on what they consider credible and effective traceability schemes and what is acceptable as a 'first trusted custodian', especially given the heterogeneity and wide range of standards.
- **Traceability is technically possible**, but it comes at a cost. Manufacturers that desire a high degree of certainty have engaged in commercial third-party tracing schemes. This has meant that a limited amount of material can be traced at a cost.
- Industry-led initiatives can lead to wide adoption, but can be undermined by weak implementation, 'washing' – that is, using membership of a scheme to claim good performance, which is not always the case and may not be effectively implemented. Often, **the cost of compliance falls on the producers**, whether ASM or industrial and for many, this is regarded as a transaction cost for selling to specific buyers but not to others.
- Traceability may be regarded as **inequitable as the benefits accrue to downstream entities** while placing much of the due diligence and compliance obligations onto upstream producers.
- The feasibility of traceability is undermined by the dual challenge of **weak or uneven state enforcement** of legislation and regulation as well as **operators' minimal implementation**, demonstrating compliance or conformity to specific standards as a proxy for wider responsible performance.
- NGO and donor-led initiatives have improved conditions for a limited number of participants, but have not had wide-reaching impacts. The high costs and challenges of incentivising adoption have meant that **many NGO-led schemes have not been self-sustaining after pilot phases**.
- Where traceability has been effective, it has often relied upon **multistakeholder partnerships** and must include communities, citizens, and national political representation, as well as a cross-section of industry that includes operators, traders and manufacturers.

3 The promises of technological innovation

The granularity of traceability has incrementally been improved through ongoing frontier technological innovations. This section takes stock of the technical and ethical issues emanating from the digitalisation of traceability, including blockchain and geochemical fingerprinting, as well as other frontier technologies. The extent to which technological innovation should be relied upon to maintain transparent and reliable supply chains is also considered.

3.1 The advent of smart mining

As with other industrial sectors, the mining industry has felt the waves of the so-called- '4th industrial revolution', consisting of digitisation and rapid technological innovation, intended to 'reduce costs, improve business productivity and transform business practices' (Barnewold and Lottermoser, 2020: 747). New technologies such as Artificial Intelligence (AI), IoT, Web 3.0, autonomous vehicles, robotics and cloud computing have been integrated into mining and supply chain operations. Increased productivity and cost reduction, not traceability, have been the drivers of digitisation in the industry: the global commodity price downturn of the mid-2010s was an incentive for mining companies to increase productivity while reducing staff and energy input, effectively lowering running costs (Cosbey et al., 2016: 5; Chatterjee et al., 2024). However, beyond profitability, digitisation and smart tools have also been heralded by many as a new chapter for traceability, overcoming the previous shortcomings of paper-based schemes.

3.1.1 Frontier technologies and their contribution to traceability

Smart contracts

Smart contracts are based on blockchain technology. They are self-executing agreements. Contract terms are written into code pre-emptively, enabling automated transactions once conditions are met. The transaction data is then automatically added to the blockchain, verifiable by all stakeholders along the supply chain from one custodian to another. Hence, transactions are transparent and fool-proof, reinforcing the validity of data on the blockchain.

Material tagging

A digital record is physically attached to the product through a QR code, GPS chips and radio-frequency identification.

Remote sensing

Remote sensing devices detect variations on the Earth's surface regardless of cloudy conditions and the time of day. Remote sensing can contribute to traceability by mapping out the informally regulated, under-studied and conflict-associated ASM sites (Nursamsi et al., 2024: 7). It is argued that better oversight of illicit or informal networks contributes to the transparency of supply chains (Ribeiro et al., 2024). This technology has been applied to remote artisanal mining sites in the DRC's copper belt to improve the mapping and monitoring of ASM dynamics in weakly governed and remote spaces (Brown et al. 2020), detecting variations in land use and digging activities.

Machine learning and AI

AI and machine learning are used as analytical tools to dissect the large quantity of data points collected (Soofastaei, 2022). AI models are trained to spot anomalies in quantities reported and transported, enabling early warning detection of diversions of mineral shipping or site incursion. Machine learning is also utilised to process imaging sensor data (Ghamini et al., 2021).

Edge computing

Edge devices such as sensors, drones, or smart cameras capture events on a given mining site, analyse the data locally and send only relevant insights to the cloud, hence requiring less bandwidth. Outlying data patterns and unauthorised diversions are spotted through AI, requiring no human oversight. The benefit of edge computing is that outlying patterns and unauthorised movements, signalling illicit activities or smuggling, are detected without needing an internet connection.

Physical authentication

Mining staff and intermediaries on the supply chain are sometimes authenticated through facial recognition or fingerprinting before they can encode data into the database about minerals they temporarily have custody over.

The few examples of frontier technologies described above provide a wide range of automated tools that function around the clock, enabling better control over formal supply chains through the validation of data entries and the statistical verification of product movement between custodians, all conducing to traceability.

3.2 Impact of mining 4.0 on responsible sourcing and traceability

Digitisation was introduced to early schemes to centralise collected data, effectively decreasing the manual workload associated with traceability and reducing associated fraud in easily forgeable paper-based systems. Around 2013, three years after the start of its first pilots in the Great Lakes, ITSCi embarked on the digitisation of its operations through a partnership with the UK-based traceability software firm Helveta. Handheld personal digital assistants were adopted for data collection, which are mobile digital devices that are easy to deploy in remote field locations. Following its collaboration with ITSCI, the national mining agency of Rwanda also adopted Personal Digital Assistants and other digital devices to improve the quality and quantity of data in its mineral sector.

The growing inclusion of digital technologies in traceability has also brought about a state of 'hyper-transparency' through 'real-time, automated data collection and analysis', deemed more objective and comprehensive than human-made assessments, audits and monitoring (Kos and Kloppenburg, 2019). However, the growing amount of automation, data collected and processed across borders raises a few legal, technical and ethical challenges explored in the following sections.

3.3 Risks and operational challenges of traceability digitisation

3.3.1 Data security and data sovereignty

Digitised traceability carries a series of operational challenges, tackled in this section. The increasing digital intensity and online reliance on key supply chain operations make digitised systems vulnerable to cybersecurity risks (Xu et al., 2024), which can cause severe operational disruptions. Beyond cybersecurity challenges, the large quantity of proprietary data generated and its transfer across jurisdictions raises data sovereignty challenges. Indeed, data regulations can conflict from one jurisdiction to another, which can interfere with the communication of traceability information along the supply chain. Specifically, different local data storing and processing requirements might complicate the interoperability of traceability systems and the sharing of traceability data. Beyond data sovereignty requirements, certain jurisdictions strictly limit data collection and the sharing of sensitive data. The very core concept of blockchain, for instance, is potentially in tension with the EU's General Data Protection Regulation requirements, as blockchains are 'often not in a position to absorb changes required by law' (Finck, 2019: 6). For instance, blockchain-based smart contracts, which are used in traceability for data validation, will execute themselves automatically even if parties change their mind, or if 'a change in token ownership is mandated by a court order' (Finck, 2019: 6).

In theory, strong confidentiality and encryption standards in most private blockchain protocols prevent both external entities' alternative usage of data and commercially sensitive leaks. Certain specificities of blockchain have been developed to enhance data protection without it being at the expense of transparency, such as Zero-knowledge proofs (ZKP). ZKPs validate specific knowledge about a piece of data without revealing the data itself. Circularise, a Dutch company founded in 2016, established a 'smart questioning' patent to make CoC details available to permissioned entities without sacrificing all the data. Data accuracy communicated to downstream actors is backed by ZKPs' mathematical guarantees.

While privacy is required when dealing with large amounts of sensitive data, too much opacity and centralised control over the data can also fundamentally contradict the very purpose of traceability. In that case, checks and governance of private blockchain protocols 'fall entirely under the purview of private institutions, be they banks or companies' (Calvao and Gronwald, 2019: 6). The relative lack of external oversight and sometimes complete control of private companies over traceability information 'contradicts the open control over digital ecosystems meant to expand transparency and accountability' (Calvao and Gronwald, 2019). It is also debated whether monopolies by companies over traceability data stored on private blockchains might fail to comply with anti-trust regulations and facilitate anticompetitive behaviour (Ristaniemi and Majcher, 2018). Lastly, the intense computing power underpinning blockchain technology and the need for data centres present a significant environmental cost. Digitised traceability must hence navigate the tension between data privacy, security, antitrust and transparency requirements. Such interoperable yet confidential and secure data systems, hence, rely on effective and widely adopted data-sharing protocols, which are essential for the upscale of mineral traceability across supply chains.

Interoperable yet confidential and restricted-access traceability systems also enable the alignment of traceability with privacy and competition regulations.

3.3.2 Ethics of data extraction

The data extraction phase also poses ethical questions relating to the privacy of people from whom data is extracted and codified and whether the process carries their informed consent. The unidirectional nature of traceability as it stands disempowers miners by not advising them where their product goes. As a response, the Estonia-based social venture Datastake envisions mining site data from local communities as a commodity for which local people should be remunerated. The group supports local communities in weak governance countries to monetise their on-site knowledge and de-mystify understudied mining zones. The European Partnership for Responsible Minerals supported Datastake in launching its Consolidated Autonomous Due Diligence framework.

3.3.3 AI's role in digitised traceability

Ethical issues are not unique to the mining industry, but the increasing application of AI to the monitoring of workers presents a risk, potentially creating new 'forms of oppression and violation of rights of the workforce' and a negative impact on 'workers' moral agency, autonomy or responsibility' (Santoni de Sio, 2024: 408). Through AI-enhanced monitoring, companies effectively acquire 'increasing socio-economic power' over their staff (Santoni de Sio, 2024). For instance, at some mining sites, AI technologies are added to computer vision devices, deriving staff behaviour patterns with increasing precision from data showing, for example, changes of posture, utilisation of equipment and positioning within space (Kaul and Soofastaei, 2021: 17). Due to the lack of sufficient meaningful human control of self-executing protocols as well as automatic data collection and analysis, 'responsibility gaps' arise when 'no human agent might be legitimately blamed or held culpable for the unwanted outcomes of actions mediated by AI systems' (Santoni de Sio and Mecacci, 2021: 1059).

3.3.4 Increased automation and local content policies

The increased automation of mining operations and supply chain management (SCM) might enhance the granular-level traceability of supply chains, but also pose risks to the domestic ability to derive benefits from extractive activities led by foreign entities. Mining automation potentially clashes with local content policies, not only suppressing low-skill and blue-collar jobs, but also creating jobs that do not necessarily match local skill sets. Local content policies are a direct way for mineral-producing countries to capture greater benefits from mining operations within their borders beyond tax and royalty collection (Nickerson and Geipel, 2019). A study by the International Institute for Sustainable Development established that mining automation directly affects jobs, reducing the number of workers on site, but also indirect jobs outside the mines that support those miners, their sustenance and their equipment (Cosbey et al., 2016), which all reduce mining's contribution to the country's Gross Domestic Product (GDP), estimating the overall loss to GDP as somewhere between 13 % and 31 % (Cosbey et al., 2016, 27).

3.3.5 Remaining barriers to digitisation

Despite the increasing adoption of digital innovations in the mining sector, BCG's 2021 Digital Readiness studies showed that the mineral and metals industry was less digitally mature than other industrial sectors (Boston Consulting Group, 2021). The barriers to digital adoption cited are: the lack of digital skills in a largely blue-collar workforce; remote and rural areas where network bandwidth and electricity infrastructure are lacking; and rough terrain, making the installation of sensors challenging. Implementing blockchain solutions also poses challenges as they require 'significant investment in infrastructure and expertise to deploy and maintain the networks effectively' (Tahir et al., 2024: 8) in countries where basic infrastructure is often lacking, and climate change is increasingly impacting electricity availability, as in Zambia (Gondwe, 2024).

3.4 Traceability technology and ASM

By definition, ASM is a low-tech enterprise (Hilson and Maconachie, 2019: 125); some traceability and responsible sourcing schemes have attempted to expand the perceived benefits of digitisation to ASM frontiers in Africa. This is so with the GemFair project in Sierra Leone, which integrated a set of hardware and software to ASM operations to maintain diamonds' traceability from the mine site through to export. Digital traceability is only one pillar of GemFair's model, which includes guaranteeing a fair price to miners and helping them improve mining conditions. As explored in the connected paper evoked in footnote 1 (Vandome and Dideberg, 2025), other schemes have incorporated geochemical fingerprinting, such as: the German BGR pilot; and the CTC in the Great Lakes Region. BGR's certification efforts between 2008 and 2011, the so-called 'Certified Trading Chains', included the Analytical Fingerprinting Method, consisting of mineralogical and geochemical analyses of the 3T ores to confirm provenance. This was used as a forensic tool. After 2011, the BGR fully supported the ICGLR RCM, which also uses analytical fingerprinting forensically. The BGR lent the required analytical facilities to the ICGLR.

Better Mining, an upstream mining accreditation mechanism established in the Great Lakes region, targets ASM exclusively and has applied a digital traceability platform to artisanal mined products called 'Trace'. Trace uses real-time data plausibility detection through pre-set algorithms validated by experts; all Better Mining on-site staff carry a Trace app on mobile devices. In this case, technology contributes to mitigating supply chain risks that are highly likely to be contaminated while avoiding a complete disengagement of buyers from difficult areas. Importantly, Better Mining envisions Trace as a component of its responsible sourcing offering rather than a standalone solution.

Box 3: Fintech 2.0. and ASM traceability

The 'Fintech 2.0.' venture capital-backed start-up GoldFinX based in Dubai makes micro-credit lines available to artisanal miners in remote areas against a lifetime royalty of 20 % on their production. This private company claims that gold mining operations' technology and adequate financing make them more environmentally and socially conscious. Sensors are part of the equipment initially invested in mining stations, enabling monitoring and tracing from a distance. Drones are also used to keep track of changes in the exploitation of the terrain (GoldFinX, 2022). A blockchain-based SCM System is reportedly used to trace the gold back to GoldFinX sources and reports the volume produced, which pays the taxes and royalties to governments. For traceability, the monitoring of exploitation is carried out remotely from the GoldFinX headquarters in the United Arab Emirates (UAE) through telemetric data collection.

3.4.1 Potential Benefits of ASM Digitisation

It has been argued that digitisation could improve the governability of ASM, unlocking its undisputable socio-economic potential, by improving 'the accessibility and appeal of the artisanal sector to investors and commercial partners' (Zuwharara, 2023). More transparency could also arguably grant artisanal miners access to a more diverse pool of buyers through digital platforms, hence increasing their negotiating power (Duncombe, 2018). Research points to Zambia, Ghana and Nigeria as African jurisdictions with comparatively more favourable regulations towards ASM and where the benefits of digitisation can be further explored. However, the digitisation of supply chain data has not necessarily resulted in the empowerment of small producers nor always facilitated their access to formal markets (Kos and Kloppenburg, 2019), but has instead placed new data collection burdens on them.

3.4.2 Tensions between digitised traceability and ASM

Envisioning top-down and tech-heavy value chains as the only means of verifying responsible conduct in supply chains risks strengthening the bias towards industrial mining as the most legitimate actor in the mining sector. Indeed, since the 2000s, large-scale mechanised extraction has often been associated with progress and 'modernisation', while artisanal operators have been ostracised and subjected to military 'sweeps' (Hilson and Maconachie, 2020: 7). Poverty, youth unemployment and general economic decline in rural communities drive informal and illegal mining (Achina-Obeng and Aram, 2022). Investing in tech-enabled, hyper-precise traceability devices while ignoring these surrounding conditions and failing to create any local added value will inescapably leave unofficial routes to thrive. ASM employs an often-marginalised workforce and generates revenue locally that can be reinvested in other sections of the local rural economy, such as fertilisers for agriculture (Hilson, 2016).

Furthermore, high-tech additions to mining operations constitute supplementary skill and capital barriers for artisanal miners to gain access to formal markets. Beyond costs, the high-tech requirements also generate asymmetrical power relations between those who extract the data and those who work in the mines. One quantitative study of the artisanal gold sector in Tanzania scrutinised the drivers behind artisanal miners' choice to sell their output on formal markets rather than through informal chains (Paschal and Kauangual, 2024). The study concludes that miners are in favour of 'policy initiatives supporting cooperatives, credit access, modern technology, training, and affordable communication devices were essential for adopting formal mineral markets, improving livelihoods, and increasing government mineral tax revenues'. Technology traceability alone does not suffice to bring about cleaner supply chains. However, it can play a role in empowering ASMs and formalising their operations, making them more compatible with traceability systems. Importantly, tech-driven traceability ignoring ASM realities risks creating a two-tier system where hyper-transparent chains obscure ongoing local realities in less tech-ready, marginalised or conflict-affected communities, whose products still find their way into global value chains.

3.5 The limits of techno-solutionism

The enthusiasm for traceability can also be seen as a case of 'techno-solutionism' or an oversimplification of complex social problems as technological puzzles to be resolved by technology (Nagpal et al., 2024). Techno-solutionism de-politicises the realities of mining in developing countries and its fundamentally extractivist paradigm to isolate traceability as an end in itself while disengaging from mining's social problems (Herian, 2018; Clavao and Archer, 2019; Smith, 2022).

Through traceability, consumers at the end of the chain 'perform a politics of caring at a distance' without engaging with the realities upstream (Bryant and Goodman, 2004). Furthermore, traceability is often performed on a for-profit basis by external actors. The tech-enabled top-down, often remote, control from corporations over distant mining locations suppresses the window for local, non-official actors' agency. Monitoring ASM through tech-intensive, top-down solutions imposed on local political economies 'creates clear distinctions between those who exercise surveillance and those who are surveilled' (Ubillús and Benites, 2023; 3). Crucially, if tech-enabled traceability serves as yet another policing device of ASM and clandestine miners, socio-economic problems will only be exacerbated. The policy approaches to traceability must, hence, be careful to avoid a situation where 'those who do not follow the tag and trace schemes are automatically considered illegal suppliers' (Ubillús and Benites, 2023).

Ideally, technological solutions should be seen more as tools than systems in and of themselves because they are 'less comprehensive than certification systems' (Levin and Cook, 2015: 13). In many schemes, digital solutions have been coupled with support for ASM formalisation and due diligence, although the schemes articulated around ASM-formalisation are found to focus on 'already established small-scale and medium-scale mining operations rather than marginalised artisanal miners' (Hilson et al., 2016). Some formalisation efforts in the eastern DRC have been found to exclude women from the value chains because, as a response to formalisation, 'some women have changed their positions on the chain by occupying less profitable positions, and others were even excluded in the chain' (Byemba, 2020: 420). Ultimately, African national authorities are lagging in terms of tech adoption. Many ASM mining permits are still being delivered on paper, and there are no publicly available digitised cadastres for people to access permit information, which hampers greater democratic scrutiny of mining operations by civil society. Technological innovation adoption is primarily driven by industrial mining companies and third-party traceability suppliers at this stage. The lack of African governmental ownership in Mining 4.0 is yet another reason not to rely solely on technological advances for traceability and supply chain transparency.

A positive example of digital solutions used to empower and reinforce state capacity as well as control over its minerals is the mineral tracking system designed by the United Nations Conference on Trade and Development (UNCTAD) and the Zambian Revenue Authority, which was first piloted in 2016. This statistical system spots underreporting in exports while allowing 'mining companies to submit their monthly mineral production reports electronically instead of travelling to the capital Lusaka, to submit them in person' (UNCTAD, 2020).

Box 4: Conclusions: The promises of technological progress

- Mining 4.0. has contributed to the traceability of some mineral supply chains through **better monitoring and real-time control of movements along the value chain**.
- Greater automation, data collection and analysis have reduced reliance on corruptible humans and falsifiable paperwork.
- AI and machine learning enable **real-time interpretation of data inconsistencies** in shipping patterns, **spotting potential unauthorised movements**.
- However, this phenomenon has mainly affected simpler, more controlled, relatively more vertically integrated supply chains. Digitisation's by-product has also been the proliferation of a shadow economy for mineral laundering and fraudulent traceability practices, especially in the ASM sector.
- **Attempts at digitising ASM are still experimental**, while technology adoption is likely to constitute an additional barrier to formal market entry. In the meantime, alternative markets and buyers absorb unethically mined products.
- As it stands, African governments have little capacity to implement tech-driven traceability unless they have donor support for digitisation. If not, they could be further sidelined from traceability efforts.
- Frontier technology in traceability presents challenges linked to **data ownership, data extraction, potential cyber threats** and AI models that might lead to 'responsibility gaps'.
- Technologies are not a neutral addition within complex socio-economic environments, such as frontier mining communities. Their insertion within those spaces creates new forms of power.
- Lastly, if tech additions to mining are used primarily as yet another policing device for illegal miners or are applied without supporting the professionalisation and legitimisation of ASM activities, then, without engaging with the drivers of illegal mining, the socio-economic issues of the mineral industry will only be exacerbated.
- Tech can still play a role in responsible sourcing, especially **to reinforce African customs capacity or ASM access to credit,** or to professionalise their activities. However, this **should not be relied upon as a panacea for the mining sector's complex environmental and socio-economic impacts**.

4 African perspectives of key benefits and costs of traceability schemes

This section explores African mining priorities, perceptions of traceability schemes and responses to EU policymaking, including the 2024 CRM Act, the CSDDDand the Carbon Border Adjustment Mechanism (CBAM). Also discussed is the dissonance between applicable national and regional legislation, together with the practical realities of mining in Africa.

4.1 African mining priorities

The primary articulation of African expectations for its mining sector is codified in the African Mining Vision (AMV), which curates the continental aspirations for this sector, in particular the desire to move beyond primary extraction and processing by supporting activities higher up the value chain. The AMV calls for a 'knowledge-driven' mining sector that 'catalyses and contributes to the broad-based growth and development of and is fully integrated into, a single African market namely through down-stream, mid-stream, and up-stream linkages into other economic activities, and the development of mutual beneficial partnerships between the state, the private sector, civil society, local communities'

(AU, 2009: v). It calls for equitable benefit sharing and distribution of resource rents, together with a 'socially responsible' industry that is 'appreciated by surrounding communities.' However, the implementation of the AMV continues to be undermined by differences between rhetorical ambition and national *realpolitik*. The AMV does not mention mineral traceability, although it does emphasise responsible sourcing.

The AMV grew out of a multilateral process involving the UN Economic Commission for Africa (UNECA), the AU and representatives from the African Mining Partnership (the intergovernmental forum of African ministers responsible for mining), the African Development Bank (AfDB), the UNCTAD and the UN Industrial Development Organisation. A technical task force was convened in 2008 in preparation for the first AU Conference of Ministers Responsible for Mineral Resources Development, following which the AMV was adopted in 2009. This was important as a continent-wide agreement with a shared vision for the industry, including a commitment to align mining codes, develop shared infrastructure and cooperate on mineral policy towards mutual development objectives.

Encapsulated by the AMV are two important theories of change: firstly, through public-private cooperation, African countries would be able to reverse a history of extractivism and use the industry as a flywheel for industrialisation; and secondly, through regional policy alignment, overhauling the neo-liberal mining codes of the re-privatisation era and infrastructure development would prevent a 'race to the bottom' competition of tax breaks and legislation waivers for investment attraction and secure regional benefits (Hilson, 2020). The Vision has been criticised both for placing too much emphasis on private operators and for not appeasing them enough (London Mining Network, 2013). The Environmental Rights Action/Friends of the Earth Nigeria claimed it favours foreign investors to the detriment of the African continent and does not address local artisans' critical livelihood concerns. Similarly, it has been criticised for applying a 'one-size-fits-all' approach to a diverse continent of countries with significant differences in colonial legacy as well as the scale and importance of their mining sectors while at the same time being accused of being voluntary and non-binding, leading to weak implementation by states (Van Wyk et al., 2019; Coderre et al., 2019). Ultimately, as Hilson notes, 'The irony of AMV's makeup, however, was overshadowed by the fanfare surrounding its launch. No one seemed to question the logic behind asking heads of state, many of whom have deliberately kept sections of mineral-rich Africa poor by marginalising their citizenries, to design and oversee the implementation of a mining-led development manifesto with "good governance" at its core' (Hilson, 2020: 419). The AMV does not mention traceability, but the implementation of traceability solutions could significantly support the transparency and equitable benefit allocation, as well as provide African metal and mineral producers with information about where their minerals are ending up and the true value they hold to strengthen their bargaining position in negotiations. Increased engagement from African regulators and businesses could ensure that traceability solutions are oriented to deliver information and intelligence to African producers as well as citizens in addition to downstream users, for the purpose of responsible sourcing.

The African Minerals Development Centre (AMDC) was created in 2013 as the AMV's implementing arm, initially under UNECA and then as an AU organisation. The AMDC advocates for the implementation of the AMV. However, despite an assertion from the AMDC that under their guidance

and supervision, many African countries would by now have aligned their national mining codes and legislation to the AMV policy objectives, at present, only four – Guinea, Mali, Zambia and Nigeria – have ratified the AMDC statutes out of a minimum of 15 ratifications needed to operationalise the centre fully. The AMDC has been instrumental in working with the AfDB, the African Legal Support Facility, the UNECA and the UNDP in developing a Green Mineral Strategy for Africa, which contains various AMV objectives applied to harnessing the CRM's potential for national development. The AU Executive Council approved the Strategy in February 2025. As with the AMV, it has faced criticism for its reliance on private operators for extraction, mixed with a statist approach to benefit sharing (Van Wyk et al., 2019).

The AMV and regional mineral frameworks necessitate three requirements for international actors seeking to support traceability on the continent. Firstly, there is beneficiation and value addition. The AMV's requirement for responsible sourcing implies an entry point for discussion on traceability, but it does not expressly discuss the topic. Engagement on traceability must be expressed in the language of value sharing and demonstration that responsible sourcing is not just a reporting requirement for end users but can bring actual development impact on the ground.

Secondly, international interlocutors need to engage and work with the existing continental frameworks. However, if aligning with the AMV is a necessary condition, it is not sufficient for supporting policy uptake. The variations in national mining policies, their evolution and inconsistent implementation mean that more direct approaches are required to ensure responsible supply chains. Furthermore, within the AMV's continental strategy, no framework is included for equitable benefit sharing across different countries, as the demands for transition resources are likely to benefit some countries more than others. For instance, not every country can host a smelter or advanced manufacturing. Such activities should be clustered to benefit from economies of scale, such as shared infrastructure and common regulation.

Thirdly and finally, to facilitate local manufacturing, some countries have imposed export restrictions on raw materials to encourage processing – for example, in 2022, Zimbabwe banned the export of raw lithium ore, and in 2023, Namibia announced an export ban on raw lithium, together with REE.

4.2 Bilateral agreements with African governments

The development of regional value chains and bilateral agreements on supporting value addition can present an opportunity for increasing the application of traceability, but these face challenges in their adoption and implementation from regional competition on existing and future supply chains on the continent (Nassen Smith, 2025; Afreximbank, 2024). In December 2022, at the USA-Africa Leadership Summit in Washington, the USA joined the two countries by signing a trilateral Memorandum of Understanding (MoU) concerning support for the Development of a Value Chain in the Electric Vehicle Battery Sector and aims to facilitate the development of an integrated value chain to produce electric vehicle batteries in the DRC and Zambia. Afreximbank (the African Export-Import Bank) and UNECA on Special Economic Zones have subsequently supported this agreement to produce Battery Electric Vehicles. Further details about the funding and the next phases have not yet been made public, but this will certainly entail the creation of Special Economic Zones in each country and the formation of committees in the respective countries to oversee this process. The African Coalition

for Green Minerals (a group of Africa-based civil society organisations founded in Lubumbashi, DRC), as well as African analysts interviewed for this paper, deplored the overall lack of transparency around the trilateral agreement in failing 'to enable populations of the various countries, represented by their parliamentarians and civil society organisations to assess their content and ensure that commitments made by the contracting parties under this Protocol are respected' (Afrewatch, 2025).

The shared ambition is to utilise both countries' respective resource endowments to develop Electric Vehicle battery manufacturing capabilities, in line with their industrialisation objectives. According to Vandome, 'Clustering production through special economic zones and industrial parks, alongside local agreements like the DRC-Zambia MoU, could be a solution for African states to build extraction and processing capacity' (Vandome, 2024). While responsible sourcing and standards' adoption are key elements of the agreement, there are significant challenges to cross-border traceability. Most copper mining is on the DRC side of the border, while much of the smelting capacity is in Zambia. There are media reports of smuggling through the Chirundu border post, fuelled by cartels and corruption (Goddard, 2020). In 2019, 10 trucks of copper ore were seized by the Zambian Revenue Authority for being smuggled into the country to avoid paying import duties (Xinhuanet News, 2019), and in 2024, the transit of copper was briefly halted due to a bilateral trade dispute (Hill, 2024). The implementation of traceability initiatives can be part of the solution to improving and limiting cross-border smuggling, but it must be enforced by governments on the ground.

The African Continental Free Trade Agreement (AfCFTA), which came into force in 2021, could support existing and new mining supply chains by coordinating the production and supply of mining goods across different African countries (Rampai and Nupen, 2024). This could 'foster closer regional co-operation and integration within the mining sector and potentially even trigger significant shifts in trade patterns, making Africa less dependent on external mining partnerships' (Rampai and Nupen, 2024).

Beyond physical infrastructure projects, such as the Standard Gauge Railway in Tanzania or the Lobito Corridor in Angola and the DRC, there is a need for improved border management, including the harmonisation of border processes, improved use of digital mechanisms for logging the transit of goods across borders and the streamlining of processes to facilitate trade. For the mining sector, in particular, streamlining processes and harmonising border management is central to improving opportunities to develop regional value chains. Malatji argues that the AfCFTA currently falls short of meeting the criteria needed for improved digital integration (Malatji, 2023). In particular, advances need to be made in specific areas: digital payment systems and financial integration; the use of digital technologies, such as blockchain and IoT, to improve logistics and transportation processes; investment in digital infrastructure and connectivity to support the growth of digital trade and cross-border transactions; developing digital skills and competencies; and establishing minimum standards for data protection and cybersecurity to secure cross-border digital transactions.

An essential component within the AfCTA is verifying the origin of products. The Rule of Origin manual (African Continental Free Trade Area Secretariat, 2022) classifies mineral resources that are obtained from the ground, seabed, below seabed or within the territory as originating in that country, as well as recycled material – for example, material recovered from scrap, irrespective of

its origin. The rule of origin relies on verification by the 'Designated Competent Authorities' of the exporting State Party, but they can also authorise approved exporters to certify the origin of the material. As such, while the ultimate responsibility is on the state, third parties could also certify the origin.

4.3 Support for traceability

National leadership's public support for traceability has been limited to those countries facing the most significant international regulatory pressures. This is perhaps understandable due to the concentration of initiatives that have emerged in these areas as governments and producers have sought to keep industries running. However, it has also led to a sense of exceptionalism and paternalistic finger-pointing.

In January 2025, in an address to Ambassadors in Kinshasa, President Felix Antoine Tshisekedi stated:

> 'En 2024, nous avons intensifié nos efforts pour renforcer la traçabilité de nos minerais avec le soutien de partenaires internationaux. Nous avons également engagé des discussions sur la mise en œuvre de mécanismes de transparence et de certification afin de garantir que les richesses de notre pays profitent aux citoyens congolais plutôt qu'à des acteurs extérieurs'.
>
> 'In 2024, we intensified efforts to strengthen the traceability of our minerals with the support of international partners. We have also initiated discussions on implementing transparency and certification mechanisms to ensure our country's wealth benefits Congolese citizens rather than external actors.' (Copperbelt Katanga Mining, 2025)

This political support was reiterated by the Prime Minister of DRC, her High Excellency Judith Suminwa, in February 2025 at the African Mining Indaba. She said:

> 'La traçabilité des minerais n'est pas une option mais un impératif tant moral que stratégique. Chaque gramme extrait doit être suivi, contrôlé et certifié'
>
> 'Mineral traceability is not an option, but a moral and strategic imperative. Every gram extracted must be monitored, controlled and certified.' (Desk Eco, 2025)

The requirement for traceability in the DRC is legislated for in the 2018 revised mining code, which mandates 'Specific legal or regulatory measures are enacted in application of national, regional and international standards in terms of transparency in the mining industry, traceability and certification of mineral substances.' In 2015, the Congolese government developed its own traceability initiative, the ITOA, consisting of physical envelopes tagged onto artisanal gold production by agents on the greenlighted sites. However, ten years later, scalability issues persist, and furthermore, the political will has lost its momentum on the Congolese side, while lower customs fees in neighbouring countries remain structural factors disincentivising artisanal miners from entering legal channels (US Government Accountability Office, 2017). A more recent limitation lies in the fact that USAID supported the initiative but was already struggling with a lack of financial commitment before the cuts in early 2025. Similarly, the Rwanda mining board claims to be one of the most advanced countries in implementing the RCM. This implies CoC tracking of 3T minerals[10], noting that the

[10] Visit Rwanda, Mining – Visit Rwanda, webpage, 2017.

'Rwanda Mining Board (RMB) organizes and conducts mine site inspections and produces reports thereof that are validated jointly with ITSCi to increase the credibility of the mineral traceability process. The country has two organisations, namely the ITSCI and RCS Global Better Mining, which offer mineral traceability services'[11]. This contrasts with other recently developed mining policies and strategies on the continent. For example, neither the Botswana Minerals Policy of 2022 nor the Zambian National Critical Minerals Strategy 2024 mentions traceability or how responsible sourcing may be verified.

The important role of external legislation fostering African initiatives is further evidenced by the formation in 2006 of the ICGLR, which established the Pact on Security, Stability and Development for the Great Lakes Region (Vogel, 2022: 81). The RINR, endorsed by the heads of state in 2010, forms an important core component of the Pact. The RINR includes 'six inter-linked tools that ICGLR member states committed to implement, namely formalization of the ASM sector; the RCM; the EITI; a database on conflict mineral flows in the region; a whistle-blowing mechanism; and the harmonization of relevant national legislation across the region' (BGR, 2016). Members of the ICGLR are Angola, Burundi (which hosts the secretariat), the Central African Republic, Congo, DRC, Kenya, Rwanda, Sudan, South Sudan, Tanzania, Uganda and Zambia, with additional 'co-opted' members Botswana, Egypt, Ethiopia, Malawi and Mozambique. As such, its membership roughly aligns with provisions of the Dodd-Frank Act in countries that border the DRC. The ICGLR implements the RCM on traceability, which is actioned in tandem with other initiatives outlined in section 2. Mine sites that produce or sell designated minerals are assessed against RCM criteria to ensure that the exploitation, processing and aggregation do not directly or indirectly provide support to non-state armed groups or public or private security forces engaged in illegal activity or serious human rights abuses. It requires that mine sites are inspected annually by a Mine Site Inspector employed or engaged by the Member State (a third party). Inspections determine the status of the mine site – characterised as green for valid, yellow for provisionally valid, red for not valid and blue for not yet inspected. The RCM requires that CoC Systems provide tracking (and records) of the CoC for all Designated Minerals before receiving an ICGLR Certificate for Designated Minerals. The ICGLR is currently finalising its Data Sharing Solution, a centralised regional database to coordinate traceability information, with the support of GiZ Zambia.

The formation of these initiatives and supportive political rhetoric has contributed to some level of stabilisation of regional conflict economies and has an ongoing and growing role in facilitating the inclusion of civil society and enabling a greater degree of local engagement in the sector. There is clearly more to be done to actualise the intended improvements in responsible performance at scale beyond specific operations and directly improve wider development outcomes (Smith, 2022). Minerals continue to play a role in the conflict in eastern DRC, including transnational smuggling as detailed by the UN Group of Experts on the DRC, which demonstrates the need for continual improvement of traceability systems to restrict the ability of their subversion (Group of Experts on the DRC, 2024).

[11] Rwanda Development Board, 'Mining sector', webpage, nd.

4.4 African responses to EU regulations: Critical Raw Materials Act, Corporate Sustainability Due Diligence Directive and Carbon Border Adjustment Mechanism

The extraterritorial nature of EU and other international regulations has been a key driver of Africa's responsible performance standards and traceability schemes. Yet, the trickle-down impact and effective implementation on the ground have often been limited due to frequent negative perceptions of 'Western imperialism', paternalism and overreach, often leading to passive resistance and limited operationalisation (various interviews with Africa-based analysts, January to February 2025). Manjonjo and Mokgonyana argue that 'While these policies [Green Industrial Plan, CBAM and Critical Raw Materials Act] aim to promote sustainability, they inadvertently create significant barriers for African countries pursuing green industrialisation and integration into the global economy' (2024). Responsible sourcing and traceability schemes must demonstrate that they facilitate benefit sharing for communities and non-governmental or commercial stakeholders. They are not simply 'reputation-washing' initiatives that enable extraction by foreign firms, but offer limited national developmental benefits. Such perceptions are not universal, and there are significant variations, including those between civil society and community groups seeking to improve performance. Criticism of the acts can be characterised as having: a limited impact on the ground, in the case of the CRMA and CSDDD; a negative impact on African economies, in the case of CBAM; and insufficient support for African mineral producers, in the case of the CRMA.

The Conflict Minerals Regulation has been shown to have had limited impact on enforcing responsible sourcing due to weak enforcement of legislation in CAHRA. In September 2024, the European Commission produced its own report on the impact of the Conflict Minerals Regulation, which was complemented by a report by the International Peace Information Service and a brief comparing the two. Notable conclusions include: regulations do not trickle down to producers in origin states, which they say is evidenced by underreporting of tin originating in CAHRA; EU authorities rely on the due diligence schemes but often discount or overlook the CSOs or investigative journalist reporting; a proposed 'white list' of responsible refiners and smelters, which could be used as an accepted first point on a CoC traceability mechanism has not been produced; and divergent interpretations of the regulation by Member States and Competent Authorities have led to an uneven implementation across the EU (de Brier & Walschot, 2024). The 2024 report findings were supported by a letter from NGOs highlighting that 'Disappointingly, more than six years after the Regulation was signed into law, and almost three years after the requirements for EU importers started applying, the Regulation has not achieved any notable impact along the supply chain, let alone in producing countries' (Hoex, Sépulchre and Moor, 2023).

African responses to EU regulations are impacted by limited understanding and a lack of analysis of the potential impacts that they could have. The EU is aware of the consequences CBAM might have for African countries, including those within the EU Green Deal and its implementation via EU mechanisms. However, there are concerns about a lack of awareness by regulators within Africa regarding CBAM, how it functions and how it could impact African producers. For example, the Konrad Adenauer Stiftung organised a conference on the impacts of CBAM in Maputo in 2024, and

their report notes that 'Political stakeholders from the Southern African Development Community (SADC) countries expressed their gratitude to have received information on CBAM as some of them had never heard about the mechanism before'. A key knowledge gap concerns the technical nature of CBAM operationalisation after the transitional phase (ending in 2025) and what impact this might have on the ability to facilitate economic growth (Konrad Adenauer Stiftung, 2024). Creating multi-stakeholder technical committees could assist in expanding technical knowledge about the scheme's implementation and what it means for exporting countries. These can also serve as important channels for discussion to link with EU financial mechanisms to be able to invest in decarbonisation and energy production, i.e. offset the negative impact of CBAM through financial support for new green activities.

There are different assessments about the impact of CBAM implementation, albeit most suggest that there will be a negative impact on African economies. While preparations for the operationalisation of this mechanism are driving the commercial adoption of traceability mechanisms by some companies, perceptions of the instrument in Africa have focused more on the potential negative economic impact. Based on current emissions intensities, the World Bank's Relative CBAM Exposure Index shows that Mozambique and Zimbabwe are among the five countries most exposed to the CBAM.[12] Mozambique features high on the list mainly, but not solely, due to the Mozal aluminium smelter. Carlos Lopes argues that the measure could perpetuate existing power imbalances in global trade, stating that 'the implementation of CBAM could result in a situation where the EU has greater control over the global trading system, further disadvantaging developing economies in Africa. This could potentially lead to a situation where African countries are forced to accept unfavourable terms of trade to maintain access to European markets' (The African Climate Foundation, 2023).

Some economic modelling shows that CBAM will negatively affect trade and industry in African countries (KAS, 2024). Manjonjo and Mokgonyana argue that it 'disproportionately affects African exporters who may struggle to meet the EU's stringent environmental standards due to a lack of resources or infrastructure' (Manjonjo and Mokgonyana, 2024). This has particular resonance for South Africa, whose Just Energy Transition Partnership with international donors faces challenges following the USA's cancellation of their commitment to the programme. However, while this could lead to a greater reliance on BRICS partners to combat the nation's energy crisis, including the replacement of its ageing coal-fired power plants, it also presents an opportunity for greater EU engagement where the country is seeking to ensure a diversified balance of international partners and not be overly reliant on a single source. For example, in March 2025, at the 8th Summit of South Africa and the EU in Cape Town, attended by European Commission President Ursula von der Leyen, European Council President António Costa and South African President Cyril Ramaphosa, an investment package worth EUR 4.7 billion was announced to support investment projects in South Africa. The package will include grants and loans from European financial institutions and businesses. The package will support a range of activities, such as vaccine production, transport and digital infrastructure, but also includes resources for the just energy transition through the

[12] World Bank, Relative CBAM Exposure Index, webpage, 2023.

development of critical raw minerals and low-carbon hydrogen. This commitment highlights the importance of delivering financial support towards the nation's own identified needs and requirements and not just engaging on issues of regulatory requirements.

African critiques of the CRMA highlight the fact that the act prioritises 'securing raw materials from African countries and does little to foster value addition or industrial development within these nations'. (Manjonjo and Mokgonyana, 2024). The EU's higher target for regional processing implicitly acknowledges the challenges of domestic mining, necessitating imports (Vandome, 2024). The CRMA aims to achieve significant EU self-sufficiency by 2030, setting targets for domestic demand for mining and extraction (10 %), processing and refining (40 %), recycled sources (25 %) and no more than 65 % of one commodity should be sourced from a single country (CRMA, 2023). However, these outward-facing objectives require international partnerships, as discussed in the following section. Meanwhile, there are high expectations from African states that they can be buttressed with financial support for infrastructure, production and, most importantly, value-adding processes.

The expectations of commerce, government and civil society actors consulted in the preparation of this analysis noted some uncertainty emanating from the development and application of the EU Omnibus I and Omnibus II on CSRD, CSDDD and CBAM.

Box 5 : Conclusions: African perspectives of key benefits and costs of traceability schemes

- Many African stakeholders recognise the **potential benefits of traceability for market access** and **sustainability**, while others see them as **transaction costs**. There are also concerns about the feasibility, costs and capacity required to meet stringent standards.
- The African Union (AU) **AMV** provides limited specific guidance on traceability, but does prioritise equitable resource governance and responsible operations. Implementing the **African Continental Free Trade Area** relies on origin data that can support traceability to some extent.
- Many African countries seek to move beyond raw material exports by promoting local beneficiation, refining and manufacturing to **capture greater economic value**, create jobs and enhance industrialisation.
- European traceability regulations are often viewed in Africa as externally imposed, complex and **potentially exclusionary**, with fears that they may **disproportionately impact small-scale producers** who lack the resources to comply.
- There are practical challenges to implementing traceability, such as limited infrastructure, financial constraints and the **absence of harmonised regulatory frameworks**.
- Practical steps to overcome these challenges include **capacity-building programmes**, investment in **digital literacy** and **inclusive policy-making**.
- **Dialogue** between African stakeholders and European regulatory bodies is crucial to ensuring that traceability initiatives are mutually beneficial, sustainable and **aligned with local economic and social realities.**
- There is a need to **deliver financial support towards the nation's own identified needs and requirements** and not just engaging on issues of regulatory requirements.

5 African geopolitical considerations: Traceability: EU diplomatic and development policy

This section strategically assesses how the EU can leverage existing engagement with African countries to pursue resource traceability objectives within a context of increased international competition, multipolarity and shifting geopolitics. Focus is on the EU diplomatic and development agendas as well as available opportunities for promoting traceability within existing international forums, partnerships and agreements, together with potential synergies between commercial, security and development objectives in the EU sourcing of strategic and critical material.

5.1 Geopolitical considerations

The race for CRMs not only poses geopolitical challenges but equally presents economic, social, and environmental issues that need to be resolved. SCM is vital for achieving energy security that meets international and governmental commitments to green energy transition. The geopolitical shift towards multipolarity has necessitated new forms of market intervention and cooperation amongst allies for sustainable and secure supply chains. The securitisation of commodity supply chains and changing state-market dynamics drive new partnerships and political alliances to secure access to CRMs, thereby protecting future energy security against potential competitors, hostile states and non-state actors. The EU is an important stakeholder in many of these new partnerships. However, while adherence to responsible sourcing requirements and ESG criteria necessary for export into the EU are being promoted as part of the EU's 'offer' to gain competitive advantage, much more must be done to ensure that this value is felt on the ground.

Two key drivers of EU intervention in CRMs are codified in the CRMA and the EU Net-Zero Industry Act, which form key pillars of the EU's 'Green Deal Industrial Plan for the Net-Zero Age'[13]. The first driver is the need for a significant increase in overall global production to meet expected energy and digital transition demand needs. The second driver concerns securing the required minerals for future energy security where renewable energy security could be threatened by the concentration of processing capacity in specific geographic locations, notably China. Many of the specific minerals and metals required – such as antimony, graphite, lithium, manganese and REE – are currently used for purposes unrelated to the energy industry and at insufficient scale to match projected demand (Bazilian, 2018).

China currently provides 100 % of the EU's needs for heavy REE, 91 % of its processed magnesium, 67 % of its graphite and is the main supplier for 25 of the 45 most economically important processed metals and minerals (Grohol and Veeh, 2023).

Key African suppliers that export directly to the EU are Guinea, which provides 63 % of the EU's aluminium; the DRC, which provides 35 % of its cobalt; and South Africa, which provides 43 % of its manganese[14].

[13] European Commission, 'The Green Deal Industrial Plan', webpage.

[14] European Council, 'Critical Raw Materials Act', explainers, webpage, 2024.

Beyond this, African endowments are strategically important, such as the DRC's dominance in cobalt extraction and South Africa's provision of platinum group metals as well as chromium – much of which is exported to China for processing. However, many significant deposits across the continent could support supply chain diversification. China's past export restrictions to Japan and Korea, together with restrictions on graphite exports introduced in October 2023, have given rise to expected supply chain risks. In December 2024, China imposed an export ban on antimony, gallium, germanium and superhard materials intended for the US, citing national security concerns in reaction to the USA's latest technology restrictions imposed on China (S&P Global, 2025). Reliance on China also has pricing implications, with Toman and Bohi (2012) arguing that the country can impose high price increases to extract rents or alternatively exert price reductions to suppress competition. Meanwhile, the China in Africa Podcast team has noted that overproduction by China and Chinese firms could also be part of the nation's stockpiling towards its own energy transition, for which it will need an immense supply of raw materials.

Changing geopolitics has intensified the need to protect European supply chains. This includes policy uncertainty in the USA, the acceleration of Gulf states' investment in Africa and African partnerships with Russia. The EU has not been able to compete with the scale of subsidies for green energy generation in the US Inflation Reduction Act (US Congress, 2022b), which represented a market-shifting financial commitment to support production and processing in the US. While the future of green energy subsidies in the USA is uncertain following President Trump's signing of an executive order that pauses the Inflation Reduction Act funding and eliminates the electric vehicle mandate, the USA's pursuit of CRMs will likely complement and compete with the EU.

The USA has six key approaches to developing critical minerals supply chains in Africa:

- The country has been instrumental in forming the Mineral Security Partnership (discussed below), of which the EU is a member.
- The USA has financially supported infrastructure development, most notably rehabilitating the Lobito railway corridor.
- The Biden administration undersigned an agreement between DRC and Zambia to develop trans-national value chains for electric vehicle batteries.
- The previous administration created an inter-departmental agency, Prosper Africa, to streamline and support US investment into Africa, including CRMs. The entity was housed in USAID, but is likely to be re-sited following the restructuring of US departments under the present Trump administration.
- A critical mineral partnership with Saudi Arabia, which has its own ambitions for increasing the processing of CRMs, presents additional security in its supply chain.
- In April/May 2025 (at the time of writing), there is a proposal for a minerals agreement with DRC and Rwanda as part of a conflict mediation process led by Qatar. Of particular focus are 3TG minerals within the conflict area – including coltan from Rubaya, tin, and tungsten from Rwanda.
- American resource companies are stockpiling materials in the USA from the existing market.

The Gulf states are increasingly competitive in Africa, with sovereign-backed investments often able to carry higher risks and longer-term horizons than Western commercial firms. Saudi Arabia and the United Arab Emirates (UAE) have rapidly reinvested oil rents into critical minerals mining and processing to diversify away from their over-reliance on hydrocarbons and a need to future-proof their economic future. Saudi Arabia's ambition to be at the centre of a mining super-region, straddling Africa, the Gulf, the Middle East and Asia, has led to partnerships that straddle wider geopolitical divides. Saudi Arabia manoeuvred to place itself as a key middleman for consumer countries through bilateral agreements, MoUs and partnerships, including those with the USA, but has notably kept out of wider multilateral partnerships. Its Future Minerals Forum conference, held annually since 2021, has become one of the world's largest industry events, with significant African attendance. While Riyadh's main objective is for increased domestic processing, they have also been supporting infrastructure projects in Africa and have begun discussions on investing in processing capacity on the continent. Its Gulf state rival UAE is seemingly also seeking to move into SCM production, having 2024 acquired a 51 % stake in Zambia's Mopani copper mine for USD 1.1 billion (Money, 2024), building on Abu Dhabi's commercial expansion into Africa via infrastructure operations through state-owned DP World and Abu Dhabi Ports group (Money, 2024). The UAE is central to the gold and diamond trade from the continent, especially for ASM gold production.

An EU strategy for sourcing materials should consider multi-partner diversification, with small amounts of resources coming from multiple sources for processing domestically, replicating the USA's broad approach. This will support a diversity of supply and better synergise CRM objectives, with the diplomatic offer of 'value' enshrined in responsible sourcing, and enable companies to comply with Union regulations. An alternative would be to develop a 'China plus one' strategy, where most material still comes from China, but with a sufficient alternative supply to offset the risk of potential future Chinese export restrictions, albeit using other partners' export restrictions could inhibit this approach.

5.2 Multilateral partnerships, initiatives and 'clubs'

Partnerships and multilateral strategies are important in leveraging both EU resources and those of its allies to support increases in the supply of raw materials, thus ensuring that the EU can be assured of consistent market access. Whilst there is a shared ambition for improved traceability, which complements EU requirements, specific recommendations for implementing such mechanisms are currently limited to proposals for mapping and feasibility studies rather than practical actions.

5.2.1 The Mineral Security Partnership

In June 2022, the USA and key partner countries announced the establishment of the Minerals Security Partnership (MSP), 'an ambitious new initiative to bolster critical mineral supply chains'[15]. The other initial founding members were Australia, Canada, Finland, France, Germany, Japan, South Korea, Sweden, the UK, the USA and the EU. The MSP's stated goal is to 'ensure that critical minerals are produced, processed and recycled in a manner that supports the ability of countries to realize the

[15] US Department of State, Minerals Security Partnership, webpage.

full economic development benefit of their geological endowments', with the aim of using state resources to catalyse private sector investment into resource production and uphold 'the highest environmental, social, and governance standards' (US Department of State, 2022). The MSP has expanded its core participation to include India and Italy in 2023, along with Estonia in 2024. India's acceptance was an important step in the partnership in expanding membership with democratic states from the global south. African countries engage via the MSP forum, and there is seemingly little appetite from either side for membership expansion of the MSP on the continent. Despite some developmental objectives, MSP membership and direction are overtly Western and Group 7 (G7)-dominated as an alliance based upon security interests, particularly those of the USA.

The MSP developed and released its own Principles for Responsible Critical Mineral Supply Chains (Minerals Security Partnership, 2023). This is an important statement of intent. The principles advocate only for OECD Guidelines and the UNGPs (Minerals Security Partnership, 2023). The MSP principles support the intention of ongoing efforts by mineral producers and processors, financiers, and end-users to elevate the role of ESG risk management and increase transparency, accountability, and raw material traceability. Beyond a commitment to traceability, the MSP principles do not provide additional specific and accepted means to achieve it or the required level of confidence.

American participation and leadership of the MSP have been unclear since the start of the Trump administration. The USA is now pursuing a more transactional approach to external economic engagements towards narrow national interests. While it seems mineral supplies as an important part of its economic future, there are questions about its commitment to multilateral arrangements such as the MSP. Nevertheless, the MSP's development as a fledgling initiative for cooperation on the security of mineral supplies offers lessons for the EU, as well as a decision on whether the EU could work with allies and partners to continue the MSP or a similar arrangement without American involvement.

MSP activities in Africa have focused on financing industrial projects, including infrastructure and stakeholder engagement. ESG criteria and responsible sourcing are seen as part of the 'offer' from MSP members to African states, but there has been no specific requirement for traceability. The MSP Forum is an important arena for discussion on shared priorities, but it faces three challenges in communicating its mandate in Africa: firstly, it is often seen as a 'neo-imperialist' extractivist project, interested in exports and not value addition; secondly, it is not clear where projects are being implemented by the MSP or by the individual member state; and thirdly, there is little detail on proposed ESG and responsible sourcing. The EU CRMA included provision for the creation of a 'CRM club', which became part of the MSP Forum, to establish a more extensive and 'ambitious collaborative initiative connected to the MSP' (Beuter et al., 2024), including its response to criticism that such a mechanism could become an exclusive cartel, with possible free-riders and limited benefits for producing states (Hendrix, 2023).

The USA has used the Investing in African Mining Indaba in 2023 and 2024 as a forum to engage African countries on investment and ESG priorities. In February 2023, on the Indaba side, Under Secretary for Economic Growth, Energy and the Environment Jose W. Fernandez and other MSP members met African non-MSP member representatives from Angola, Botswana, the DRC, South Africa, Tanzania, Uganda and Zambia. Similarly, the European Commission held a session on ESG at

the 2025 Indaba. On 18 July 2024, the MSP Forum was announced with new members: Argentina, Greenland, Kazakhstan, Mexico, Namibia, Peru, Ukraine and Uzbekistan. It is unclear what the objectives of this forum will be beyond the rhetoric of responsible sourcing. There is also an apparent change in tone between the energy and economic security priorities of the main MSP when compared with the extractive industry for development rhetoric of the Forum and wider MSP engagement.

MSP-supported projects often link manufacturers and off-takers to projects, improving the working potential for increasing traceability through simplified supply chains. The MSP is involved in a total of 23 projects, with 16 in upstream mining and mineral extraction, 7 undertaking midstream processing and 7 working on recycling and recovery. Some 13 project sites are located in Africa. Of these, the most notable are in Mozambique, Tanzania, the DRC and Zambia. In 2023, a USD 150 million loan was agreed by the US International Development Finance Corporation for Twigg Exploration and Mining, operating the Balama Graphite mine in Cabo Delgado, Mozambique, which Syrah Resources Limited of Australia wholly owns. The mine has one of the world's largest graphite reserves and reached commercial production in 2019. Syrah Resources reached an off-take agreement with US electric carmaker Tesla in 2021.

In Tanzania, MSP partner Australian-based EcoGraf authorised German-based KfW IPEX-Bank to arrange a senior debt facility of up to USD 105 million to develop the Epanko Graphite Project. The untied loan guarantee is contingent on the support of German off-takers for the project's initial phase, which is expected to produce 73 000 tons of graphite annually. Both projects reflect the early stage of MSP investment in mining on the continent, as well as the extent to which MSP investments are tied to individual members' national priorities. The most prominent MSP announcement for the DRC was the February 2024 signing of a MoU between the Congolese state-owned mining entity Gécamines and the Japan Organisation for Metals and Energy Security. This collaboration, forged through dialogue among MSP partners, creates a framework for coordination in mineral exploration, production and processing in alignment with the wider development of the G7 Partnership for Global Infrastructure and Investment (PGI)'s development of the Lobito Corridor in which Gécamines is a key partner. It also complements the US' signing at the African Leaders Summit in Washington in December 2022 of an agreement with the DRC and Zambia to develop the region's electric vehicle value chains.

5.2.2 UN Secretary General's Panel on Critical Energy Transition Minerals

Partly in response to the MSP's formation and other international initiatives that excluded producing countries in the global south, the UN created a panel to create internationally accepted principles for the sector. The Panel's report in September 2024 recommended a global traceability framework, but did not make any specific recommendations for how this could be achieved (UN, 2024).

On 26 April 2024, the UN launched the Secretary General's Panel on Critical Energy Transition Minerals. The importance of Africa for this initiative is made clear not only by the choice of a South African chair, but also by African representatives (8 states + the AU) accounting for 9 of the 25 government and intergovernmental actors. The composition of this UN panel demonstrates an attempt to transcend geopolitical divides. It is more inclusive than the MSP, and China is a member, although Saudi Arabia is not. In addition to African and other state representation, the AMDC, the

European Commission's DG for Energy, EITI, IRMA, ICMM, the World Bank and the Church of England Pensions Board are included. At the UN panel launch, the UN Secretary-General António Guterres said, 'the race to net zero cannot trample over the poor. The renewables revolution is happening – but we must guide it towards justice' (UN, 2024). The panel could provide a framework for African states to triangulate partners and benefit from the demand for green transition materials. African governments need to use this opportunity to push on their demands for value addition and industrialisation. However, a partnership without processing is viewed as unjust for many countries seeking to industrialise.

The Panel report, launched in 2024, recommends a global traceability framework, but offers few practical suggestions for overcoming some of the inherent challenges discussed in this analysis. It proposes a 'global traceability, transparency and accountability framework along the entire mineral value chain – from mining to recycling – to strengthen due diligence, facilitate corporate accountability and build a global market for critical energy transition minerals, though the framework should not be used as a unilateral trade barrier' (UN, 2024: 18). It also argues that '[p]erformance standards and traceability mechanisms should also be made conditional for access to finance and markets' (UN, 2024: 5). The panel has called for a multi-stakeholder expert process to develop a global traceability, transparency and accountability framework. As such, the report firmly aligns the concept of traceability with social performance rather than simply origin verification. Its global scope would necessitate a further debate on the trade-offs between certainty and breadth of scope. The panel and its report are important diplomatic interlocutors for the EU in demonstrating wide support for traceability and potential implementing partners on this issue.

5.2.3 Triangulation with China

The EU faces significant challenges in ensuring end-to-end supply chain tracking and traceability due to the nature of trading and market dynamics, but also the dominant role that China plays, in particular in processing. There are some practical ways in which the EU can engage with China, especially in light of increasing Chinese attention to responsible sourcing and traceability, not least as they seek greater knowledge and control over their supply chains as trade flows become more politicised in an era of increased tariffs.

Triangulation of standard-setting for traceability EU-China-Africa

The EU, China, and African representative organisations could collaborate to develop mutually acceptable traceability standards and practices. Whist acknowledging challenges of transparency and compliance enforcement across multiple jurisdictions, partners could define baseline traceability requirements that would be considered acceptable and credible, including verification of origin and labour standards. There may also be opportunities to leverage China's desire to avoid isolation within the World Trade Organisation to advocate for minimal requirements for transparent sourcing. The Group of Twenty (G20) and the UN Secretary General's Panel on Critical Minerals are key forums to propose binding reporting standards for mineral supply chains with many international partners, including China, building on the G7's Partnership for Global Infrastructure and Investment.

EU-China-Africa Trilateral Funding Partnerships

There is some scope for the EU's Global Gateway and China's Belt and Road Initiative (BRI) to co-fund traceability-focused projects in Africa including: Co-investment in processing hubs through joint venture in African initial mineral processing that would also work with third-party traceability providers to establish tracking and tracing of materials; alignment between with China's infrastructure projects to embed traceability requirements; fund platforms to track mineral flows, accessible to EU and Chinese buyers.

Conditional market access

There is some scope for the EU to use its purchasing power as a major market for green technologies, but such policies would need to be done with appropriate consultation with Chinese authorities. For example, the EU could reduce import duties for Chinese firms providing third-party-certified traceability data or restrict sales of mining technology to Chinese entities lacking traceability commitments in Africa. New regulation in the EU will mean that components entering the EU will need to carry some identification and traceability data.

The EU's engagement with China on African raw material traceability requires a mix of cooperation and coalition-building. Success hinges on aligning incentives for Chinese firms and state actors. A key challenge would be that the EU and China will need to set clear red lines and limits to knowledge, data, technology, and information sharing on commercially sensitive issues whilst supporting transparency and the sharing of relevant information to sourcing and shipment of materials.

5.2.4 Lobito Corridor

The Lobito Corridor rail project is not strictly a partnership but a multi-stakeholder infrastructure project with which the EU has politically aligned itself. While the EU is not financing this infrastructure project, it can play a key role in supporting wider developmental initiatives around the railway line itself.

This was the first strategic economic corridor launched under the flagship G7 Partnership for Global Infrastructure and Investment (also known as 'PGII') in May 2023. At the margins of the G20 Summit in New Delhi in September 2023, the EU and USA released a Joint Statement, teaming up to support the development of the Corridor (European Commission, 2023a). This corridor comprises various proposed commercial and developmental activities around the rail and road infrastructure connections extending from the port of Lobito in Angola to the central African Copperbelt, including Angola, the DRC and Zambia. Angola's part of the rail route received a rehabilitation investment of USD 1.8 billion from the Chinese back in 2002. In 2023, the Lobito Atlantic Railway company took control of the concession, comprising Trafigura Pte Ltd, Portuguese infrastructure firm Mota-Engil Engenharia e Construção and Belgian rail firm Vecturis. The DRC produces over four million tonnes of mined product a year, with between half and two-thirds of that being copper, which underpins the commercial logic of connection into the DRC. The USA-led investment for the project seeks to extend the line beyond its current commercial viability and make it part of a larger American infrastructure strategy to counter Chinese influence on the continent and lock in investment from other MSP members. In October 2023, the G7 Partnership for Global Infrastructure and Investment signed an MoU between the US, Angola, the DRC, the EU, Zambia, the AfDB and the Africa Finance Corporation

to develop the Corridor via a USD 250 million loan from the US International Development Finance Corporation (DFC) which increased to USD 553 million in 2024. Although achieved under the G7 banner, all seven state members are part of the MSP and members are heavily involved in activities around the project, citing the MSP as a driver.

On 16 and 17 January 2025, the European Commissioner for International Partnerships, Jozef Síkela, participated in the Angola-France Economic Forum held in Paris. Commissioner Síkela and President Lourenço reinforced the Lobito Corridor project by announcing a EUR 76.5 million EU assistance package. This package aims not only to 'deliver tangible benefits for the Angolan people through better jobs, enhanced education and sustainable economic growth' but also to 'develop the Lobito Corridor' further (European Commission, 2025). This package highlights the potential role that EU members can play alongside commercial operators and American finance in supporting responsible sourcing and traceability, linking the project's export objectives with the EU's development objectives. In addition to supporting physical infrastructure for transport and beneficiation, including energy, the EU could consider supporting traceability-dependent infrastructure, such as telecoms, remote access to data and power, and other tracking and tracing needs.

5.3 Bilateral Partnerships

The EU has entered bilateral partnerships on CRMs with four African countries – the DRC, Namibia, Rwanda and Zambia. For context, the African Policy Research Initiative has demonstrated that between 2019 and 2024, African countries entered a total of 82 partnerships with external nations, the highest being South Africa with 10, Zambia with 7 and Nigeria with 6. From external partners, those with wide partnership arrangements include Turkey with 17, China with 11, Saudi Arabia with 8, India with 9 and Russia with 5 specific mineral partnerships across the national liberation movement-led countries of Southern Africa, drawing on historical political ties. Although it has no specific mineral partnership in West Africa, its security relationship with governments in the Sahel is in part related to accessing mining deposits. DRC has 4 partnerships, the EU, Japan, Saudi Arabia and the USA, whilst Rwanda only has agreements with the EU and China.

There are some differences in the nature of the EU's partnerships, albeit they are all built around five common pillars (Beuter et al., 2025):

i) The integration of mineral value chains with the promotion of trade and investment linkages through joint ventures, networking events and the joint identification of bankable projects;

ii) The mobilisation of EU private and public funds for infrastructure projects;

iii) The exchange of knowledge and technology;

iv) Skills development and capacity building;

v) Cooperation to enhance the observance of ESG principles.

Most significantly, through the facilitation of commercial engagements and linkages, the mobilisation of funds and focus on capacity building, these partnerships form a primary conduit for supporting an economic ecosystem which is conducive to traceability, thus enabling direct support for traceability schemes and mechanisms. Successful implementation will depend on demonstrating equitable

shared value in mining and infrastructure operations. How agreements have been made demonstrates the centrality of the Global Gateway as a fundamental arm of EU engagement in Africa on CRMs

Joined up alliances and EU convening

In addition to the bilateral partnerships listed below, there is scope for the EU to convene and drive triangulated cooperation with and between African states, using partnerships as building blocks for a broader cooperative framework.

The existing bilateral minerals partnerships with DRC, Namibia, Rwanda and Zambia, as well as the strategic partnership with South Africa, offer an entry point for a coordinated approach across central and southern Africa, with the inclusion of other regional actors such as Angola. South Africa is also the EU's first Climate Trade Investment Partner on the continent. Pascal Lamy and others have called for the mobilisation of these partnerships to become regional entry points that allow for engaging with regional economic communities such as SADC to 'allow the Commission to leverage existing free trade areas while avoiding creating divisions within such an integrated regional bloc. However, negotiations at a regional level will likely take longer' (van der Ven, 2025)

Box 5: EU Critical Minerals Partnerships in Africa

Namibia – 2022: In November 2022, Namibia and the EU signed an MoU establishing a strategic partnership on Sustainable Raw Materials Value Chains and Renewable Hydrogen. The partnership has six pillars across mobilising finance for infrastructure, harmonising regulation and supporting capacity building (European Commission, 2023b).

In 2023, on the eve of the Global Gateway Forum, European Commission President Ursula von der Leyen and former President of Namibia Hage Geingob endorsed a roadmap for the EU-Namibia strategic partnership on sustainable raw materials value chains and renewable hydrogen to be supported by EUR 1 billion in investments by the EU, its Member States and European financial institutions. EU relations with Namibia, and opportunities in the energy sector, were the subject of a workshop and two briefings (PE 754.438) commissioned by the European Parliament's Committee on Development in 2023 (Sánchez Jacob, Gerres and Cossent Arín, 2023).

DRC-Zambia – 2023: At the Global Gateway forum in 2023, the EU simultaneously signed an MoU for a partnership on critical and strategic raw materials value chains with the DRC and a strategic partnership on sustainable raw materials value chains with Zambia.

These partnerships are generally focussed on mineral value chain development and infrastructure as well as sustainable and responsible production. This particular partnership is part of increased EU support around the Lobito railway corridor, with ambitions to support wider economic and trade linkages, which could be an important means of supporting responsible industrial performance.

However, the development programming needs to tie into the commercial underpinning of the transnational corridor. For example, this includes supporting a cross-border digital trade mechanism, harmonisation of standards and due diligence costs for smaller firms seeking to tie into the project.

At present, the European Investment Bank (EIB) and Global Gateway Initiative could be deployed more effectively. An EIB minimum financing threshold excludes many small-scale initiatives. The focus is on mature operations, there currently being no support for exploration or pre-production initiatives. EU and other international objectives need to deal with local energy realities and severe electricity shortages which limit the growth in critical minerals but also energy justice.

Rwanda – 2024: In February 2024, the EU signed a MoU to strengthen Rwanda's role in fostering sustainable development and resilient value chains across Africa (European Business Council for Africa, 2024).

The agreement included specific provisions on traceability, in particular: 'Cooperation to achieve sustainable and responsible production together with valorisation of critical and strategic raw materials. This includes 'increased due diligence and traceability, cooperation in fighting against the illegal trafficking of raw materials and alignment with international Environmental, Social and Governance (ESG) standards'.

Provisions in the agreement are buttressed by 'the EU's Global Gateway investment plan [which] will be instrumental in providing the financial support needed in skills development in the mining sector, improved transparency and traceability and support to mobilising funds for infrastructures'. Following the intensification of conflict in the eastern DRC and allegations of Rwandan involvement, pressure has mounted on the European Commission to suspend this agreement. This includes calls from Members of the European Parliament.

5.4 EU development instruments

The EU is supporting its objectives on CRMs through the Global Gateway strategy, the EIB and the AfricaMaVal platform for research support and diplomatic engagement. This is in addition to the regulatory and normative shaping role that the EU plays, which is detailed throughout this analysis. These entities are the core components of EU resource diplomacy, buttressed by EEAS missions in partner countries.

In September 2024, former European Central Bank president and former Prime Minister of Italy, Mario Draghi, launched 'The future of European competitiveness' Part A report (Draghi, 2024). This report recommends that the EU further develop its 'resource diplomacy' for CRMs. It proposed upgrading the Global Gateway to focus more strategically on meeting the EU's own requirements and developing requisite national partnerships. The report notes that the global market for CRMs has doubled during the past five years, reaching EUR 300 billion in 2022, with China's dominance presenting a risk to the EU. Finally, Draghi notes that the EU lacks a comprehensive strategy for covering all stages of the supply chain (from exploration to recycling) and, unlike its competitors, leaves the mining and trading of commodities largely to private actors and market forces. Hence, in this respect, the EU is less competitive than others, with few European mining and trading companies active in Africa. Meanwhile, Australia, Canada, China, South Africa and the UK are the key home nations for industrial miners on the continent, with Switzerland hosting important registered traders. Nevertheless, EU-located manufacturers and industrial companies do have a valuable commercial role to play, with the EU being a major hub for investors and financial centres.

In addition to European support not only for capacity building in Africa, developing skills in mining and infrastructure, but also regarding due diligence, responsible sourcing implementation and digital processes for borders and transit, there is a mirrored need for ensuring that EEAS deployed staff have the requisite skills to manage mining investment negotiations. This includes understanding the sector's configuration, strategic points for intervention and cooperative working practices to support African needs and objectives, together with practical knowledge of what is possible and implementable in complex settings. It is essential to develop a greater awareness of how traceability mechanisms function and an ability to help African producers identify workable schemes that suit both their own needs and those of their customers.

The Global Gateway

The Global Gateway is the EU's overarching funding strategy for channelling investment into a range of strategically important energy and infrastructure activities, which includes support for accessing CRMs. This initiative has a projected investment of up to EUR 300 billion (USD 326 billion) globally to boost value addition and exploration, including EUR 150 billion (USD 163 billion) for Africa. Global Gateway draws on new financial tools in the EU's multi-annual financial framework for 2021-2027. These include particularly the Neighbourhood, Development and International Cooperation Instrument (NDICI)-Global Europe; the Instrument for Pre-Accession Assistance III; the digital and international part of the Connecting Europe Facility; but also, Interreg, InvestEU and Horizon Europe, the EU research and innovation programme.

The Global Gateway forum has served as an important political and diplomatic engagement tool, *inter alia*, for signing certain bilateral agreements, as discussed above. Moreover, as mapped on its website, the initiative has supported various energy, digital, transport, infrastructure, health, education and research projects for the African continent.

European Investment Bank

The EIB has been an essential component in the financial corridor between the EU and targeted CRM partner countries. At the Group Forum in February 2024, European Commission Vice President Maros Sefcovic said that this institution 'should establish, within its structure, a dedicated 'Task Force' for sustainable critical commodities, focusing exclusively on facilitating projects along the entire value chain of critical commodities' (Luca, 2024).

The EIB has extensive presence and experience in Africa, funding initiatives and financing various funds with a focus on infrastructure, agriculture, micro-finance and poverty alleviation. Whilst the Bank has limited experience in funding mining initiatives in the exploration and early extractive phases and should not focus attention on these high-risk areas, nevertheless, it can partner with initiatives to formalise the ASM sector through sustainable finance as a mechanism for driving responsible ASM and thus inclusion in responsible value chains. This lack of experience in financing due diligence and responsible sourcing compliance initiatives also represents a cost hurdle for many operators. Indeed, previous EIB financing in mining has been a source of criticism from environmental groups for their involvement in projects that subsequently had negative environmental and social impacts (Joint Civil Society Letter, 2024).

Africa MaVal

AfricaMaVal is a 42-month project gathering 18 partners from 11 countries and funded by the European Health and Digital Executive Agency. The project objective is to develop an EU-Africa partnership ensuring responsible sourcing of mineral resources for the European industry while granting a sustainable local co-development in the best ESG conditions and leading to a long-term business environment for European and African companies. It is coordinated by BRGM, the French Geological Survey. This consortium gathers together experienced African and European organisations, associations and networks which are deeply anchored and involved in the raw material domain with specific expertise as well as general knowledge.

Over the past two years, AfricaMaVal has partnered on an extensive work package titled 'Responsible Investment Opportunities', which has been led by BGR. Together, they have evaluated a range of these opportunities, following which a range of significant research material has been produced, including:

- The documentation of national policy frameworks and ASM sector dynamics through dedicated country profiles (Vasters and Schütte, 2023).
- Recommendations on EU-Africa value chain engagement opportunities, ranging from projects of interest to general instruments as well as ideas for technical assistance and policy dialogue (Schütte et al., 2025).

- 80 mining and infrastructure factsheets to inform investors, industry and government stakeholders (Schütte et al., 2024).

Box 6: Conclusions on African geopolitical considerations, traceability and EU diplomatic and development policy

- The race for CRMs is heavily influenced by **geopolitical shifts**, with increasing securitisation of supply chains. The EU must navigate competition from China, Gulf states and the USA and while securing diversified, sustainable access to CRMs from African partners.
- Existing diplomatic and development initiatives provide **opportunities to integrate traceability into EU-Africa trade relations**. However, initiatives such as the MSP and the UN Panel on Critical Energy Transition Minerals lack concrete mechanisms to enforce traceability.
- The Lobito Corridor and similar **infrastructure projects** where producers and manufacturers are linked represent a strategic opportunity for the EU to work with partners across the project to support responsible sourcing and traceability. However, financing and project oversight remain dominated by the USA and private sector interests.
- Multilateral bodies acknowledge the need for traceability and furthermore, **current frameworks lack enforcement mechanisms**. The EU must link access to markets and finance with robust traceability standards to ensure compliance.
- The **EU should leverage its membership of the G20, MSP and the UN Secretary General's Panels on Critical Minerals** to advocate for increased traceability, as well as work with partners, including Australia, Canada, China, the UK and the USA that all have strategic incentives to increase traceability of CRM supply chains.
- EU-Africa partnerships should **prioritise regulatory harmonisation** and digital trade facilitation for transnational projects. Supporting the adoption of common standards, digital customs processes and financing mechanisms for small-scale operators will enhance regional trade linkages and ensure more inclusive economic benefits.

6 Recommendations

The paper makes four key recommendations, each with options for implementation by EU bodies. These reflect the EU's capacity as a regulator and norm setter, with economic diplomacy capabilities that can also input into the actions of Member States.

6.1 Headline recommendations

- The development, implementation and enforcement of traceability in Africa require a **strong, clear, coherent and consistent demand signal** stressing the need to comply with regulations and standards to gain market access from the European Commission as a regulator.
- Achieving EU traceability objectives is dependent on **supporting African states' broader legal enforcement and implementation capacities** for stronger institutional governance of the sector. Such initiatives should be undertaken *with* African governments and regional bodies rather than being externally imposed.
- The EU should **continue to support the scientific research and development of technology** that has advanced traceability mechanisms, buttressed with increased social science research

on the impact and operational feasibility of such technology. Furthermore, there should be continued investment in developing efficient mechanisms for incentivising and enabling quality traceability mechanisms that are well-governed, credible, affordable and accessible.

- EU diplomatic and economic resources can play a more active role in **assisting not only industrial operators but also ASM producers in implementing and enforcing standards as well as adopting traceability mechanisms** strategically targeted to EU partnership countries and EU-supported transnational development corridors.

6.2 Options for implementation

A strong, clear, coherent and consistent demand signal

Political recommendations

- The European Commission should clearly articulate its CRM three pillars approach in Africa, stating: its energy security objectives for obtaining minerals and metals; its developmental objectives of using mineral sourcing to facilitate local development; and its traceability requirements, to ensure conformity and compliance.
- The European Commission should set out a concise and coherent view of why traceability is a priority for achieving EU policy objectives and how this vital necessity is mainstreamed into its regulations and initiatives. It should also set out key expectations as to how traceability should work – in whose interests, with what objectives – noting that it should not be extractive but bring mutual benefit across the value chain to all users and thus empower downstream producers.
- The European Commission should cooperate with national European governments to engage in the elaboration of a shared protocol for data sharing and interoperability of traceability schemes. This includes greater backing and engagement with the UN Transparency Protocol for technical interoperability, including its 2025 pilot focusing on the CRM industry.
- Negotiations on the Omnibus proposals from the European Commission should ensure that the final outcomes provide regulatory clarity on the scope, mandate and requirements of regulations in relation to traceability specifically.
- The EU can use its G20 membership to work with the African Union and UNDP to centralise traceability within the G20 working group on critical minerals within the task force on G20 Inclusive Economic Growth, Industrialisation, Employment and Reduced Inequality under the South African presidency.
- In line with recommendations from the EU's Conflict Minerals Regulation report (European Commission, 2017), the European Commission should adopt implementing acts recognising supply chain due diligence schemes based on applications from scheme owners. Assessments for recognition should be based on clear criteria and set a standard to which a competitive range of schemes can conform. In reflecting different supply chains, this should allow a degree of choice which prioritises ease of implementation and incentivises adoption while retaining credibility and ethical standards.

- The European Commission could engage with African states, through the EEAS, on the list of CRMs, considering African export priorities whilst acknowledging the developmental linkages and potential economies of scale in supporting supply chain development beyond the identified CRM list and 3TG.
- The European Commission could include mutually agreed targeted agreements with African states and regional organisations that promote traceability, local value addition and responsible sourcing, ensuring African partners experience tangible benefits from cooperation. Including specific frameworks on traceability with existing partners and building on regional initiatives such as the International Conference on the Great Lakes Region, the Southern African Development Community, and others to advocate for more targeted and specific traceability measures.
- The European Commission, as a member of the Minerals Security Partnership, should take a leading role in advocating responsible sourcing and traceability whilst supporting the development of specific binding mechanisms and requirements that the initiative can implement. It should leverage existing standards on which the EU has played a collaborative role with African states, including OECD Minerals Guidance.
- The European Commission and the European Parliament should support mineral-producing countries in developing local content policies and equitable mineral rent-sharing mechanisms, such as equity or governance participation, that ensure mining benefits for local economies. This includes promoting local procurement, job creation and skill development. Such policies should be clear, coherent and consistent over time to provide clear parameters within which private investors can work and not be subject to undue political discretion or rent-seeking opportunities.
- The European Commission and the European Parliament should also deepen engagement with the African Union, African Minerals Development Centre and African Continental Free Trade Area Secretariat to promote traceability and leverage partnerships through DG INTPA with UNDP and other agencies to advocate for strong traceability.
- Bilateral, multilateral and corridor agreements need to be transparent. Additional MoUs, working documents, agreements and other reports related to the projects and partnerships should be made public, hence open for consultation by African civil society groups and citizens alike.

Diplomatic recommendations

- The EU should take a leading facilitatory role to work with UN Panel partners from African nations and other participants to develop a workable framework for traceability, in line with recommendations from the Panel report. Such a multi-stakeholder approach based on the Panel membership provides a platform for engaging with top mining and processing jurisdictions that are critical interlocutors, including China.
- A shift in diplomatic tone could add clarity to messages of traceability and increase traction. Engagements should highlight and build upon the point to which African leaders have taken a

role in creating responsible sourcing systems in the past. This should be framed around how African states can support the EU in achieving its objectives and *vice versa*.

- The EU could support EEAS personnel on technical issues on mining investment negotiations, value chain configurations and traceability mechanisms through the creation of an interinstitutional network based on DG INTPA, DG for Energy, DG GROW, and DG TRADE that could provide a back-office for requests coming from EEAS and host specialist expertise that could be deployed when needed. This will enable EU diplomats to improve their support for African partners in structuring agreements that balance economic benefits with sustainability and transparency.
- EEAS should deploy mining specialists alongside developmental specialists to missions. The EEAS should also deploy diplomats from non-ex-colonial powers, moving beyond language and history-linked relations between EU Member States and former colonies.
- Through the Global Gateway as well as existing education and research funds, the EU can support technocratic skills development on the needs and requirements for traceability through the support of traceability and responsible sourcing programmes at African education institutions, including universities and mining schools. The EU can support fellowship programmes for African civil servants from ministries of mines, finance, or environment, as well as engineers, professionals and others working in the sector to undertake discrete training programmes at EU education establishments to work on technical skills for management and governance practices that support traceability.

Development-related recommendations

- The European Parliament's Committee on Development and the Committee on Industry, Research and Energy can together play an important facilitator role in cementing synergies between green technologies, traceability and development objectives. The Committees can offer guidance on potential compromises between the need for confidence of traceability and cost or breadth of implementation to promote development objectives and encourage peace-supporting economic engagement in CAHRAs.

Supporting broader legal enforcement and implementation capacities of African states

Political recommendations

- The European Parliament can work with parliamentary committees from Africa in two-way learning and sharing of best practices for parliamentary oversight of mineral resources, including parliamentary debate on nationally significant mineral deals as well as multi-partisan engagement on responsible sourcing and traceability requirements.
- The European Commission needs to communicate its position clearly and clarify possible contradictions regarding its partnerships with the DRC and Rwanda following allegations of mineral trade being used by state and non-state armed groups in the escalation of conflict in the East of DRC.

Diplomatic recommendations

- The EEAS, in cooperation with EU law enforcement agencies, can offer technical assistance at the request of local regulatory agencies to advise on strategies to improve oversight at mines.
- The EU should support and advocate African states' engagement with and seeking membership of the Voluntary Principles on Security and Human Rights Initiative to enhance the application of guidelines for state and non-state security providers around extractive sites, thus improving the social license to operate and reducing human rights abuse.
- The EU should work with UN partners from the Office of the High Commissioner for Human Rights, the UN Children's Fund and the UNDP to support the development of national action plans on business and human rights in line with the UNGPs. National action plans could include specific frameworks or recommendations for applying and implementing Chain of Custody and traceability mechanisms.
- The EU, through the EEAS and the European Commission, can leverage the political support and engagement of African countries that were involved in creating the OECD Minerals Guidance to demonstrate long-standing African support for initiatives and work with countries across the continent to better understand the needs of those countries in enforcing the standards.
- The EU, through the European Commission and EEAS, should push for panels and seminars on traceability through its organisation, support and participation in industry conferences and events. Including Critical Raw Materials Week – the annual conference hosted by the European Commission in December– and the Investing in African Mining Indaba, held annually in Cape Town in February.
- EEAS diplomatic missions could facilitate conferences and round-table meetings with regional traceability scheme members, as well as third-party providers and industry stakeholders, to facilitate greater cross-sector dialogue about the feasibility of traceability, expectations and realistic delivery metrics on credibility whilst also supporting discussion on interoperability and complementarity of different schemes and initiatives. This could lead to the creation of structured fora that enable consensus-building and decision-making and generate cooperation within the traceability community and between policymakers and industry to overcome policy and commercial barriers to scalability.
- The EEAS and the European Commission's DG GROW and DG TRADE should support African countries in formulating investor-friendly policies that attract investment and ascribe to international best practices on legislating equitable benefit-sharing mechanisms that are transparent and accountable.
- The EEAS should encourage African states to make investment agreements with mining companies public to support transparency and accountability.
- The EU, through EEAS, DG GROW and other departments, should engage with standard convergence mechanisms, both those led by industry and other stakeholders, to understand the applicability of these schemes to new investments. Without 'winner picking', EU economic diplomacy can encourage and support new investors to engage with these initiatives.

- EU agencies involved in cross-border trade management and regional connectivity can work with African nations in supporting the harmonisation of regulations affecting regional supply chains, including taxes, levies, border management, customs and reporting requirements.

Development-related recommendations

- The Global Gateway should channel investment towards distributed energy generation and networks to increase energy access in areas of remote mineral production to support the implementation of digital-based traceability schemes, but also, more importantly, expand the access to electricity of communities across the continent.
- The Global Gateway can support the digitalisation of the border management process in strategic areas. This includes, for example, helping the Chirundu border post between the DRC and Zambia or supporting a digital border management and trade system for the Southern African Customs Union region, which includes CRM suppliers in Botswana, Namibia and South Africa as well as neighbouring states.
- The EIB and the Global Gateway strategy could help channel additional financing for local due diligence providers and local third-party verification schemes in Africa as well as financing development of a local due diligence and auditing sector together with crowding in additional private and development finance.
- The EU should consider reinforcing its support of African metal and mineral recycling SMEs and consider joint ventures between African and European recycling companies, in line with the commission's Circular economy action plan.

Support the scientific research and development of traceability technology

Political recommendations

- Foster technological partnerships between EU and African universities on industrial technology, geosciences and engineering for mining-related activities that include applying technology 'beyond the gate'.
- Support the training of geoscientific staff from African Geological Surveys and their scientific exchanges with European Geological Surveys.

Diplomatic recommendations

- Establish cooperative frameworks with African governments and African nongovernmental organisations to develop locally owned, tech-enabled traceability solutions that do not marginalise ASM and are interoperable with international solutions.
- Establish an EU-African Union partnership on mining technology, including geo-surveys, the use of AI for commercial as well as due diligence and traceability purposes, together with shared development of blockchain applications
- Support awareness and implementation of technological safeguards, including data protection, the security of keeping commercially sensitive data and the protection of ownership rights over data.

- The DG for Research and Innovation and the European Commission Joint Research Centre should work on developing guidelines on AI ethics for mineral value chains, trade, processing, transportation and logistics, including commitments to labour rights, human oversight requirements, transparency on AI decision-making in traceability and limiting the bias against small artisanal miners.
- Strengthen collaboration with relevant regional bodies, such as the African Development Bank, the African Union, the African Minerals Development Centre, the Economic Community of West African States, the International Conference on the Great Lakes Region, the Intergovernmental Authority on Development and Southern African Development Community, as well as UN agencies such as UNECA, UNDP, and the UN Industrial Development Organisation, to develop shared digital infrastructure for responsible mining governance.
- Advocate social impact assessments and dialogue between governments, companies and local communities before large-scale deployment of mining automation and support re-skilling training for displaced African workforces.
- EU human rights diplomacy should include technological rights and safeguards.

Development-related recommendations

- EU development finance can be directed to support digital readiness and provide funding as well as technical assistance to improve digital literacy, electricity access and internet connectivity in mining communities to enable equitable digital adoption. Such finance should be geared towards gender-sensitive projects that pay careful attention to the societal position of women and other vulnerable groups in mining communities and challenge harmful gender norms in artisanal mining, but also gender discrimination across global value chains.
- Support multi-stakeholder piloting of digital traceability initiatives undertaken by, *inter alia*: African governmental agencies and CSOs; industrial digital traceability efforts (similar to the Mutoshi project for digitally tracing artisanal cobalt to legal markets) in scaling proven solutions.
- Support and advocate for the expansion of access to microfinance and fintech solutions that empower women and artisanal miners to access formal markets without exploitative conditions. Enhance ASM miners' access to geological data, thereby promoting higher yields from better-targeted, hence more profitable and less environmentally damaging mining operations, in turn facilitating their access to formal credit lines.
- Ensure that EU-supported traceability programmes include mechanisms that do not place excessive burdens on small-scale miners and instead facilitate access to formal markets and compliance. Encourage skill and technology transfers from companies and traceability schemes to African mining agencies.

Assisting industrial operators and ASM producers in implementing and enforcing standards and adopting traceability mechanisms

Political recommendations

- Efforts to promote and support traceability should recognise the different needs and requirements of industrial and ASM producers, as well as the socio-economic dynamics of ASM.
- The EU frameworks and standards should state what is considered an acceptable first custodian for traceability purposes. It should make clear which criteria must be met for an entity to be considered a first custodian. It should make clear when and why there is a need for more traceability.

Diplomatic recommendations

- The EEAS should support continual dialogue, engagement, and support between industrial buyers in the EU with MSP and local suppliers involved in mining and processing, where this is possible and viable.
- EU-Africa partnerships should prioritise regulatory harmonisation and digital trade facilitation for transnational projects such as the Lobito Railway Corridor. They should use corridor projects, a structure for developing clustered mining and processing projects, supporting the adoption of common standards, digital customs processes and financing mechanisms for both industrial and small-scale operators across corridor-linked jurisdictions to enhance regional trade linkages and ensure more inclusive economic benefits. Clustering can support more efficacious use of technology to monitor and manage adverse impacts on people as well as nature and simplify traceability of origin claims and risk assessments.
- EEAS diplomatic missions should engage with national regulatory agencies, state mining operators and holding companies, together with other state actors, to promote responsible sourcing and traceability.

Development-related recommendations

- The Global Gateway and EIB can provide finance and training to ASM and mid-sized industrial producers to support the uptake and usage of technology-based solutions.
- The Global Gateway and EIB should consider the feasibility of financing a new or expanding an existing training school or technology hub within a partner country that can service the region to support technical training and skills development on technological applications that promote traceability. Access to training facilities should be equitable across genders.
- The EU could use the Global Gateway and other development finance funds to support 'train the trainer' programmes, to train state agents and local civil society organisations to work with ASM operators on skills development for traceability systems, responsible sourcing and compliance regulations. This should be conducted openly and transparently. It could also develop training programmes with international development financiers and organisations, such as the World Bank's Delve platform, which teaches ASM producers how to train other ASM workers.
- The Global Gateway, EIB and other EU development finance initiatives could provide incentives and support to ASM and industrial operators to finance the costs of compliance and conformity for their participation in traceability schemes and their adoption of standards that impose

transaction costs. There are opportunities for collaboration with the World Gold Council, London Bullion Market Association, other minerals associations and supply chain initiatives with dedicated programmes to support the commercial formalisation and professionalisation of ASM.

- The Global Gateway should allocate targeted funding specifically for African mining projects to support infrastructure, traceability and responsible sourcing mechanisms. Despite a significant budget, no African mining projects have yet received funding, creating uncertainty about the initiative's effectiveness. A dedicated funding stream for CRMs would align Global Gateway's objectives with Africa's mining sector needs.
- The Global Gateway and the EIB could target financing towards the creation of regional processing hubs, with mechanisms for traceable transnational movement of products, as well as regional benefit-sharing mechanisms.
- The EIB should reconsider its minimum threshold requirements for financing projects to support greater participation and access by small and medium actors.

7 Annex: Comparative table of traceability actors and opportunities for EU engagement

Actor	Engagement in traceability	Advantages and limitations	Opportunities for EU engagement
International organisations and governments	• Import regulations and standards • Financial support for initiative development • The whole supply chain ambitions	+ Driving factor for traceability efforts - Countries that import materials but have no mining industry have little way of impacting practices on the ground.	• Provide greater clarity on what standards are acceptable for traceability
African national governments and agencies	• Export regulations and standards • Jurisdiction regulator, including policy and legislation • Financial support for initiative development • Agencies' staff direct involvement in some traceability schemes (e.g. DRC's SAEMAPE collaboration with ITSCI) • Up to midstream	+ Better alignment with African mining priorities - Limited resources result in weak and uneven implementation of regulations. - In some regions, not necessarily greater local legitimacy of governmental agents and institutions	• Reinforce national capacity for export monitoring through digitisation and sample analysis to avoid undervaluing and underreporting of mineral exports • Focus development budget on clean energy generation. • Invest in Africa-based tailings and waste rock reprocessing.
Industrial mining companies	• Use of traceability to verify the adoption and implementation of standards and regulations • Adoption of digitisation for greater trackability, engagement with third-party providers • Participation in multi-stakeholder initiatives • Engage with smelters and processers	+ Potentially wider adoption but limited usage of traceability schemes, largely restricted to specific jurisdictions or products - Reluctance to share commercially sensitive information - Voluntary and self-policing nature of schemes	• Work on interoperability of standards for traceability systems • Potentially support some Public-Private partnerships, which simplifies the supply chain • Follow the discussions on the Consolidated Mining Standard Initiative.

Manufacturing companies	• Use of traceability scheme and third-party providers to verify implementation of standards and regulations across the supply chain • Participation in multi-stakeholder initiatives	-	Limited ability to trace minerals due to offshoring of global value chains	• Clarity on which traceability standards are acceptable	
Trading companies and trading hubs	• Limited uptake of traceability but engagement in responsible sourcing with traders and smelters	+ - -	At a strategic bottleneck of the supply chain Complexity due to blending of various sources, spot market purchases harder to trace, regulatory frameworks vary across jurisdictions Risk undermining strategic centrality		
Artisanal miners	• Cooperative formation, participation in formalisation schemes, bag and tag schemes and data collection	-	Artisanal miners are largely driven by subsistence imperatives and bear the cost of compliance with certain schemes through lower prices	• Engage with African formalisation strategies	
National NGOs/CSOs	• Monitor the effectiveness of schemes, impact on local communities	+ -	Increases local legitimacy, checks responsible sourcing claims, supports marginalised people with complaints Lack of means	• Engage national civil societies in MOUs, • Enhance transparency of bilateral dealings with African partners for civil societies to assess their content	
International NGOs/CSOs	• Direct engagement in some largely ASM-focused traceability schemes	+ -	Improved conditions for participants lack of self-sustenance beyond the pilot phase		

	• Monitor the effectiveness of schemes, impact on local communities	- Limited impact	
Academic and research institutions	• Lead technological frontier traceability R&D • The provision of geological knowledge and impact studies all contribute to ESG upstream • Monitor the effectiveness of schemes, impact on local communities and African governments' ability to benefit from CRMs	+ No commercial or political sensitivity	• Support Africa-based geological surveys • Support international skill and knowledge sharing and transfers • Support Africa-based universities' geosciences programmes.

8 References

Abram, K., 'Are Fairmined and Fairtrade Gold Elitist?', *Ethical Metalsmiths*, 23 February 2022.

Acheampong, A. O., Dzator, J., Abunyewah, M., Odei Erdiaw-Kwasie, M. and Evans, E., 'Sub-Saharan Africa's Tragedy: Resource Curse, Democracy and Income Inequality', *Social Indicators Research*, Vol 168, No 1-3, 2023, pp. 471-509.

Afreximbank, Regional Value Chains and Intra-African Trade Promotion: Transforming Africa's Trade, Report, Afreximbank Research and University of Development Studies, 2024.

African Climate Foundation and The London School of Economics and Political Science, Implications for African Countries of a Carbon Border Adjustment Mechanism in the EU, Report, 2023.

African Continental Free Trade Area Secretariat, Rules of Origin Manual: Creating One African Market, Report, Vol 1, 2022.

African Natural Resources Management and Investment Centre, Approach Paper towards preparation of an African Green Minerals Strategy, Report, African Development Bank, 2021.

African Resources Watch, 'Press Release N °2 2025', 07 January 2025.

African Union, Action Plan for Boosting Intra-African Trade, report, 2012.

African Union, Africa Mining Vision, report, 2009.

Agência de Informação de Moçambique, 'Syrah Resources to supply processed graphite to Tesla', *Club of Mozambique News*, 22 May 2022.

Alamin, M. and Marks, S., 'Sudan's Gold Output Spikes Amid Civil War as New Mining Deals Signed', *Bloomberg.com*, 24 February 2025.

Aluminium Stewardship Initiative, ASI Chain of Custody (CoC) Standard, report, 2023a.

Amoah Awuah, M., 'Raw materials diplomacy and extractives governance: The influence of the EU on the African extractive industry space', *South African Journal of International Affairs*, Vol 26, No 2, 2019, pp. 251-275.

Anyadike, N., 'Transparency in supply: Putting minerals on the blockchain', October 2023.

Barnewold, L. and Lottermoser, B. G., 'Identification of digital technologies and digitalisation trends in the mining industry', *International Journal of Mining Science and Technology*, Vol 30, No 6, 2020, pp. 747-757.

Bazilian, M. D., 'The mineral foundation of the energy transition', *The Extractive Industries and Society*, Vol 5, No 1, 2018, 93-97.

Bazillier, R. and Girard, V., 'The gold digger and the machine. Evidence on the distributive effect of the artisanal and industrial gold rushes in Burkina Faso', *Journal of Development Economics*, Vol 143, 2020.

Benabdallah, L., 'China's Role in Africa's Critical Minerals Landscape: Challenges and Key Opportunities', *Africa Policy Research Institute*, 06 September, 2024.

Berger, D., Easterly, W., Nunn, N. and Satyanath, S., 'Commercial Imperialism? Political Influence and Trade During the Cold War', *American Economic Review*, Vol 103, No 2, 2013, pp. 863-896

Besada, H. and Martin, P., 'Mining codes in Africa: emergence of a "fourth" generation?', *Cambridge Review of International Affairs*, Vol 28, No 2, 2014, pp. 263-282.

Beuter, P., Bhuee, R., Gabadadze, L., Gnanguênon A. and Hofmeyr, J., Mapping Africa's Green Mineral Partnerships, report, Africa Policy Research Institute, 2024.

Bohi, D. R., and Toman, M. A., *The Economics of Energy Security*. Springer Science & Business Media, Berlin, 2012.

Boutton, A., 'Fair-Weather Allies? Terrorism and the Allocation of US Foreign Aid', *Journal of Conflict Resolution*, Vol 58, No 7, 2014, pp. 1144-1173.

Brown, C., Daniels, A., Boyd, D. S., Sowter, A., Foody, G. and Kara, S., 'Investigating the Potential of Radar Interferometry for Monitoring Rural Artisanal Cobalt Mines in the Democratic Republic of the Congo', *Sustainability*, Vol 12, No 23, 2020.

Bryant, R. L. and Goodman, M. K., 'Consuming narratives: the political ecology of "alternative" consumption', *Transactions of the Institute of British Geographers*, Vol 29, No 3, 2004, pp. 344-366.

Buchanan, J. M., 'An Economic Theory of Clubs', *Economica*, Vol 32, No 125, 1965, pp. 01-14.

Bundesanstalt für Geowissenschaften und Rohstoffe, 'The ICGLR Regional Mineral Certification Framework', *Federal Institute for Geosciences and Natural Resources*, 2016.

Business for Social Responsibility, 'A Guide to Traceability: A Practical Approach to Advance Sustainability in Global Supply Chains', 2014.

Cacciuttolo, C., Guzmán, V., Catriñir, P., Atencio, E., Komarizadehasl, S. and Lozano-Galant, J. A, 'Low-Cost Sensors Technologies for Monitoring Sustainability and Safety Issues in Mining Activities: Advances, Gaps, and Future Directions in the Digitalization for Smart Mining', *Sensors*, Vol 23, No 15, 2023.

Campbell, B. K., *Mining in Africa: regulation and development*, London Pluto Press, London, United Kingdom, 2009.

Campbell, B., 'Revisiting the Reform Process of African Mining Regimes', *Canadian Journal of Development Studies / Revue Canadienne d'Études Du Développement*, Vol 30, No 1-2, 2010, pp. 197–217.

Chatterjee, C., Sindhwani, R., Kumar Mangla, S. and Hasteer, N., 'Digitization of the mining industry: Pathways to sustainability through enabling technologies', *Resources Policy*, No 100, 2024.

Coderre, M., Diallo, M. L., Diawara, A. and Campbell, B., 'La Vision minière pour l'Afrique et les transformations des cadres règlementaires miniers : les expériences du Mali et du Sénégal', *Canadian Journal of Development Studies/Revue Canadienne D Études Du Développement*, Vol 40, No 04, 2019, pp. 464-481.

Copperbelt Katanga Mining, 'Le président Tshisekedi plaide pour la traçabilité des minéraux afin de freiner le financement des groupes armés en RDC', 19 January 2025.

Cosbey, A., Mann, H., Maennling, N., Toledano, P., Martin, J. and Brauch, D., Mining a Mirage? Reassessing the shared-value paradigm in light of the technological advances in the mining sector, International Institute for Sustainable Development, 2016.

Davis, C. L. and Pratt, T., 'The forces of attraction: How security interests shape membership in economic institutions', *The Review of International Organizations*, Vol 16, No 4, 2020.

de Brier, G. and Walschot, M., 'EU acknowledges shortcomings of Conflict Minerals Regulation: What next?', *International Peace Information Service*, 04 December 2024.

Dempsey, H. and White, S., 'Indonesia to wipe out global nickel rivals, warns French miner Eramet chief', *Financial Times*, 2024.

DeskEco, 'Mining Indaba 2025 : Judith Suminwa insiste sur la traçabilité des minerais et appelle les investisseurs à en tenir compte avant de s'en procurer', 04 February 2025.

Dou, S., Xu, D., Zhu, Y. and Keenan, R., 'Critical mineral sustainable supply: Challenges and governance', *Futures*, No 146, 2023.

Draghi, M., The Future of European Competitiveness—A Competitiveness Strategy for Europe, 2024.

Duncombe, R., *Digital technologies for agricultural and rural development in the global south*, Centre for Agriculture and Biosciences International, West Sussex, 2018.

European Commission, 'Global Gateway: EU strengthens partnership with Angola and bolsters Lobito Corridor Investments', News Announcement, International Partnerships, 2025.

European Commission, Connecting the Democratic Republic of the Congo, Zambia, and Angola to Global Markets through the Lobito Corridor', 2023a.

European Commission, Global Gateway: EU and Namibia agree on next steps of strategic partnership on sustainable raw materials and green hydrogen, Press Release, IP/23/5263, 2023b.

European Commission, Review of the functioning and effectiveness of Regulation (EU) 2017/821 (Conflict Minerals Regulation) pursuant to Article 17 (2) of Regulation (EU) 2017/821, COM/2024/415 final, 2017.

European Partnership for Responsible Minerals Secretariat, 'Company Case Study Wolfram Bergbau & Hütten AG (WBH)', 2025.

European Partnership for Responsible Minerals Secretariat, Case Study USAID's Zahabu Safi', The European Partnership for Responsible Minerals, 2022.

Faki Mahamat, M., 'Remarks of the Chairperson of the African Union Commission, H.E. Moussa Faki Mahamat, at the Virtual Summit of the Non-Aligned Movement', Speeches, African Union, 2025.

Finck, M., 'Blockchain and the General Data Protection Regulation Can distributed ledgers be squared with European data protection law?', Scientific Foresight Unit, Directorate-General for Parliamentary Research Services, PE 634.445, 2019.

Girard V., Molina-Millán T., Vic, G., 'Artisanal Mining in Africa', NOVA Africa, Working Paper Series, 2024.

Ghamisi, P., Shahi, K. R., Duan, P., Rasti, B., Lorenz, S., Booysen, R., Thiele, S., Contreras, I. C., Kirsch, M. and Gloaguen, R., 'The Potential of Machine Learning for a More Responsible Sourcing of Critical Raw Materials', *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, Vol 14, 2021, pp. 8971-8988.

Goddard, E., 'Chirundu Remains a Nightmare for Copper BeltCargo', *Freight News*, 21 May 2020.

Gondwe, K., 'Zambia Electricity Crisis: Drought Hits Hydro-Powered Kariba Dam', *BBC News*, 02 October 2024.

Grohol, M. and Veeh, C., 'Study on the critical raw materials for the EU 2023', European Commission's Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, 2023.

Group of Experts on the Democratic Republic of the Congo, Letter dated 27 December 2024 from the Group of Experts on the Democratic Republic of the Congo addressed to the President of the Security Council, United Nations, 27 December 2024.

Heldt, L., 'Space Technology and Supply Chain Sustainability: Satellite-Based Due Diligence and the EU Deforestation Regulation', in. H. Jahankhani, S. Kendzierskyj, S. Pournouri and M. A. Pozza (eds.), *Space Law Principles and Sustainable Measures. Space Law and Policy*, Springer, Cham, 2024, pp.109-134.

Hendrix, C. S., 'Why the Proposed Brussels Buyers Club to Procure Critical Minerals is a Bad Idea', Policy Briefs, Vol 23, No 6, *Peterson Institute for International Economics*, 2023.

Hidalgo, J. J. and Centeno, J. A., 'Geospatial Intelligence and Artificial Intelligence for Detecting Potential Coca Paste Production Infrastructure in the Border Region of Venezuela and Colombia', *Journal of Applied Security Research*, 2022, pp. 01-51.

Hill, M., 'Zambia Closes Border with Congo, Blocking Key Copper Trade Route', *MINING.COM*, 11 August 2024.

Hilson, G., 'The Africa Mining Vision: A Manifesto for More Inclusive Extractive Industry-Led Development?', *Canadian Journal of Development Studies / Revue Canadienne d'Études Du Développement*, Vol 41, No 3, 2020, pp. 417-431.

Hilson, G., '"Constructing" Ethical Mineral Supply Chains in Sub-Saharan Africa: The Case of Malawian Fair Trade Rubies', *Development and Change*, Vol 45, No 1, 2014, pp. 53-78.

Hilson, G. and Maconachie, R., 'For the Environment: An Assessment of Recent Military Intervention in Informal Gold Mining Communities in Ghana', *Land Use Policy*, Vol 96, 2020.

Hilson, G. and Maconachie, R., 'Artisanal and Small-Scale Mining and the Sustainable Development Goals: Opportunities and New Directions for Sub-Saharan Africa', *Geoforum*, Vol 111, 2019.

Hilson, G., Hilson, A. and McQuilken, J., 'Ethical Minerals: Fairer Trade for Whom?', *Resources Policy*, Vol 49, 2016, pp. 232-247.

Hoex, L., Sépulchre, J-S. and Moor, M., 'The EU Conflict Minerals Regulation High Stakes, Disappointing Results-Paper on the Effectiveness of European Union Regulation 2017/821', *IPIS and PAX*, 2023.

International Energy Agency and Organization for Economic Co-operation and Development, The Role of Traceability in Critical Mineral Supply Chains, 28 February 2025.

International Energy Agency, 'Energy security in energy transitions – World Energy Outlook 2022 – Analysis', World Energy Outlook 2022, 2022.

International Renewable Energy Agency, Geopolitics of the Energy Transition: Critical Materials, 2018.

Javaid, M., Haleem, A., Singh, R. P., Suman, R. and Gonzalez, E. S., 'Understanding the Adoption of Industry 4.0 Technologies in Improving Environmental Sustainability', *Sustainable Operations and Computers*, Vol 3, No 1, 2022, pp. 203–217.

Jiskani, I. M., Zhou, W., Hosseini, S. and Wang, Z., 'Mining 4.0 and Climate Neutrality: A Unified and Reliable Decision System for Safe, Intelligent, and Green & Climate-Smart Mining', *Journal of Cleaner Production*, Vol 410, 2023.

Katho, O., Lebert, J., Lonema, J. P., Singo, P. and van der Burg, G., 'Lessons for the Future of Artisanal Gold in Democratic Republic of Congo', *The Just Gold Project*, 2021.

Joint Civil Society Letter, Halt Investments for the Extraction of Critical Raw Materials, 14 October 2024.

Just Gold Project, Just Gold – Tracing conflict-free and legal artisanal gold in Africa, *IMPACT*, 14 November 2022.

Katz-Lavigne, S., 'Distributional Impact of Corporate Extraction and (Un)authorised Clandestine Mining at and Around Large-Scale Copper- and Cobalt-Mining Sites in DR Congo', *Resources Policy*, Vol 65, 2020.

Katz-Lavigne, S., Mkodzongi, G. and Nyandoro, M., '"Bandits" and Machete Gangs: The Criminalization of Artisanal and Small-Scale Mining in the Democratic Republic of Congo and Zimbabwe', *The Extractive Industries and Society*, Vol 19, 2024.

Keating, M. F., Kuzemko, C., Belyi, A. V. and Goldthau, A., 'Introduction: Bringing Energy into International Political Economy', in. C. Kuzemko, A. V. Belyi, A. Goldthau, M. F. Keating (eds.), *Dynamics of Energy Governance in Europe and Russia*, International Political Economy Series, Palgrave Macmillan, London, 2012, pp. 1–19.

Keohane, R. O. and Nye, J. S., *Power and Interdependence*, Addison-Wesley Educational Publishers, Boston, 1977.

Khurshid, A., Chen, Y., Rauf, A. and Khan, K., 'Critical Metals in Uncertainty: How Russia-Ukraine Conflict Drives Their Prices?', *Resources Policy*, Vol 85, 2023.

Konrad Adenauer Stiftung, Conference Report: Energy, Trade and Climate Dialogue III: Opportunities to Link Sustainable Development and Economic Growth, Maputo, Mozambique, 2024.

Kos, D. and Kloppenburg, S., 'Digital technologies, Hyper-transparency and Smallholder Farmer Inclusion in Global Value Chains', *Current Opinion in Environmental Sustainability*, Vol 41, 2019, pp. 56–63.

Kulkarni, N., 'Going Beyond "Conflict-free": Transition Minerals Governance in DRC and Rwanda', *New Security Beat*, 31 July 2024.

Kwakkenbos, J., 'The EU's Global Gateway: The European Financial Architecture for Development', Blogs, *Oxfam International*, 30 May 2023.

Lammy, D., 'The Case for Progressive Realism', *Foreign Affairs*, 17 April 2024.

Ledger Insights, 'Volvo invests in blockchain startup Circulor for battery supply chain traceability', 2020.

Levin, E. and Cook, R., Comparative Study of Certification and Traceability Systems, Final Report, Estelle Levin LTD, 2015.

Levin, E., Certification and Artisanal and Small-Scale Mining: an Emerging Opportunity for Sustainable Development, Communities and Small-scale Mining Secretariat, 2008.

Le Bec, C., 'DRC: Gécamines takes over the artisanal cobalt mining sector', The Africa Report, 08 April 2021.

London Mining Network, 'African Mining Vision Detrimental to Africa, Group Says', News, 18 September 2013.

Luca, F., 'Brussels Countson Internal EIB Task Force for Critical Commodities', *Eunews*, 8 February 2024.

Malatji, M., 'Accelerating the African Continental Free Trade Area Through Optimization of Digital Supply Chains', Engineering Reports, Vol 6, No 2, 2023.

Manjonjo, K. and Mokgonyana, K., 'Foreign Countries Are Lining Up to Exploit Africa's Critical Minerals', *LSE Blogs*, 28 October 2024.

Mansfield, E. and Pollins, B. (eds.), Economic Interdependence and International Conflict, University of Michigan Press, Michigan, 2023.

Money, D., 'The UAE Has Set Its Sights on Africa's Critical Minerals', Briefing, *World Politics Review*, 17 April 2024.

Mouton, J. and Roux, A.T. E-waste recycling and collection in South Africa: views of industry and proposed guidelines to improve the system. *International Journal of Environmental Studies*, Vol 81, No 4, 2023.

Moyen Massa, G. and Archodoulaki, V.-M. Electrical and Electronic Waste Management Problems in Africa: Deficits and Solution Approach. *Environments*, Vol 10, No 3, 2023.

Müller, M., Saulich, C., Schöneich, S. and Schulze, M., 'From Competition to a Sustainable Raw Materials Diplomacy: Pointers for European Policymakers', SWP Research Paper, *German Institute for International and Security Affairs*, 2023.

Nagpal M., De Cremer, D. and Van Hiel, A., 'Is Technology Uniquely Placed to Solve Our Problems? An Examination Into Technosolutionism, What It Entails and What It Predicts', *Business & Society*, 2024.

Nassen Smith, M., 'Mining Global Decarbonisation for Development in Africa? Regional Geopolitics and the Question of South Africa in Africa', *The Extractive Industries and Society*, Vol 22, 2025.

Nature Editorial, 'The Politics of Energy Security', *Nature Energy*, Vol 8, No 10, 2023, pp. 1047-1047.

Neumann, M., Barume, B., Ducellier, B., Ombeni, A., Näher, U., Schütte, P., von Baggehufwudt, U., Ruppen, D. and Weyns, Y., Traceability in Artisanal Gold Supply Chains in the Democratic Republic of the Congo: Lessons Learned from the Kampene Gold Pilot Project, *Federal Institute for Geosciences and Natural Resources*, 2019.

Nursamsi, I., Phinn, S. R., Levin, N., Luskin, M. S. and Sonter, L. J., 'Remote Sensing of Artisanal and Small-Scale Mining: A Review of Scalable Mapping Approaches', *Science of the Total Environment*, Vol 951, 2024.

Oakley, P., 'Searching for Pure Gold: The Impact of Ethical Gold Sourcing Certification Programmes in the UK and Switzerland', *Environmental Science & Policy*, Vol 132, No 1, 2022, pp. 101–108.

Organisation for Economic Co-operation and Development, Recommendation of the Council on OECD Legal Instruments Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas, OECD/LEGAL/0386, 2025.

Organisation for Economic Co-operation and Development, OECD Due Diligence Guidance for Responsible Business Conduct, 2018.

Oshionebo, E., 'Overview of Mining in Africa' in. E. Oshionebo (ed), *Mineral Mining in Africa. Legal and Fiscal Regimes*, Routledge, London, 2020, pp. 01–18.

Owen, J. R. and Kemp, D., 'Mining-Induced Displacement and Resettlement: A Critical Appraisal', *Journal of Cleaner Production*, Vol 87, No 1, 2015, pp. 78–488.

Paschal, M. and Kauangal, J., 'Determinants of Formalised Mineral Market Outlet Choice Decision of Artisanal and Small-Scale Gold Miners in Geita, Tanzania', *Resources Policy*, Vol 100, 2024.

Pottinger, M. and Gallagher, M., 'No Substitute for Victory', *Foreign Affairs*, 10 April 2024.

Radley, B., *Disrupted Development in the Congo: The Fragile Foundations of the African Mining Consensus*, Oxford University Press, Oxford, 2023.

Rampai, T. and Nupen, S., Impact of the AfCFTA Agreement on Mining Sector Trade Alliances, *Africa Mining*, 2024.

Ribeiro, V. De Souza Mendes, F. Chandrakant, S. and Heilmayr R., 'Leveraging Remote Sensing for Transparency and Accountability in Amazonian Commodity Supply Chains', *One Earth*, Vol 7, No 11, *Cell Press*, 2024, pp. 1935–1940.

Ristaniemi, M. and Majcher, K., 'Blockchains in Competition Law – Friend or Foe? - Kluwer Competition Law Blog', *Kluwer Competition Law Blog*, 21 July 2018.

Robertson, R., 'Lights On: How Transparency Increases Compliance in Cambodian Global Value Chains', *Industrial and Labor Relations Review*, Vol 73, No 4, 2019.

S&P Global, 'China Responds to US Restrictions With Export Ban on Select Critical Minerals', *S&P Global Market Intelligence*, 30 January 2025.

Sánchez Jacob, E., Gerres, T. and Cossent Arín, R., 'Workshop: Developing countries' energy needs and priorities under a sustainable development perspective: The specific case of Africa and green hydrogen', European Parliament's Policy Department for External Relations Directorate General for External Policies of the Union, PE 754.438, November 2023.

Santoni de Sio, F. and Mecacci, G., 'Four Responsibility Gaps With Artificial Intelligence: Why They Matter and How to Address Them', *Philosophy & Technology*, Vol 34, 2021, pp. 1057–1084.

Santoni de Sio, F., 'Artificial Intelligence and the Future of Work: Mapping the Ethical Issues', *The Journal of Ethics*, Vol 28, No 1, 2024, pp. 407–427.

Schütte, P., Drobe, M., Kühnel, K., Stoltnow, M. and Vasters, J., Summary Report and Recommendations on Responsible Investment Opportunities in Africa's Critical Raw Materials Sector, AfricaMaVal Project Deliverable D7.3, *Federal Institute for Geosciences and Natural Resources*, 2025.

Schütte, P., Osbahr, I., Damm, S., Marbler, H., Erdmann, M., McDonald, S., Ndlela, S. and Phetla, S., Fact Sheets on Project Evaluation (Strategic, Economic, ESG, Infrastructure), AfricaMaVal Project Deliverable D7.1, *Federal Institute for Geosciences and Natural Resources*, 2024.

Smith, J. H., *The Eyes of the World: Mining the Digital Age in the Eastern DR Congo*, University of Chicago Press, Chicago, 2022.

Soofastaei, A., 'Advanced Analytics for Mining Industry', in. A. Soofastaei (ed.), *Advanced Analytics in Mining Engineering*, Springer, Cham, 2022, pp. 01–22.

Stibbs, J., McKeigue, J. and Raboca, J., 'Will Consumers Pay More for Sustainably Sourced Metals?: LME Week – Fastmarkets', *Fastmarkets*, 30 September 2024.

Storey, K., 'From FIFO to LILO: The Place Effects of Digitalization in the Mining Sector', *The Extractive Industries and Society*, Vol 13, 2023.

Swissaid, On the Trail of African Gold: Quantifying Production and Trade to Combat Illicit Flows, Report, 2024.

Tahir, I., Shahzad, K. and Ensari, M. S., 'Utilising Blockchain Technology for Managing Natural Resources: A Case Study of Reko Diq Copper-Gold Project, Pakistan', *Resources Policy*, Vol 98, 2024.

Taylor, I., 'Understanding Africa's Extractive Sector', *South African Journal of International Affairs*, Vol 26, No 2, 2019, pp. 303–306.

The European Business Council for Africa, 'EU and Rwanda sign a Memorandum of Understanding on Sustainable Raw Materials Value Chains', 11 March 2024.

The White House, Joint Statement from the United States and India, 22 June 2023.

Ubillús, A. and Benites, G., 'Performing traceability: Unpacking the Artisanal and Small-scale Gold Mining (ASGM) Trade Circuit in Peru', *Journal of Rural Studies*, Vol 102, 2023.

United Nations Conference on Trade and Development, Mineral Tracking Tool Helps Zambia Combat Illicit Financial Flows, 01 October 2020.

United Nations, Resourcing the Energy Transition: Principles to Guide Critical Energy Transition Minerals Towards Equity and Justice, UN Secretary-General's Panel on Critical Energy Transition Minerals, 2024.

United Nations General Assembly, 'Permanent sovereignty over natural resources', Resolutions adopted by the General Assembly during its 17th session, A/5217, 18 September-20 December 1962, 1962.

United States Congress, H. Rept. 117-130, Book 1 - BUILD BACK BETTER ACT, 2022.

United States Congress, Public Law No. 117-169, 2022.

United States Congress, Dodd-Frank Wall Street Reform and Consumer Protection Act, Public Law 111-203, 21 July 2010.

United States Department of State, MSP Principles for Responsible Critical Mineral Supply Chains, 2023.

United States Government Accountability Office, Conflict Minerals: Information on Artisanal Mined Gold and Efforts to Encourage Responsible Sourcing in the Democratic Republic of the Congo, Report to Congressional Committees, 2017.

United States Government, Addressing the Threat to the Domestic Supply Chain From Reliance on Critical Minerals From Foreign Adversaries and Supporting the Domestic Mining and Processing Industries, Executive Order 13953, 5 October 2020.

United States Government, Promoting Energy Infrastructure and Economic Growth, Executive Order 13868, 15 April 2019.

United States Government, A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals, Executive Order 13817, 20 December 2017.

United States Agency for International Development, 'USAID's Zahabu Safi (Clean Gold) Project', *Global Communities*, 2021.

Van der Ven, C., Azevedo, C., Pons, G., and Lamy, P. 'A new era of EU mini-trade deals? Re-prioritising sustainable development through clean trade and investment partnerships (CTIPS)', Europe Jaques Delors Discussion paper, March 2025

Van Wyk, D., Reyneke, S. and Bain, E., 'Attainable Vision or Fairy Tale?', in. A. Bohne and I. Thiam (eds.), *The Africa Mining Vision – Can Business as Usual be Visionary? Perspectives From Four Regions*, Rosa Luxemburg Stiftung, 2019.

Vandome, C., 'How can African states benefit from the EU Critical Raw Material Act and the UK Critical Minerals Strategy?', *Africa Policy Research Institute*, 11 September, 2024.

Vasters, J. and Schütte, P., Country Profiles of Artisanal and Small-Scale ECRM Mine Production and Processing Developments, AfricaMaVal Project Deliverable D1.4, Federal Institute for Geosciences and Natural Resources, 2023.

Vivoda, V., 'Friend-Shoring and Critical Minerals: Exploring the Role of the Minerals Security Partnership', *Energy Research & Social Science*, Vol 100, 2023.

Vogel, C. N., *Conflict Minerals, Inc.*, Hurst Publishers, London, UK, 2022.

Wilson, J. D., 'A Securitisation Approach to International Energy Politics', *Energy Research & Social Science*, Vol 49, 2019, pp. 114–125.

Xinhuanet News, Zambia Revenue Agency Intercepts 10 Trucks with Smuggled Copper Ore, 24 December 2019.

Xu, Y., Nassani, A. A., Qazi Abro, M. M., Naseem, I. and Zaman, K., 'FinTech Revolution in Mineral Management: Exploring the Nexus Between Technology Adoption and Sustainable Resource Utilization in an Industry 4.0 Context', *Heliyon*, 2024.

Zhuwarara, S. K., *The Potential of Digitisation in Enhancing Regulation and Sustainability in the Artisanal and Small-Scale Mining (ASM) Sector in Zambia, Nigeria, and Ghana*, Routledge, London, 2023.

World Bank Group, State of the Artisanal and Small-Scale Mining Sector 2019, Washington D.C., World Bank, 2019.

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