



RCS GLOBAL
Making Sure.



BLOCKCHAIN FOR TRACEABILITY IN MINERALS AND METALS SUPPLY CHAINS: OPPORTUNITIES AND CHALLENGES

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1. Executive Summary

Background

Downstream manufacturing companies such as electronics and automotive companies are increasingly demanding the following information from upstream producers with regards to the metals and mineral in their end products:

1. **Provenance:** From which mines/miners are the minerals and metals that are contained in their end products?
2. **Production methods:** Under which methods are they produced? Are they produced responsibly?

The ICMM has commissioned the following report to understand how blockchain technology could potentially provide the above-mentioned claims as part of robust Chain of Custody (CoC) systems.

What is blockchain?

Blockchain is a technology that allows for data to be validated and subsequently stored as an immutable ‘block’ on a collectively owned and distributed digital database. The resulting blockchain is immutable because every block is validated based on previous blocks, making it very difficult to alter – as the modification of a recorded transaction would require modifying all previous blocks. Blocks are validated either by an algorithm or a third party in the field.

How could a blockchain-enabled CoC system provide provenance and responsible production claims?

At its most basic explanation, blockchain is a database. Like other databases, a blockchain database provides a platform onto which supply chain transactions can be recorded from mine to smelter and beyond. Data including weight, quantity, grade, but also provenance information and responsible production certificates can be uploaded to the system and validated at the appropriate supply chain points, and then linked to the physical material using bar codes, tags or other internet of things applications (such as RFID tags). This information could then be shared with downstream buyers and other third parties.

Potential advantages

- Builds a consensus and trust around responsible production standards between downstream and upstream companies
- The immutability of and decentralized control over a blockchain system minimizes the risk of fraud.
- Defined datasets can be made accessible in real time to any third party, including downstream buyers, auditors, investors, etc. but at the same time encrypted so as to share a proof of fact rather than confidential information
- A blockchain system can be easily scaled to include other producers and supply chains beyond those initially involved
- Cost reduction due to the paperless nature of a blockchain-enabled CoC system, the potential reduction of audits, and reduction in transaction costs

Thus, specific features of blockchain technology could theoretically contribute to overcoming specific barriers to traceability, such as confidentiality concerns, a lack of standardized CoC systems, a lack of digitization, and administrative and governance costs.

Application of blockchain to other industry supply chains

Several companies are already exploring the use of blockchain in their supply chains. These ‘use cases’ present important lessons learnt for a potential application to the minerals and metals context, including how blockchain

allows for sharing geological data between vendors (BHP Billiton), detecting fraud in the diamond supply chain (Everledger), validating local supply chain data with the help of NGOs (Provenance), overcoming confidentiality concerns in the chemicals supply chain (Stratumn), and identifying more quickly potential contamination of the food supply chain (Walmart).

Potential challenges in the minerals and metals supply chain

However, as can be expected with a technology as new and largely untested in the minerals and metals supply chain context, several challenges exist:

- Finding a consensus around CoC data and responsible production standards amongst companies with different risk exposure and supply chain positions
- Technical challenges around data input – ‘garbage in, garbage out’
- Transforming paper-based, non-standardized CoC systems into a digital system
- Complex points of aggregation, mixing and processing depending on the mineral/metal that make it difficult to control material flows
- High cost due to the amount of computing power needed and large operational costs (estimates range from USD 100 per GB to USD 50,000 – 100,000 per user)
- Blockchain’s application in supply chains is still in an experimental phase and is largely untested

Furthermore, research and discussions at the ICMM MSRT revealed several open questions around the technology, including the need to identify a clear objective for using the technology – as a marketing tool, to improve supply chain efficiency, achieve regulatory compliance, etc. Likewise, implementation questions remain outstanding, such as the possibility to add a blockchain system to an existing blockchain platform and to which level material should be traced on the blockchain (smelter only or beyond).

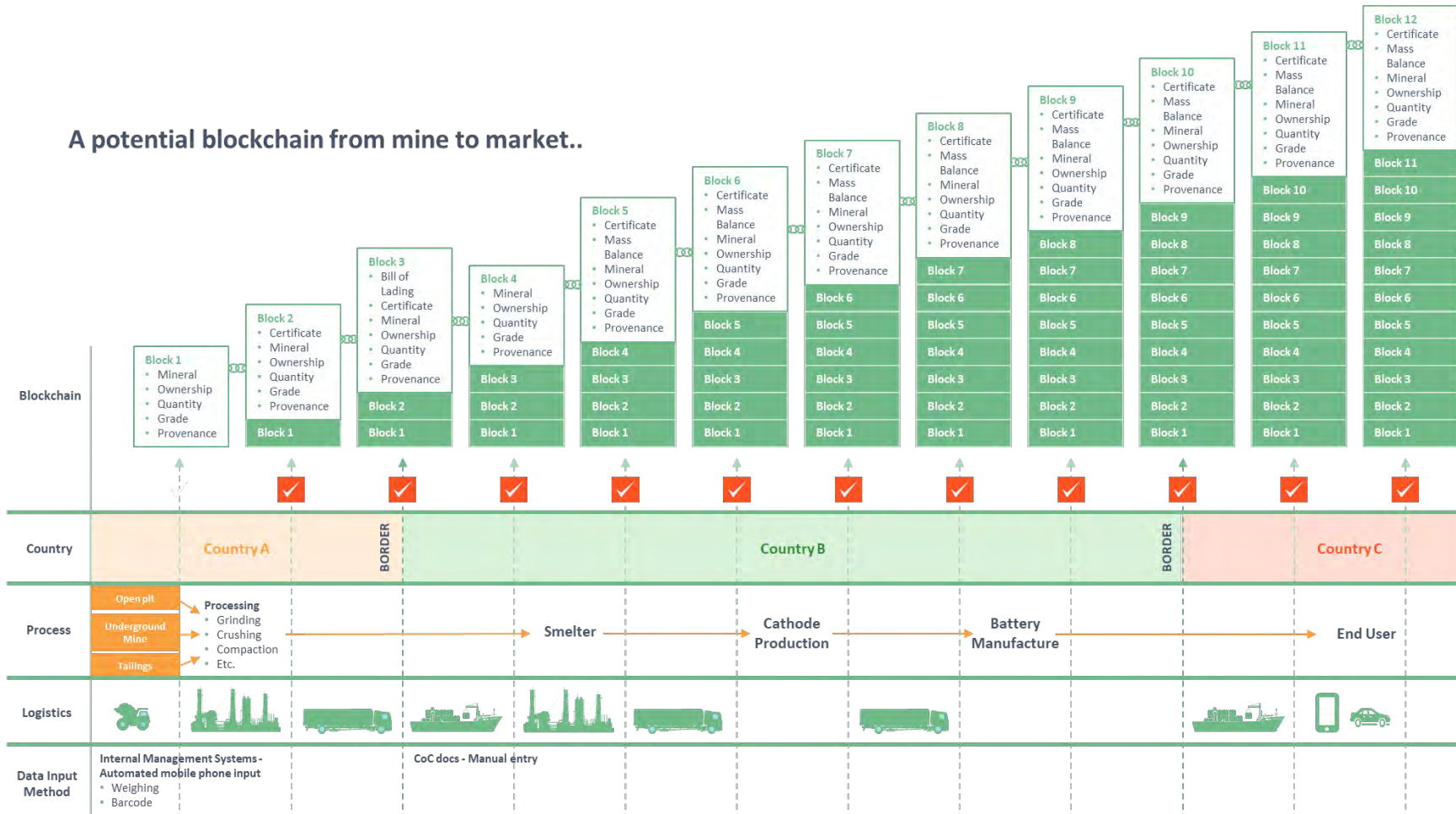
In conclusion, blockchain is not a magic panacea that can solve all existing structural issues in minerals and metals supply chain management. However, the potential benefits that a shared blockchain database presents for the transparency and traceability along supply chains are immense. Not only could the technology help reward / incentivize responsible production, but it will also build trust between upstream and downstream partners, and reduce transaction time and costs. Most importantly, blockchain could facilitate a collaborative effort for the industry to increase transparency around minerals and metals sourcing in the face of growing public awareness and expectations.

Recommendations

RCS Global recommends the **establishment of a working group** that includes upstream producers, downstream buyers, intermediaries, commodity industry associations, ethical investors, and minerals and metals exchanges, to explore the concept of a blockchain-based CoC system and potential other uses of the technology. The ICMM would be a strong partner in facilitating the establishment of such a working group. Throughout the research conducted for this report, specific interest on behalf of the afore-mentioned potential partners was registered.

Also, RCS Global, based on comments made at the ICMM MSRT, recommends that any pilot project focus on a **small consortium of companies** rather than an industry-wide application.

A potential blockchain from mine to market..



2. Introduction

2.1 Background

Buyers of metals and minerals are coming under increased pressure to prove that the materials they source are responsibly produced. Tin, tantalum, tungsten and gold (3TG) supply chains are under regulatory scrutiny in the United States and the European Union for their potential contribution to armed conflict in the Great Lakes region in Africa. Recent media attention has also focused on child labour in cobalt mines in the Democratic Republic of Congo (DRC) and water pollution in the South American ‘lithium triangle’. Both cobalt and lithium are key components of lithium-ion batteries that power most smartphones, laptops and electric vehicles (EVs).

The main approach to providing downstream customers with greater assurance around social and environmental sustainability in mining and metals supply chains is by achieving greater supply chain transparency and traceability.

As a first part of its research series on traceability, the International Council of Mining and Metals (ICMM) conducted a study on the challenges and opportunities for traceability of materials in metals and minerals supply chains.

This paper forms the second part of this series and focuses on understanding blockchain and its potential as a tool to overcome the identified barriers to traceability.

2.2 Objectives

RCS Global was contracted by ICMM to conduct research to understand:

- the attributes of blockchain theory and technology and how these could facilitate traceability in supply chains and
- the opportunities and challenges for utilising blockchain in metals and minerals supply chains.

These overarching research objectives are covered by focusing on the following elements:

1. Current downstream expectations
2. Key considerations for Chain of Custody (CoC) systems
3. Barriers to traceability in the metals and minerals supply chain
4. Blockchain technology explained
5. Potential application of a blockchain-enabled CoC system in the metals and minerals supply chain
6. Potential advantages associated with a blockchain-enabled CoC system in the metals and minerals supply chain
7. Blockchain in supply chains use cases in other industries
8. Potential challenges associated with a blockchain-enabled CoC system in the metals and minerals supply chain

Initial conclusions will seek to respond to the following question:

- Is blockchain a viable option to overcome barriers to transparency in metals and minerals supply chains?

2.3 Methodology

In response to the research question posed above, RCS Global has conducted qualitative interviews with seven blockchain providers to understand what lessons learnt can be taken from applications of blockchain in other commodity sectors to the minerals and metals context.

In addition, RCS Global presented initial research findings at the ICMM Material Stewardship Roundtable (MSRT) to ICMM members and selected invitees from the blockchain space and downstream buyers. The point was to gauge participants' interest in and concerns with the technology and understand questions for further research.

3. Current downstream expectations

Downstream expectations are the main drivers for attempts to achieve greater traceability in the minerals and metals supply chain. These expectations are mainly driven by two main factors:

1. **Regulation:** Buyers of minerals and metals are subject to a number of laws in various countries that require them to conduct increased due diligence around the provenance of the raw materials they source. Legislation includes the Dodd Frank Act Section 1502 in the United States (for 3TG), the EU Conflict Minerals Legislation (for importers of 3TG), the French corporate vigilance law, and the Modern Slavery Act in the United Kingdom.
2. **Public scrutiny:** In addition to legislators, international news media, non-governmental organizations, and international organizations are raising the public's awareness of responsible sourcing issues in minerals beyond the 3TG. Reports published by Amnesty International¹, the Washington Post², and Sky News³ have linked cobalt production to child labour in the Democratic Republic of Congo (DRC), while the OECD will be publishing a handbook on risks associated with the trade and production of 30 different minerals and metals.

Both drivers are increasing the public pressure on companies to identify and manage risks to human rights in their supply chains, and to exercise appropriate leverage to remediate them. In order to do so, companies are currently focusing primarily on acquiring the following information with regards to the minerals and metals they source:

1. **Provenance:** In which mines and by whom are the minerals and metals produced that are contained in end products?
2. **Production methods:** Under which methods are they produced? Are they produced responsibly?

Attempting to achieve greater traceability through a Chain of Custody (CoC) system appears as the logical consequence of these downstream demands.

4. Key considerations for Chain of Custody (CoC) systems

Products are often traced through the supply chain by monitoring and tracking the Chain of Custody. A Chain of Custody refers to "all steps in a supply chain that take possession of the product, including manufacturers, exporters, traders and importers" (ISEAL Alliance). Traceability is one type of CoC model whereby the material in the chain can be traced back to its actual sources.

A strong, fully-developed CoC system typically allows for two claims:

1. **Material stewardship:** Providing a robust material stewardship from production to customer (surviving transformation), i.e. who has 'owned' the material at which point of the supply chain

¹ Amnesty International. 2016. This is what we die for: Human rights abuses in the Democratic Republic of the Congo power the global trade in cobalt.

² Washington Post. 2016. The cobalt pipeline: Tracing the path from deadly hand-dug mines in Congo to consumers' phones and laptops.

³ Sky News. 2017. Special report: Inside the Congo cobalt mines that exploit children.



2. **Responsible production:** That the material is produced against a given standard – thereby ‘labelling’ the material as Responsibly Produced against responsible production standards, such as the ICMM 10 Principles (for example)

Different types of CoC systems exist that allow for different claims, including a closed pipe supply chain, segregation, mass balance, and book and claim (see Annex 1 for further details).

However, several barriers to traceability currently exist in minerals and metals supply chains that inhibit robust CoC systems and thus the potential claims associated with them.

5. Barriers to traceability in the metals and minerals supply chain

As a first part of its research series on traceability, ICMM conducted a study on the challenges and opportunities for traceability of materials in metals and minerals supply chains. Through its own research, RCS Global has identified further challenges to robust CoC systems. The following presents a summary of these challenges:

5.1 Underlying factors

There are two underlying factors that make it difficult for companies to design robust CoC systems that are able to respond to downstream demands:

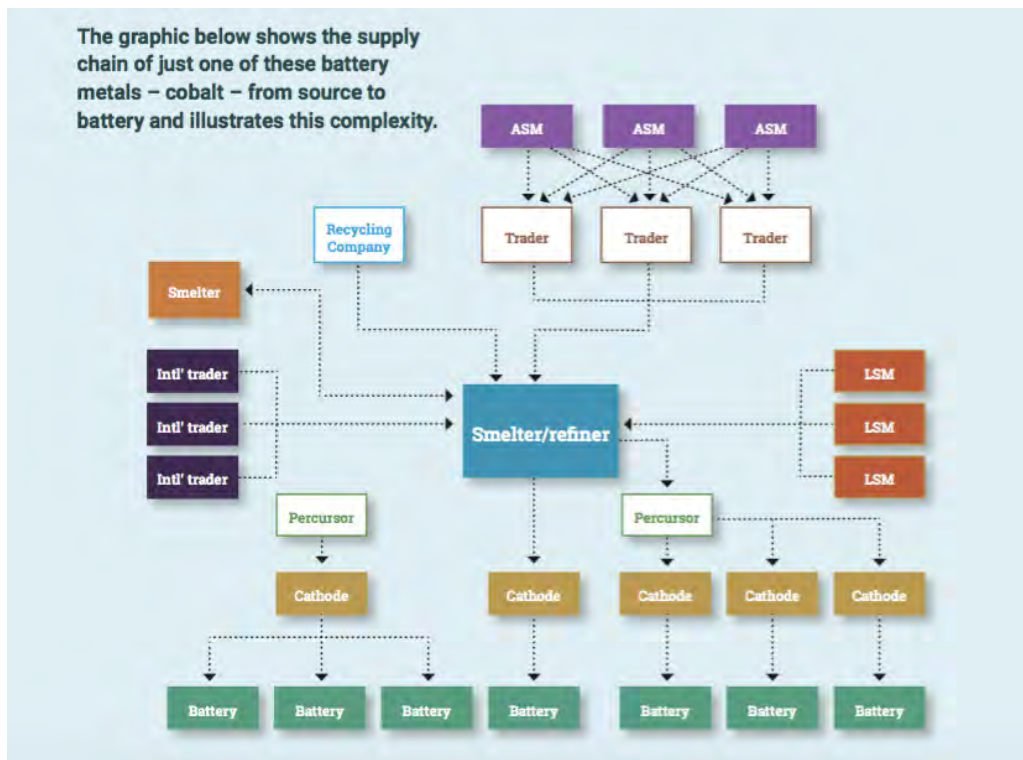
- **Non-standard, unilateral customer requests for information:** Downstream buyers often request specific information from refiners, smelters, traders, and mining companies in an ad-hoc manner with their own forms and questionnaires that is different from information requested by other downstream buyers.
- **No broadly accepted material control standard:** Furthermore, CoC systems require a material control standard. However, there is currently no broadly accepted material control standard for the mining and metals industry as a whole (the Responsible Jewellery Council/RJC developed a CoC standard for the jewellery context).

These underlying factors add to the following implementation barriers:

5.2 Implementation barriers

- **Points of aggregation:** The minerals and metals supply chain features important material aggregation points – primarily at the smelter/refiner level – where minerals and metals from different sources – including potentially from artisanal and small-scale mining (ASM) as in the cobalt example (see Figure 1 below) – are combined.

Figure 1: Illustration of the cobalt supply chain



- **Points of transformation:** Minerals and metals also undergo several processing stages along the supply chain, including crushing, washing, grinding, separation, etc. (depending on the supply chain) during which product characteristics such as size, weight, grade, and price change.
- **A lack of technical capacity:** Technical considerations like language, availability of suitable personnel and non-centralized record keeping can all be obstacles, particularly in smaller and fragmented supply chains.
- **Confidentiality concerns:** Information about suppliers can have competitive implications for actors in the minerals and metals supply chain. Thus, there may be a reluctance to share supplier information or identities.
- **A lack of standardized CoC documentation and digitization:** Research found that CoC documentation between supply chains varies. Furthermore, most CoC systems are still paper-based, which means that there is no central digital database that could be accessed by downstream customers. It also makes CoC systems susceptible to fraud or incorrect data entry.
- **Administrative and governance costs:** Costs for implementing a robust CoC system are also quite high, in part due to responding to unilateral requests for information, but also because implementing a sophisticated system that is able to handle the amount of data required as well as audits are costly.

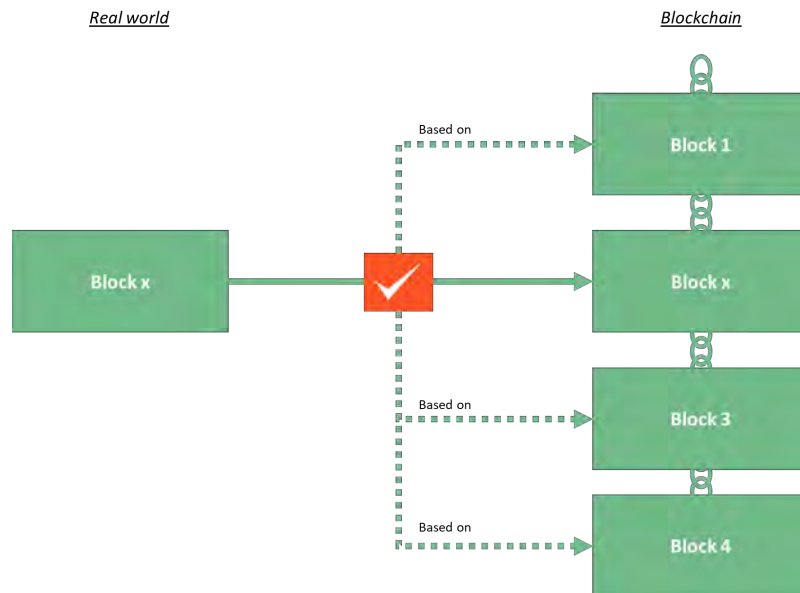
While technology-based traceability solutions, such as the Geotraceability-enabled Better Sourcing platform, exist, blockchain features several significant advantages.

6. Blockchain explained

Blockchain is a technology that allows for real-world data to be validated and subsequently stored as an immutable ‘block’ on a collectively owned and distributed digital database. The resulting blockchain is immutable because every block is validated based on previous blocks, making it very difficult to alter – the

modification of a recorded transaction would require modifying all previous blocks. Blocks are validated either by an algorithm or physical actor.

Figure 2: Blockchain validation

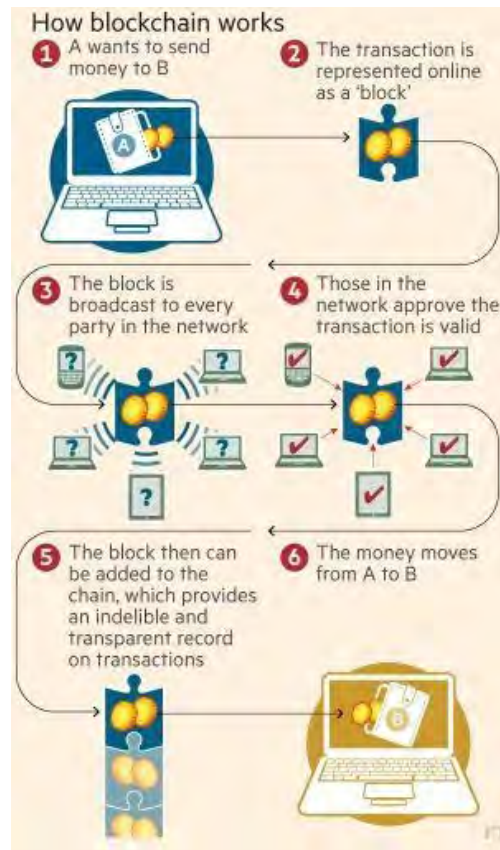


Source: RCS Global, 2017

Blocks can be any type of data, including financial transactions, a contract, or a transfer of assets.

Blockchain came to prominence as the technology underlying the digital cryptocurrency Bitcoin since 2007. Bitcoin does not rely on banks as intermediaries to guarantee the validity of financial transactions as the blockchain technology automatically plays that role. In the Bitcoin system, persons can trust each other also because every transaction is publicly available on a decentraly-owned database. The following figure from the FT describes how the technology enables Bitcoin transactions.

Figure 3: How blockchain works in Bitcoin



Source: Financial Times, 2016

In the past years, many different industries beyond cryptocurrencies have experimented with the technology as a way to promote trust between users of a same system, including in the insurance industry, as an information system for medical records, for land registration, or as an online voting system.

One of the most promising 'use cases', however, is for transactions along global supply chains.

7. Blockchain for traceability in minerals and metals supply chains: How it could work

Blockchain provides a database onto which supply chain transactions can be recorded. Usually using bar codes, digital tags or serial numbers assigned to physical goods, it allows for those goods to be tracked along a supply chain. Data recorded can include properties of the product, transfer locations, actors involved in supply chain transaction, and adherence to responsible production standards linked to all of the above.

In the minerals and metals supply chain, the following properties of minerals (or other properties) could be recorded onto a blockchain system:

- Weight
- Quantity
- Grade
- 3D images of the material
- Mineral fingerprints

- Ownership of the material at a certain supply chain point
- Life cycle assessments
- Bills of lading
- Transfer locations

More importantly given the above-mentioned downstream expectations, such a system could also add **provenance information and certificates of responsible production**. All this information could be easily shared with downstream buyers and other third parties.

Blockchain's validation mechanism would ensure – either through an algorithm or through a physical actor who validates data in the field – that the data is entered according to a previously agreed consensus. The blockchain would flag any abnormalities if not entered according to that consensus. This would make it be possible to identify problematic supply chain links within minutes. In other words, blockchain provides for the fitting database for a robust CoC system.

The data could thus be recorded in a series of added blocks that create a 'digital' fingerprint for the product that would allow the downstream buyer to understand what percentage of material in their end product comes from a particular mine site / is responsibly produced, as shown in Figure 4 below.

Box 1: How to account for mixing and processing

Existing traceability solutions such as those used by Geo-Traceability and Better Sourcing (BSP) allow for traceability despite mixing and processing as follows: The software automatically tallies and assesses acceptable ranges in material change and sends alerts if the range exceeds acceptable rules. The rules can be defined based on different sources or as an average – depending on the supply chain. Such an approach can be applied to a blockchain solution.

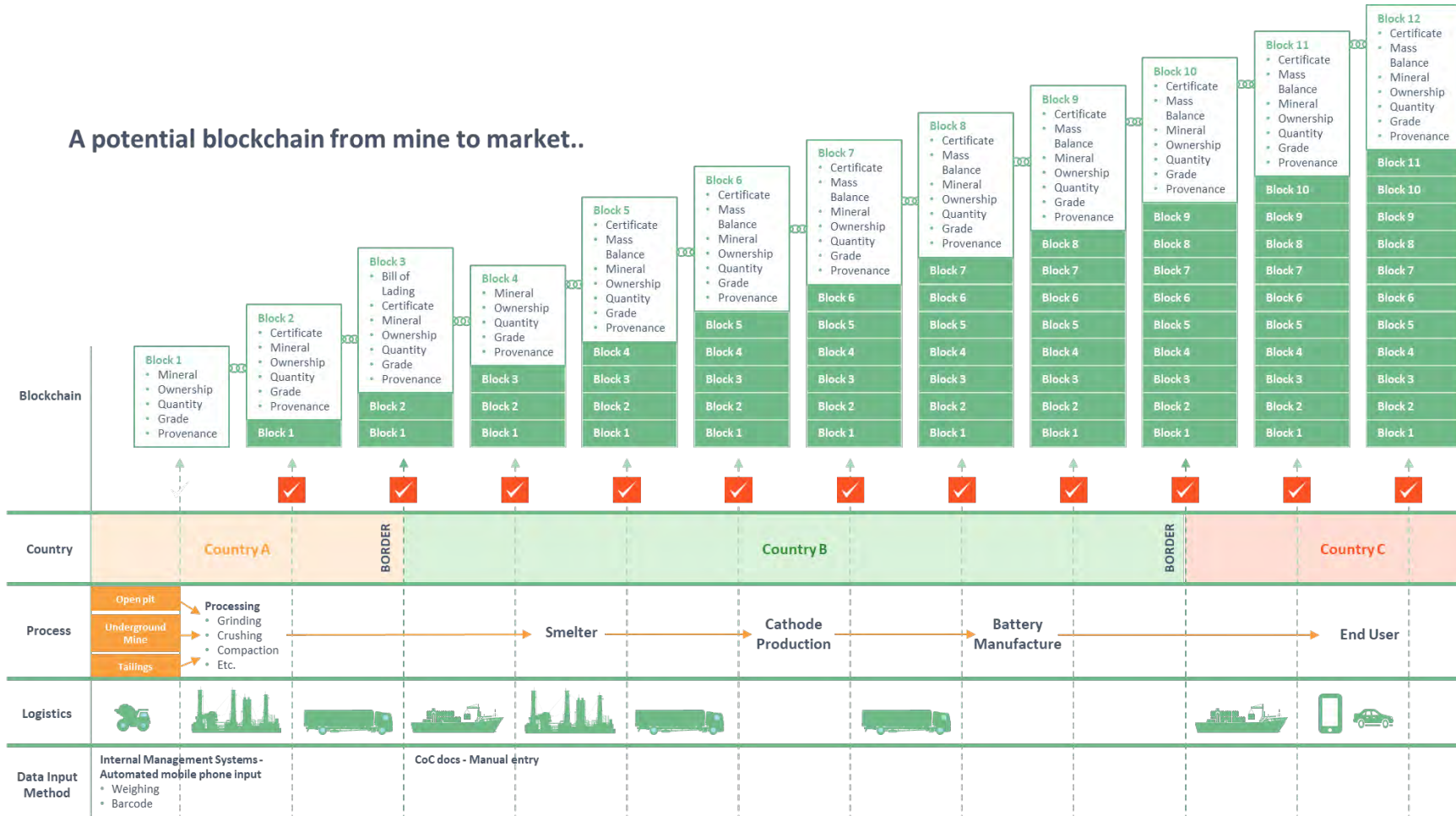
In this way, the transformation, mixing and dilution can be recorded on the CoC system to ensure full traceability.

Other options may include 3D images of the material, adding impurities, and 'mineral fingerprinting'. However, as the technology is new, these options need to be tested through a use case, which has not yet occurred.

Thus, a blockchain-based CoC system could allow for downstream companies to make trusted claims as to the provenance and production methods for the materials in their end products. While technology-based traceability solutions exist, blockchain features a number of significant advantages.

Figure 4: A potential blockchain from mine to market

A potential blockchain from mine to market..



Source: RCS Global, 2017

8. Potential advantages associated with blockchain in supply chains

Blockchain has various features that differentiate it from existing traceability tools:

- **Consensus mechanism:** A blockchain system requires that all participants in the system reach a consensus over the type of information recorded on the database. In the context of responsible minerals and metals, this would encourage downstream and upstream companies to agree on responsible production standards and the role of audits. However, consensus is already occurring within industry groups around the standards and frameworks developed by organisations such as the ICMM, the Cobalt Institute (CI), the Responsible Minerals Initiative (RMI), and other associations.
- **Immutable, un-corruptible records:** Once a transaction – or ‘block’ – has been successfully added to the blockchain, it is time-stamped, validated, and linked to the block before and after it. It thus minimizes the risk of fraud.
- **Decentralized control:** Shared ownership means that the system cannot be controlled or corrupted by a single entity. The data must be stored on a server, but is ultimately self-executing. It thus promotes trust across the actors involved.
- **Sharable, but encrypted supply chain information:** Defined data-sets can be made accessible in real time to any third party, including downstream buyers, but also auditors, investors, shareholders, insurers, logistics providers, traders, etc. This direct and easy access to information can help improve supply chain efficiency. Certain blockchain providers specialise in solutions whereby third-party access can be managed to avoid confidentiality concerns. This mechanism could be used to attach a responsible sourcing claim to material and provide this information to customers in the downstream. The possibility of sending encrypted proof of a fact rather than data itself to external counterparts (see Stratum use case in Section 9.4) allows companies to demonstrate dynamic and continuous compliance to external stakeholders while retaining confidentiality over sensitive supply chain information.
- **Scalability:** Once a consensus is agreed and a system is established, there are hardly any technical (non-financial) limits as to how many users can be onboarded onto a blockchain-based data platform. This allows for a quick scalability of a pilot project.
- **Costs reduction:** There are several ways in which a blockchain-based CoC system could reduce costs. Firstly, it provides a paperless system, which reduces the time and effort required to enter and access CoC data. Secondly, it reduces potential audit burden as certain audit information – depending on the consensus governing the system – could be accessed more easily. Thirdly, the trust being built could reduce transaction time from days to near instantaneous (see Box 2 on ‘Smart Contracts’).

Box 2: Blockchain-enabled Smart Contracts

Blockchain enables business terms agreed upon through a contract to be recorded onto a blockchain and self-execute when these terms are met. These ‘smart contracts’ could implement rules that prevent/allow/increase/reduce payment if certain conditions hold, for instance if % metal is below threshold in the ore or if the goods are a certain % of the way to destination. Both the contract and the digital fingerprint can be structured to respect business confidentiality.

Such smart contracts can minimize manual effort costs and the need for legal intermediaries in supply chain transactions or mineral purchases.

Thus, specific features of blockchain technology could theoretically contribute to overcoming specific barriers to traceability, such as confidentiality concerns, a lack of standardized CoC systems, a lack of

digitization, and administrative and governance costs. Several companies are already exploring the use of blockchain in their supply chains in practice. These ‘use cases’ present important lessons learnt for a potential application to the minerals and metals context.

9. Blockchain supply chain use cases

Over the last five years, the value of blockchain beyond facilitating financial transactions has been realised. Amongst other use cases, the potential for blockchain to provide a transparent and permanent record for transactions along supply chains has been explored. Several companies are exploring the advantages the blockchain technology holds for supply chain management:

9.1 BHP Billiton: Sharing geological data between vendors

BHP Billiton, the largest mining firm by market capitalization, revealed in September 2016 that it intends to use blockchain to record movements of wellbore rock and fluid samples and better secure the real-time data that is generated during delivery. According to the company, the blockchain will allow BHP to constantly share data between vendors (e.g. geologists, shipping companies) distributed across continents. BHP intends to begin requiring that its vendors use blockchain to collect real-time data. While introducing a new technology to an existing operation may seem risky, the company said it is confident in the user experience the app will provide: “The web application is designed for the vendor. The vendor will see a dashboard and options on what to do that are very streamlined to their job,” BHP geophysicist Tyler Smith said.⁴ BHP hopes that the blockchain will increase internal efficiency as well as allowing it to work more efficiently with partners.

It must be noted, however, that BHP Billiton’s approach is confined to its operations and is not currently integrated further downstream or with other mining companies and supply chains.

9.2 Everledger: Detecting fraud in the diamond supply chain

Everledger is a start-up that uses blockchain as a digital ledger for diamond transactions. It built its application using IBM’s blockchain architecture. The main objective of Everledger is to detect fraud along the diamond supply chain. It operates 1) a public blockchain, which records diamond certifications to enable transparency for consumers and 2) a private blockchain that supports diamond trade, production, and certification through so-called ‘smart contracts’ - contracts that allow the owner/seller to finance and insure these luxury items more efficiently. Validation of supply chain data is conducted through a third-party inspection or self-declaration. Everledger’s blockchain currently covers about 980,000 diamonds and is scaled to accommodate a pipeline of 10 million diamonds.⁵ Everledger’s clients include banks, insurance companies, and diamond companies.

Figure 4: Excerpt of Everledger’s diamond blockchain

TRANSACTIONS	BLOCK INFO	# TXS	HEIGHT	BROADCASTED
4642640f136bfee38cc7fd84563157e2541..	bc1d686ec9..	2511	430477	3 months ago
d4100ab5a30f7697d812fa4ebc6b5c858bb..	1d7dbd6313..	2085	430476	3 months ago
1b22136dca61d2e0575bec071db47059ab4..	a0406aba54..	1981	430475	3 months ago
f3dfbd5c72c8ff37ad09b339a9d009c4c5d..	140fcb1f2b..	2596	430474	3 months ago
ce804be95945af9cc73e562c75e7a6890af..	5c0c0d23e2..	2622	430473	3 months ago
362be4a20b30000ecf6bb54e1c6c4928078..	a1038b4aaf..	2146	430472	3 months ago
e8dfab60404e83765700a3bf268a8f174a3..	586f03ac25..	1948	430471	3 months ago
2a3cce92f40e980978d7ad2f438d4d1a457..	135451476f..	2116	430470	3 months ago
bcb2da63688352a704ecde3ec52795e0a19..	b6366e85a9..	1545	430469	3 months ago
8f633b414d2f191cbeb6c846306932fbd35..	da4eeafa2e..	2093	430468	3 months ago

Source: <http://www.everledger.io/>

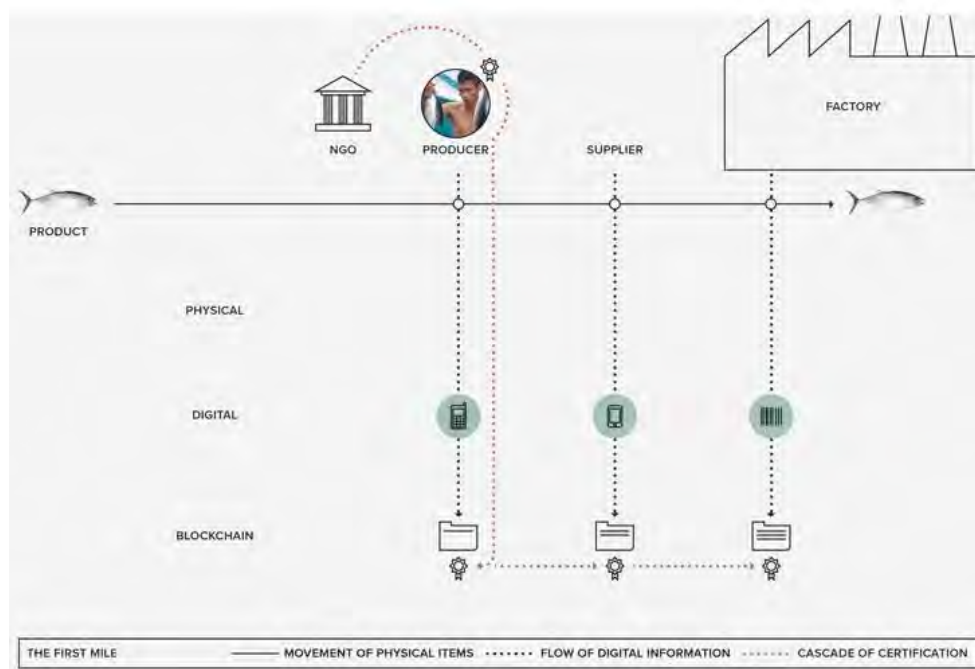
⁴ “World’s Largest Mining Company to Use Blockchain for Supply Chain.” CoinDesk. September 23, 2016. <http://www.coindesk.com/bhp-billiton-blockchain-mining-company-supply-chain/>

⁵ “Everledger Pitch by Leanne Kemp in Blockchain / Bitcoin category at European FinTech Awards 2016.” April 22, 2016. <https://www.youtube.com/watch?v=aow2hxPI5DI&t=321s>

9.3 Provenance: Validation of local supply chain data through NGOs

Using the blockchain, London-based start-up Provenance has built a mobile phone application that tracks product information – such as certification data, where it was made, who it was made by, environmental impact – along a supply chain. It does so by allowing suppliers in the field to use their mobile phones to add data securely to the blockchain. For example, local fishermen send SMS to register their catch directly to the blockchain. The social and environmental conditions at the point of capture are verified through trusted local NGOs whose audit systems validate their compliance to an external standard, resulting in their eligibility to participate in the Provenance-validated chain of custody. End customers are then able to access this information.

Figure 5: How Provenance’s blockchain works in the ‘first mile’



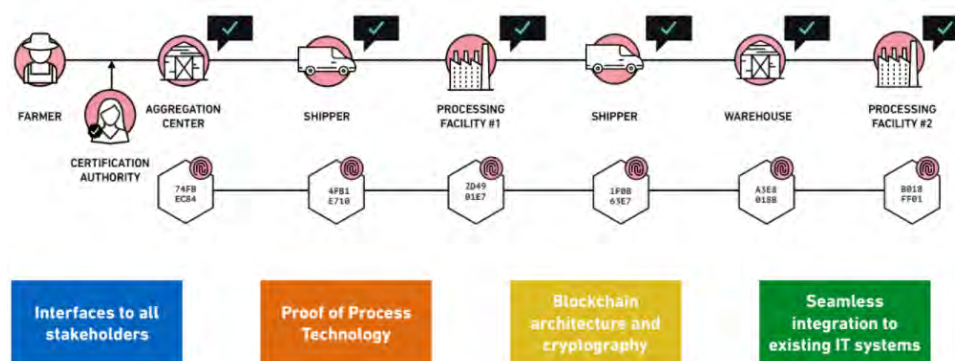
Source: https://www.provenance.org/tracking_tuna_on_the_blockchain

9.4 Stratumn: Overcoming confidentiality concerns in the chemicals supply chain

The blockchain provider Stratumn leverages blockchain and cryptography⁶ technologies to build networks connecting supply chain partners. Stratumn’s advanced use of cryptography guarantees privacy and provides flexible and modular access to stakeholders. This approach enables partners to communicate data in a modular and private way, and to communicate proof rather than raw data to external counterparts. It is thus a tool to demonstrate compliance to external stakeholders and not fully trusted stakeholders while retaining confidentiality over sensitive supply chain information. The approach has been applied to experiment with end-to-end traceability of sensitive commodities for a leading chemical company, including sustainable production certificates.

⁶ “Cryptography is a method of storing and transmitting data in a particular form so that only those for whom it is intended can read and process it.” <http://searchsoftwarequality.techtarget.com/definition/cryptography>

Figure 6: Stratumn's approach to the chemicals supply chain



Source: Stratumn, 2017

9.5 Walmart: More efficiently identifying problematic food supply chain nodes

Walmart is using blockchain to track pre-packaged food items, such as mangoes from Mexico and pork from China, from farm to store in order to improve food safety. The technology helps Walmart more efficiently identify when and where food items are contaminated, which can help producers and public health officials limit contagion. IBM has already started testing out the technology with Walmart, which was able to track a product from a farm all the way to its store shelves. That tracking process, which historically has taken days or weeks, took only seconds.⁷

10. Potential challenges to blockchain for supply chain traceability in the minerals and metals context

The above-noted case studies and pilot projects demonstrate several advantages of blockchain that are also applicable to the minerals and metals supply chain. However, as can be expected with a technology as new and largely untested in this context, several challenges exist.

Based on interviews conducted with blockchain providers, responses gathered at the ICMM MSRT, and RCS Global's experience in implementing technology-based traceability solutions (such as Better Sourcing) and responsible production standards, the following implementation challenges could be expected in the minerals and metals context:

- **Need for a consensus:** As much as requiring a consensus is an advantage of a blockchain system, coming to an agreement of responsible production standards and standardized CoC information is a tall order in an industry with such different risk exposures and market demands. The RMI's Risk Readiness Assessment (RRA) – a framework providing an indication of downstream expectations of upstream production standards – for instance, identifies 31 material issues based on 50 commonly used voluntary sustainability standards. Coming to an agreement which responsible production standards a blockchain-enabled CoC system would be based on as well as deciding on the types of CoC data that should be recorded on a blockchain system could be a major barrier. Yet, blockchains rely on it: the more data is on a blockchain, the more valuable, verifiable, and immutable the information contained therein becomes.
- **Technical challenges around data input – ‘garbage in, garbage out’:** The experience from other technology-based traceability solutions show that implementation can be hampered by a lack of

⁷ “IBM wants to use the technology that underlies bitcoin to help prevent major foodborne outbreaks like salmonella. “BusinessInsider. August 22, 2017. <http://www.businessinsider.com/ibm-and-walmart-are-using-blockchain-in-the-food-supply-chain-2017-8>



technical capacity in the real world. If users are not trained and garbage (poor quality information) goes into the system, garbage will come out – no matter how robust the IT system itself may be. The same goes for the validators of information, including responsible production claims, that are integral to a blockchain system. It is also important to note that blockchain does not provide protection against deliberately false information input and malfeasance.

- **Need for audits:** Both the consensus requirement and technical challenges cannot be solved by blockchain. There is thus a persistent need for external assurance of data and responsible production. Thus, audits would still need to take place.
- **Slow digitization of CoC systems:** Research has shown that digitization of CoC systems in mining is lacking or absent. Transforming paper-based, non-standardized CoC systems into a digital database, however, could be a lengthy undertaking. While rarely covering the full supply chain, these systems often discourage interoperability and open standards. “Typically, companies spend years putting [supply chains] in place and refining them. It is not very easy to insert [a] new technology inside established supply chain systems because the integration challenges are not to be underestimated,” William Mougayar, author of *The Business Blockchain* (2016), said in an interview in December 2016.⁸
- **Aggregation and processing challenges specific to minerals:** As mentioned before, tracing a product the characteristics of which change at several processing points and that is potentially aggregated with minerals from other sources will be a more challenging endeavour than tracing a mango, for instance, as Walmart is currently doing (See Section 9.5). While there are ways in which technology-based traceability solutions are accounting for this challenge (see Box 1), it may be more difficult to calculate material change such as weight loss due to processing for certain minerals than others. Where the supply chain does not allow for segregated processing and a mass balance approach will be required (see Annex 1), it remains to be seen whether this would fulfil downstream expectations.
- **High cost of blockchain systems:** Another obstacle to ensuring the necessary scale of blockchains is the large amount of computing power required to operate it, making the blockchain still an expensive⁹ and complicated technology to use. Implementing a blockchain system would require – depending on the costing model – transaction fees, data storage costs, and operational costs (staff, facilities, marketing and outreach, legal and accounting, etc.). Cost estimates range from USD 100 per GB¹⁰ to USD 50,000 – 100,000 per user.
- **A new, largely untested technology:** Blockchain’s application in supply chains is still in its experimental phase and has not yet been sufficiently tested. Successful pilot projects in traceability are rare (See Section 9). Early generations are inherently slow and cannot necessarily ensure fairness among members, according to experts.¹¹ Data security issues may still arise, as they have in the cryptocurrency space.

Several underlying barriers to traceability highlighted in Section 5 recur when looking at developing a blockchain system. This, again, shows that blockchain cannot solve underlying issues. However, conversations around blockchain in this context could help address some of the underlying issues as well.

⁸ “Blockchain not a panacea for supply chain traceability, transparency.” TechTarget.
<http://searchmanufacturingerp.techtarget.com/feature/Blockchain-not-a-panacea-for-supply-chain-traceability-transparency>. Accessed on December 22, 2016.

⁹ Kaminsky, I. Financial Times. As interviewed in “BBC on Bitcoin & The Blockchain” at
<https://www.youtube.com/watch?v=2ky3mDUoh74>

¹⁰ Medium Corp. Forever Isn’t Free: The Cost of Storage on a Blockchain Database. July 19, 2017.

<https://medium.com/ipdb-blog/forever-isnt-free-the-cost-of-storage-on-a-blockchain-database-59003f63e01>

¹¹ “Blockchain not a panacea for supply chain traceability, transparency.” TechTarget.
<http://searchmanufacturingerp.techtarget.com/feature/Blockchain-not-a-panacea-for-supply-chain-traceability-transparency>. Accessed on December 22, 2016.

11. Open questions: Blockchain as a means, not an end

11.1 What is the objective?

An important lesson learnt from applying a technology-based traceability solution in the 3TG sector in the Great Lakes region is that traceability must not become the end, but should always only be the means. Companies exploring the use of blockchain for CoC systems in the minerals and metals supply chains must first be very clear what their ultimate objective is in doing so – a notion that was echoed several times during the ICMM MSRT 2017. Will it be a marketing tool to differentiate responsible producers from other producers? Would it create market distortion? Is the ultimate objective to integrate all actors – including artisanal and small-scale mining (ASM) – in a specific commodity supply chain? Is it to improve supply chain efficiency? Why is the technology needed in the end?

11.2 Implementation

Further questions raised pertaining to the implementation of such a system include: What level of sophistication is needed? To what level should material be traced (to the smelter only or beyond)? Are there existing blockchain platforms that a system could be built on? What data should be recorded? Is there a risk that demand for data will increase once downstream companies have access to it (the more detail you provide, the more will be demanded)?

12. Conclusion: Not a magic panacea, but potentially a powerful benefit for responsible production

In conclusion, blockchain is not a magic panacea that can solve all barriers to traceability in the minerals and metals supply chain. Blockchain is currently experiencing a ‘hype cycle’ and has become a buzzword without sufficient feasibility research being conducted. Expecting blockchain to patch or fix a flawed supply chain management process might put the wrong expectations on the technology seeing as though end-to-end processes are always multifaceted, and pose challenges beyond technology. Putting the technology into practice in this field could prove to be much more complicated than in the cryptocurrency space.

However, the potential benefits that blockchain presents for the transparency and traceability along supply chains are immense. It could help reward / incentivize responsible production, build trust between upstream and downstream partners, and reduce transaction time and costs. Most importantly, blockchain could facilitate a collaborative effort for the industry to increase transparency around minerals and metals sourcing in the face of growing public awareness and expectations. This collaboration has the potential to transform certain parts of the mineral supply chain, including the development of transparent markets on the blockchain to facilitate the sale of responsibly produced material and drive demand.

13. Recommendations

RCS Global recommends the **establishment of a working group** that includes upstream producers, downstream buyers, traders, commodity industry associations, ethical investors, and minerals and metals exchanges, to explore the concept of a blockchain-based CoC system and potential other uses of the technology. Other uses may include a digital trading platform on which downstream companies can directly purchase provenance-enabled and responsibly produced mined and unmined minerals. The ICMM would be a strong partner in facilitating the establishment of such a working group. Throughout the research conducted for this report, specific interest on behalf of the afore-mentioned potential partners was registered.

Also, RCS Global, based on comments made at the ICMM MSRT, recommends that any pilot project focus on a **small consortium of companies** rather than an industry-wide application.

Annex: Chain of Custody system options

Different types of CoC systems exist that allow for different claims, including a closed pipe supply chain, segregation, mass balance, and book and claim:

- **Closed pipe supply chain** – *Claim: full provenance integrity from one source to product.*
- **Segregation** – between responsibly sourced material and not: Downstream customers request smelters and downstream processors to segregate the responsible minerals from other material and only produce products based on responsible minerals. *Claim: All products can be traced to responsibly sourced material (from various sources but which are all responsible)*
- **Mass balance** – of responsibly sourced % against total volume: A mixing of responsible and non-responsible material occurs, but the volume of the material is carefully measured. *Claim: A % of material in the product is responsibly sourced. (This is the claim made by Fairtrade).*
- **Book and claim:** Buyers buy a ‘credit’ of responsibly sourced material and claim responsible sourcing on this basis. However, the actual physical material is mixed up with all other material in the market. *Claim: A % of purchased material is responsibly sourced.*

The decision on which type of CoC system should predominantly rely upon the organization and structure of the supply chain (e.g. do smelter facilities allow for segregation?) and the ability to establish CoC beyond a few actors as well as participation by other actors and cost and ease of implementation.



RCS GLOBAL
Making Sure.

RCS GLOBAL CHINA

Finny Tang

Finny@rcsglobal.com

RCS GLOBAL EUROPE

Harrison Mitchell

Harrison@rcsglobal.com

RCS GLOBAL AFRICA

Ferdinand Maubrey

Ferdinand@rcsglobal.com

RCS GLOBAL US

Dr. Nicholas Garrett

Nicholas@rcsglobal.com

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