State of the art

Traceability – For sustainable metals and minerals

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Introduction

We have studied and summarized concepts and realities regarding traceability. The area studied is the trade of copper with focus on how certification and blockchain may create a common basis of understanding and trust. We have collected and summarised the current state of the art based on research and with an industrial perspective to identify possible synergies and thus, how to improve resource efficiency.

Chapter one - Key concepts

Explains and defines key concepts and terms.

Chapter two - Mining market aspects

Focus on markets acceptance, both the business logic of pricing metals and an overview of the copper value chain in Sweden.

Chapter three - Sustainability certification schemes, standards and initiatives

Presentation of the present sustainability certification schemes, standards and initiatives in the mining industry including an overview of a generic certification system. Relevant academic research concerning traceability in the metal and mineral industry are summarised. It also includes a benchmarking analysis regarding the present certification schemes in the forestry industry.

Chapter four – Blockchain Technology

Presentation and overview of blockchains and their benefits and challenges.

Chapter five – Academic view of Blockchain Technology

Research projects relevant for the present project.

Chapter six – Current use of blockchains for traceability and sustainability

Description of similar projects where the blockchain technology is used for traceability and sustainability.

Chapter One - Key Concepts

Definitions

Chain of custody: 'The custodial sequence that occurs as ownership or control of the material supply is transferred from one custodian to another in the supply chain'. Documenting chain of custody describes the list of all organisations (supply chain) that take ownership or control of a product during production, processing, shipping and retail (physically and/or administratively).[1]

Chain of custody models: The general term to describe the approach taken to demonstrate the link (physical or administrative) between the verified unit of production and the claim about the final product.[2]

Traceability: The ability to verify the history, location, or application of an item by means of documented recorded identification.[3]

Traceability system: The system that records and follows the trail as products, parts, and materials come from suppliers and are processed and ultimately distributed as end products. Often when someone says 'traceability system' they mean an online traceability/tracking system, but this does not have to be the case. Systems used to ensure traceability vary widely and are designed to be fit for purpose (e.g. could be paper based or only go to a limited level of detail).[4]

Transparency: Open, comprehensive and understandable presentation of information.[5]

Standard: Standards are jointly agreed solutions to recurrent problems. They are found in every area: from the simplest nail and screw to data communications, healthcare and the environment.[6]

Initiatives: A new plan or process to achieve something or solve a problem.[7]

Declaration: First-party attestation.[8]

Certification: Third-party attestation related to products, processes, systems or persons.[9]

Certification schemes: Certification system related to specified products, to which the same specified requirements, specific rules and procedures apply. [10]

[1] https://www.sustainabilityxchange.info/filesagri/ISEAL%20Glossary%20of%20Terms%20v1%20-%2016%20Jan%202015.pdf
[2] Ibid
[3] Ibid
[4] Ibid
[5] EN ISO 14044:2006, ISO 21930:2007, ISO 21931-1:2010
[6] https://www.sis.se/en/standards/standards/
[7] https://dictionary.cambridge.org/dictionary/english/initiative
[8] Conformity assessment – Vocabulary and general principles (ISO/IEC 17000:2004)
[9] Ibid
[10] ISO / IEC 17065:2012

Chain of Custody, CoC

The global membership association for sustainability standards, Iseal alliance, has published a reference document about chain of custody models and their definition for sustainability standards systems where they explain[11];

"The objective of the CoC System is to validate claims made about the product, process, business or service covered by the sustainability standard. This is achieved by defining a set of requirements and measures that provide the necessary controls on the movement of material or products, and associated sustainability data, from approved or certified businesses through each stage of the supply chain. Many standard systems set a CoC standard for this purpose, in addition to their production or management standard.

The CoC System therefore forms the basis for any claims that can be made about the approved or certified product. The supporting assurance system (including auditing, oversight, reporting, claims approval, etc) is then used to verify that the actor involved has met the requirements of the CoC Standard and supporting policies. Each industry and each scheme is different and the requirements of the CoC standard and supporting system will vary between schemes, sometimes even within models of the same name."

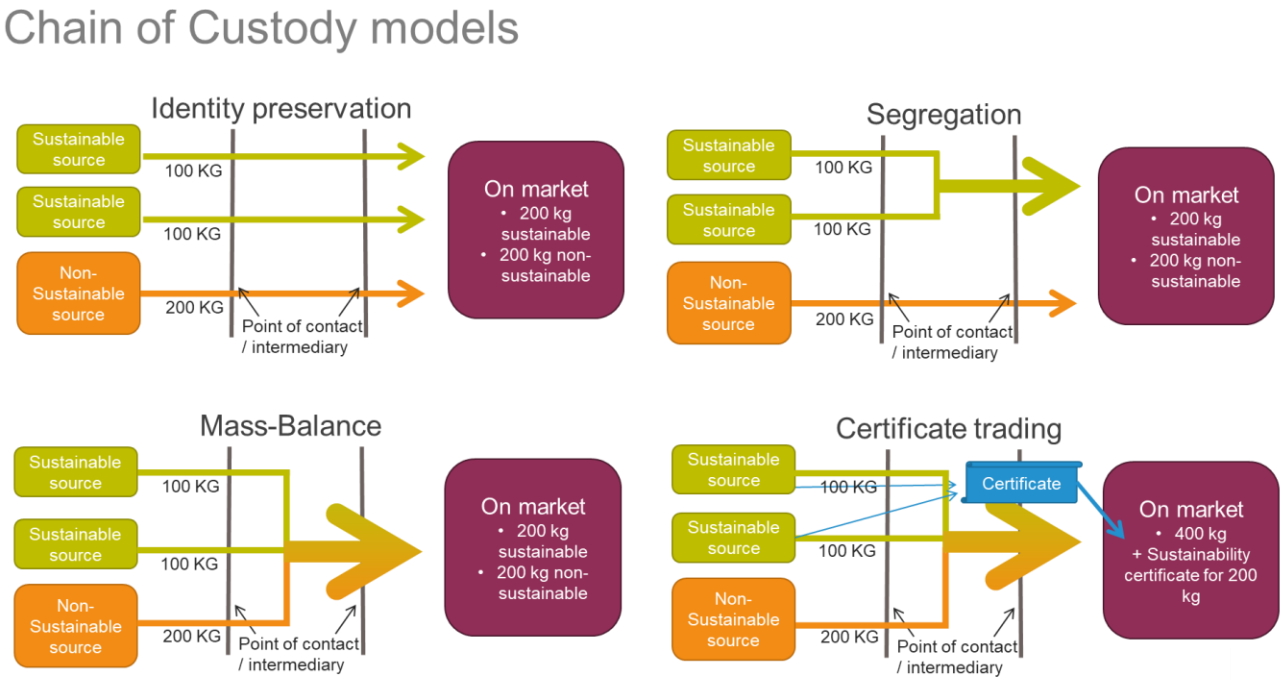


Image: Four different models for chain of custody systems

[11] https://www.isealalliance.org/get-involved/resources/iseal-guidance-chain-custody-models-and-definitions

Iseal alliance explanation of different CoC models are briefly described below, however, it is our recommendation to read the reference document. Please, follow the link in the footnote to access the Iseal guidance document.

1. Identity preservation

Simply explained, the product can be traced back to the original source.

Example: Meat that is labeled with information regarding origin (farm).

2. Segregation

In this model, only products or materials from equivalent sources will be mixed in the production. What equivalent sources are must be stated. It could be, for example, that the different sources have the same certification, are from the same region, or are only from secondary material.

Example: Organic orange juice, where organic oranges will be mixed from different organic farms, but not from non-organic farms.

3. Mass balance

The mass balance model is used when the identity preservation and segregation are lost or when physical mixing of sustainable claimed material is mixed with non-sustainable material. The fundamental of the mass balance principle is that the volume of sustainable claimed material that enters the process is equivalent to the volume of claimed material leaving (the process). Depending on the conditions and the ambition, mass balance can be conducted in three levels; i) batch, ii) site, or iii) group level.

Example: The Forest Stewardship Council, FSC, Mix label is one out of three options of FSC labels[12].

Image: https://us.fsc.org/preview.fsc-chain-of-custody-101.a-447.pdf

4. Certificate trading

Certificate trading, also referred as “book and claim” or “credit trading”, is an approach to reward responsible production when it is difficult or impossible to trace products or material in the supply chain. The sustainability claims are completely decoupled from the material. Instead, the sustainability claims are traded as certificates or credits.

This model could be an effective way for responsible producers to get a financial value as well as for manufactures to achieve their sustainable sourcing targets. However, since there is no physical traceability throughout the supply chain, and the source of material is unknown, it can be argued that certificate trading is not a genuine CoC system.

Example: By ticking a box, the end-user can choose to pay extra for renewable electricty. The energy company then commits to buy equivalent amount of renewable energy certificates. However, the

[12] https://ic.fsc.org/en/choosing-fsc/fsc-labels

energy that is transferred over to the end-user is not necessarily of sustainable origin. Follow the footnote below to read more about the Swedish energy certificate system (in Swedish)[13].

Another example is RSPO, Roundtable on Sustainable Palm Oil[14], where responsibly produced palm oil certificates are sold on a separate market.

Fungibility

Definition from Wikipedia; *Fungibility is the property of a good or a commodity whose individual units are essentially interchangeable. For example, since one kilogram of pure gold is equivalent to any other kilogram of pure gold, whether in the form of coins, ingots, or in other states, gold is fungible. Other fungible commodities include sweet crude oil, company shares, bonds, other precious metals, and currencies. Fungibility refers only to the equivalence of each unit of a commodity with other units of the same commodity and not to the exchange of one commodity for another, which is barter*.[15]

The fungibility of copper is important to understand in the present context in how to give sustainable produced copper the added value which customers will pay for even though the fundamental characteristics of copper is more or less the same. Further, and how can this added value "follow" the raw material in the value chain as it alters physical forms.

Fungibility is crucial for the mass balance approach and enables the development of new value streams in certificate trading, as exemplified earlier by the electricity market, where the value of sustainable production is separated from the product (electricity) when delivered to the end consumer.

However, it can be argued that copper cathodes are not fully fungible since they do not contain 100% pure copper. Boliden copper cathodes meet the London Metal Exchange (LME) quality requirements for Grade A copper cathode with 99,995% Cu purity or higher[16]. Both the amount and identity of impurities in the copper cathode can be of importance in downstream production, depending on the application/product the copper will be used for.

WTP, Willingness to Pay

There are many indications that the demand for sustainably mined and produced metals is growing, for example;

""We expect that sustainability will play an increasing focus in raw materials procurement, particularly when the raw materials are aimed at products that are intended to be environmentally and socially responsible, such as electric cars," said analysts at Investec."

(Electric car push drives premium for green metals, Financial Times, 4/12-17)

However, according to Tillväxtanalys, there are not many scientific studies presenting evidence for the end user´s WTP. Parallel to this project, Tillväxtanalys will investigate the end users actual WTP.

[13] http://www.energimyndigheten.se/globalassets/fornybart/elcertifikat/om/sa-har-fungerar-den-svensk-norska-elcertifikatsmarknaden-illustration.pdf
[14] https://rspo.org/
[15] https://en.wikipedia.org/wiki/Fungibility
[16] https://www.boliden.com/globalassets/operations/products/copper/copper-product-sheet-2018.pdf

Bolidens perception today is that there are many stakeholders requesting disclosure of sustainability performance for Copper and that the metal in general can contribute positively to society's general sustainability agenda, in particular in the energy efficiency space. Boliden is positive to the development of sustainability performance declarations[17].

WTP will be further analysed in WP 3, Stakeholder and market analysis.

[17] Sven Hjelmstedt, Boliden (2018.12.07)

Chapter Two - Mining Market Aspects

Metal Markets and Pricing

Copper producers can choose to sell copper cathodes to traders or directly to a manufacturer who process the cathodes into semi-products. However, the price is always stated on the London Metal Exchange (LME). Since the copper price can vary from day to day, many stakeholders prefer to plan their deals on the LME to match the market price for semi-products.

In October 2018 LME published a draft position paper, detailing new proposed requirements for listed brands regarding the responsible sourcing of metals. The proposal aligned with the principles set out by the Organization for Economic Co-operation and Development's (OECD) "Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas". The aim of the proposed requirements is that LME listed brands, not only meet the physical requirements of shape, weight, and chemical composition, but are also compliant with industry best standards in respect of responsible sourcing.

Business Cases of Sustainable Metals

In the end of 2017, the Norwegian company Hydro launched two new products which are independently certified by DNV GL.

- Hydro 4.0; hydropower-based aluminium with a maximum content of 4.0 kg CO2 per kg aluminium, and;
- Hydro 75R; aluminium with a guaranteed post-consumer recycled content of minimum 75 percent

A key factor for Hydro in order to calculate and claim their products level of footprints and recycled content, is that Hydro have all the mining and production resources in-house. [18]

Copper in Sweden

Boliden is the only actor in the industry of copper mining and smelting in Sweden.

Boliden is a significant copper mining actor in Europe, but a small operator in the world. Most of Boliden's copper is sold directly to long time industrial customers and only partly to traders. The London Metal Exchange is always used as a reference to agree on a price[19].

Boliden Mines

In 2017 Boliden mines mined 143 ktonnes copper[20]. Boliden mines in Sweden are certified to ISO 50001, OHSAS 18001, ISO 14001 and FSC Forest Management Certificate. Boliden's mining operations in Finland, Kevitsa and Kylylahti,do not have any certificate as of yet. This is partly due to both the Finnish mines are two fairly recent additions in the Boliden mine portfolio. Kylylahti was acquired in 2014 and Kevitsa in 2016. Kevitsa is planned to be part of the Swedish mines multicertificate on ISO 50001, OHSAS 18001, ISO 14001. No certifications are planned for Kylylahti.[21]

[18] https://hydro.com/en/press-room/Archive/2017/hydro-launches-certified-low-carbon-aluminum-products/
[19] Sven Hjelmstedt, Boliden (2018.06.05)
[20] https://vp217.alertir.com/afw/files/press/boliden/201803060692-1.pdf
[21] Sara Olsson, Boliden, 2018.05.14

Boliden Smelters

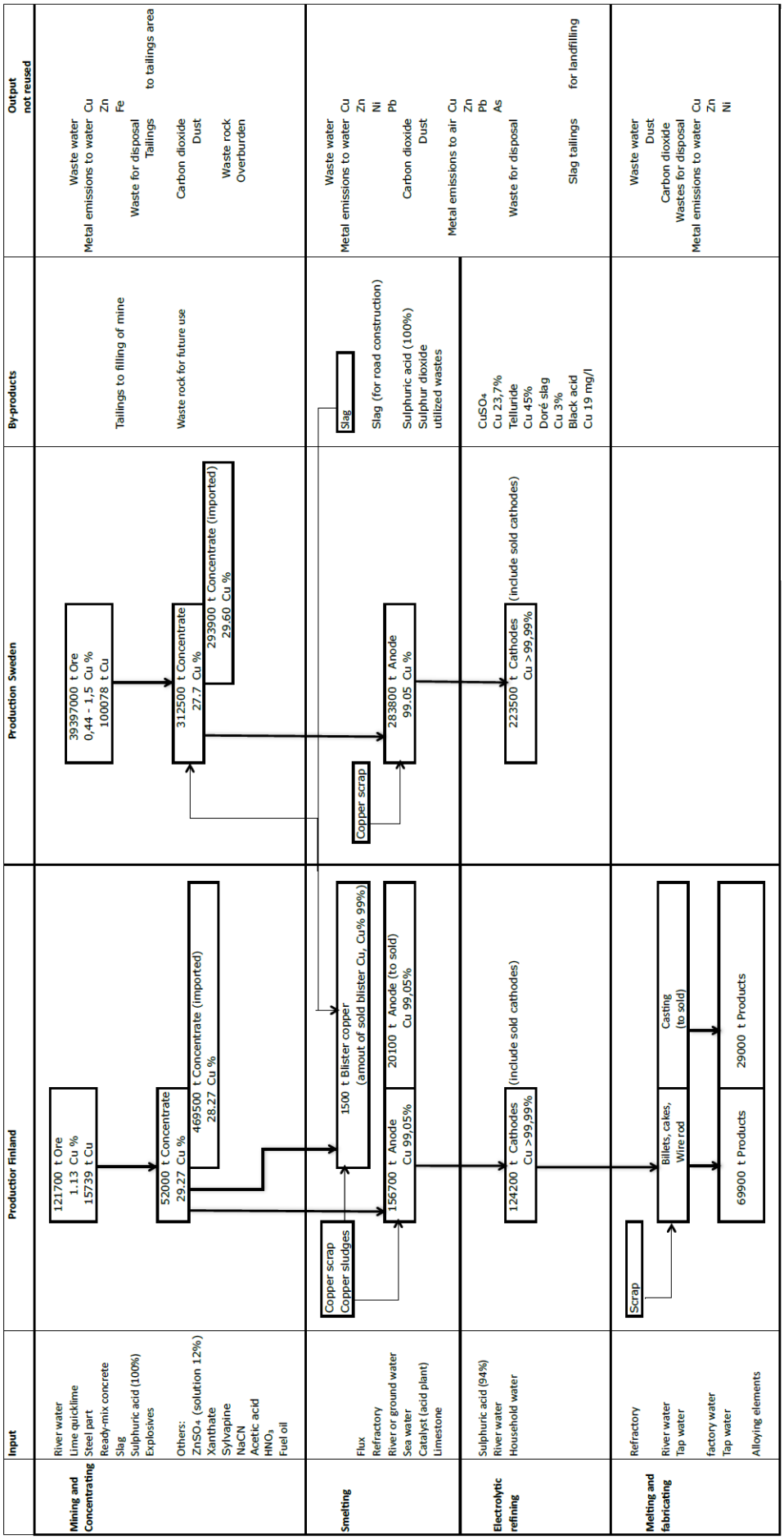
Boliden is the sixteenth largest copper smelting company in the world. Boliden smelters produced 353 ktonnes copper from 1174 ktonnes concentrate and 204 ktonnes secondary raw materials. Most of the secondary raw materials, 180 ktonnes, is smelted in Rönnskär.[22]

Rönnskär (Sweden) and Harjavalta (Finland) are certified to ISO 9001, ISO 14001, OHSAS 18001, and ISO 50001. Rönnskär is also certified to LBMA RGG (Responsible Gold Guidance). Rönnskär and Harjavalta receive about 50 % of their concentrates from Boliden's own mines in Aitik, Boliden Area, Kylylahti and Kevitsa. The rest comes from external sources.[23]

Material Flow Analysis of Copper in Scandinavia from a Life Cycle Perspective

In 2009 Leena Tuominen conducted a Master´s thesis called "Material flow analysis of copper in Scandinavia from a life cycle perspective". She used data from 2005, however, regarding copper flows, no significant changes have taken place since then[24]. The image below explains the flow, energy and transports are not included.

[22] https://vp217.alertir.com/afw/files/press/boliden/201803060692-1.pdf
[23] Sara Olsson, Boliden, 2018.05.14
[24] Pia Voutilainen, Director at Scandinavian Copper Development Association (2018-10-19)



Material flow analysis of copper, Leena Tuominen 2009

Chapter three - Sustainability certification schemes, standards and initiatives

An overview of current sustainability certification schemes, standards and initiatives is required for a State of the Art of traceability in the mining and metal industry. However, the aim of our research is not to settle criteria or define what is sustainable metals but to develop knowledge and insights about different traceability solutions.

Sustainability certification schemes, standards and initiatives in the mining industry

In this section we have gather sustainability certification schemes, standards and initiatives in the mining industry. Is it important to have in mind, that certification, standards and initiatives are different concepts with different aims (see the definitions). In addition to this list, some stakeholders have their own company-specific systems.

The sustainability certification schemes, standards and initiatives can be clustered in different ways, for example by the role of the initiator, industry, governments or NGO. Another possible grouping could be in theme criteria, for example conflict metals, Carbon footprint or human rights. A third clustering could be in approached stakeholder, if the aim is to approach B2B or consumers for example. This list cluster in themes of commodity specific, mining and metal industry specific, general and supply chain focused are used.

Commodity-specific – gold

- CFGS Conflict-Free Gold Standard
- Fairmined Standard for Gold and Associated Precious Metals
- Fairtrade Standard for Gold and Associated Precious Metals
- Better gold initiative

Commodity-specific - diamonds & Jewelry

- RJC Responsible Jewelry Council Code of Practices
- Kimberly process
- DDS Development Diamonds Standards

Commodity-specific - other

- ASI Aluminium Stewardship Initiative;
- BC Bettercoal Code
- RSS Responsible Steel Stewardship

Generic management systems and sustainability initiatives

- ISO 14001, 9001, 26000 International Standards Organization
- AA1000 Account Ability
- IFC Performance Standards
- UN Global Compact
- GRI The Global Reporting Initiative
- OECD Guidelines for Multinational Enterprises
- VP Voluntary principles
- EP Equator Principles

Sustainability management systems and initiatives in mining and metal industries

- TSM Towards Sustainable Mining
- IRMA Initiative for Responsible Mining Assurance
- ICMM SDF Sustainable Development Framework
- FTSE/JSE Responsible Investment index series
- e3Plus Environmental excellence in exploration
- ICMC International Cyanide Management Code
- EITI Extractive Industries Transparency Initiative
- RMI Responsible Minerals Initiative
- RMI The Responsible Mining Index
- UNE 22480:2008 Sustainable Mining Management System
- UNE 22470:2008 Sustainable Mining Management Indicators

Supply chain

- ICGLR Mineral Certification Scheme of the International Conference on the Great Lakes Region
- iTSCi ITRI Tin Supply Chain Initiative
- OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas

Voluntary Responsible Mining Initiatives - A review

In 2015 the World economic forum conducted a white paper based on a survey of informed stakeholders' views and experience of voluntary responsible mining initiatives. The majority of the respondents want to see better linkages between existing voluntary initiatives, not new initiatives. Transparency is identified as an important factor together with third party audit[25].

LCA - Life Cycle Assessment

In ISO 14040:2006 Environmental management — Life cycle assessment — Principles and framework, LCA Life cycle assessment is defined as; compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.

[25] World economic forum, white paper, Voluntary Responsible Mining Initiatives - A review

Life cycle is defined as; "consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal."

The LCA methodology have given birth to many different system and initiatives, for example EPD - Environmental Product Declaration. One common EPD systems is called International EPD® System, at their webpage, they explain[26];

"An Environmental Product Declaration (EPD) is a document that communicates verified, transparent and comparable information about the life-cycle environmental impact of products.

The International EPD® System is a global programme for environmental declarations based on ISO 14025 and EN 15804. Our online database currently contains more than 900 EPDs for a wide range of product categories by companies in 42 countries."

Another example of an LCA system is the PEF – Product Environmental Footprint system initiated by the European Commission. The mission of the PEF system is to create a basis for product comparison, benchmarking, harmonize green certification and EPD for products in the construction industry and develop eco-design and eco-label products. The commission had a pilot project where they wanted to create Product Environmental Footprint category rules (PEFCR) for different products, among them pipes and metal sheets. However, the pilot on pipes is on time out since the stakeholders cannot agree on common category rules[27].

The Forest Stewardship Council, FSC – A Benchmark

There are two mayor certification systems in the forest industry, the Forest Stewardship Council, FSC, and Programme for the Endorsement of Forest Certification, PEFC. In recent years, FSC has become more widely applied and has received international acceptance[28]. To better understand what we can learn from these two certification systems resulting in a global forest industry's acceptance of a certification system, Lena Jönsson, experienced auditor of both systems, has been interviewed.

A crucial factor of FSC success over PEFC is that (E)NGOs choose to support FSC. The reason behind is that PEFC did not consider the rights of indigenous people and had slightly lower demands on the industry. Another learning from FSC is how they have protected and cared for its brand. However, Jönsson believe that PEFC might grow stronger and become a stronger competitor to FSC in the future. Jönsson's personal belief is that when NGOs are responsible for certification systems, two competing system is needed in the long term, for sustainable relationships among stakeholders and a functional system.

FSC has two types of standards, one for forest management and one for chain of custody. The forest management is nationally developed, taking local conditions into consideration while the chain of custody is operating on an international level. The forest management standard declares what is sustainable forestry in different regions. The chain of custody standard declares how stakeholders in the supply chain may claim certificated raw material. End products can be labeled with three different FSC labels, all depending on how the material has been handled in the supply chain, for example if they have

[26] https://www.environdec.com/
[27] Pia Voutilainen, Director at Scandinavian Copper Development Association (2018-10-19)
[28] Lena Jönsson, RISE (2018-07-05)

been mixed or not. The FSC labels are; FSC 100%, FSC Mix and FSC Recycled. FSC 100% is using segregation as the chain of custody, while FSC Mix and FSC Recycled apply the mass balance model.[29]

Sustainability Certification Schemes in the Mining Industry – An Research Overview

Towards Sustainability in Nordic Mining - A path towards sustainability for the Nordic mining industry

Helena Ranängen, Åsa Lindman and Thomas Ejdemo conducted in 2016 an extensive study with the aim to examine the Nordic mining industry´s sustainability practices and aiming at developing guidelines for the sustainability efforts. Follow the link in the footnote to read the full study.[30]

Relevant findings for our project are that from eight identified core subjects covered in sustainability initiatives, the least mentioned is product responsibility. According to the authors, this could be because it is a "business to business" industry. The most frequently mentioned core subjects are corporate governance, labor practices and the environment (p 45).

Another relevant insight is that GRI, the Global Reporting Initiative, is mentioned in all sustainability reports studied and the ISO 14001 certification is mentioned in six out of seven (p 47).

Designing sustainability certification for greater impact- An analysis of the design characteristics of 15 sustainability certification schemes in the mining industry

Dr. Renzo Junior, Dr. Daniel Franks and Professor Saleem Ali, researchers at Centre for Social Responsibility in Mining have in this report analysed 15 sustainability certification schemes. The key finding was that although different schemes are designed for different applications, in order to succeed they must be effective, transparent and accountable to the schemes goals and aims (p 50). Follow the link in the footnote to read the full report.[31]

Other Relevant Research Projects and inquiries

Traceability and sustainability labelling for metals and minerals

The Swedish government has commissioned the authority Tillväxtanalys to review traceability and sustainability labelling for metals and minerals[32]. Since Tillväxtanalys review will be covering many of the same topics as the present this project, we will have a close co-operation. To ensure that, Tobias Person, Project Manager of Tillväxtanalys review has been appointed to the steering committee.

CERA

CERA is funded by EIT Raw Materials and is explained at the web page[33];

"CERA will be a standardized certification scheme ensuring environmental, social and economic sustainability in extraction, processing, trading and manufacturing of all mineral raw materials including

[29] https://ic.fsc.org/en/document-center/id/80
[30] https://www.ltu.se/cms_fs/1.164980!/file/Towards%20sustainabylity%20in%20Nordic%20mines.pdf
[31] https://www.csrm.uq.edu.au/publications/designing-sustainablity-certification-for-greater-impact-an-analysis-of-the-design-characteristics-of-15-sustainability-standards-in-the-mining-industry
[32] http://www.regeringen.se/pressmeddelanden/2018/03/hallbarhetsmarkta-metaller-och-mineral-underlattar-for-konsumenten/
[33] https://www.cera-standard.org/home/

fossil fuels. It guarantees traceability of certified materials by using a combination of traceability technologies including proof of origin methods throughout the entire value chain."

RISE have together with CERA submitted an application of an additional WP, work package, aiming for developing a blockchain-technology as the infrastructure to secure Chain of Custody claims made by certified companies. If accepted, the WP will start in 2019. CERA is requesting a technology that will support a traditional identity preservation chain of custody.

Smart steel

Smart steel, financed by SIP PiiA[34], aims to develop a "DNA"- solution for steel and create an infrastructure of digital twins to the physical products where more information about the product can be accessed. If this succeeds it will be possible to add many different new services to the product.

Today there is no obvious way to add a unique identification to a metal, but if feasible DNA-solutions to easily trace a metal may be developed, the prerequisites to create a traceability system for metals will change dramatically.

[34] http://sip-piia.se/om-piia/piias-uppdrag/

Chapter Four - Blockchain and Distributed Ledger Technology

Blockchain and other distributed ledger technology originates from the Bitcoin electronic currency. The traditional solution for securing an electronic currency has been in the form of trusted intermediaries such as banks, who account for which money has been spent by whom.

The originator(s) of Bitcoin wanted to create a decentralized currency, which did not have any single trusted entity. In Bitcoin this is done by collecting all payment transactions into blocks which have been validated by the participants. The blockchain forms a shared ledger where anyone can check the validity of transactions.

Once Bitcoin rose to prominence, people recognized that there are other potential applications which can benefit from a decentralized verification of transactions. There exist today many blockchain platforms which are programmable.

Blockchain deployments can be categorized as being either public or permissioned.

Public (or “non-permissioned”) blockchains are blockchains which are open for participation for anyone in the process to produce blocks, possibly on an anonymous basis. Public blockchains typically use “mining”, which is a computationally demanding process to produce the blocks. The purpose is to protect against someone trying to replace past blocks on the blockchain in order to double spend currency.

Permissioned blockchains in contrast are walled off from public access and only identified and approved parties may participate in the process to produce blocks. The participants can for instance be members of some consortium. This means that mining is not required and permissioned blockchains typically have much higher transaction capacity and require less resources to operate than public blockchains, though this is changing with the more efficient proof of stake public blockchains.

The term “smart contract” refers to the program code of the application logic which is executed on the blockchain.

The Case for Traceability Using Blockchains

The properties of being resistant to fraud and corruption and being operated on an equal peer-to-peer basis makes blockchain an interesting technology to consider in sustainability applications.

The history of data which a blockchain platform provides is useful for audit purposes and to prevent fraud. The validation of transactions also enforces rules and prevents some kinds of fraud.

Another benefit of the decentralized nature of a blockchain application is that it can be operated without any dependency on any specific party. This may be helpful in the security and trust in the system if there are concerns about trusting a central entity.

Challenges with Blockchain Technologies

Besides the benefits provided by blockchain technologies, there are also challenges in designing, deploying and using blockchain based applications.

Privacy and Confidentiality

Privacy and confidentiality of information is one concern. Most blockchains will distribute all transaction data to all nodes because the nodes participate in the validation of the transactions. The data is also stored permanently on the blockchain, which may be a violation of privacy law.

There is a separate section on privacy and confidentiality with more details in the solution concept document.

Node Operators

A blockchain network consists of several nodes which store and process the blockchain data. Any blockchain application deployment needs to provide an answer to whom will operate the nodes.

In case of public blockchains, the nodes are operated by so called “miners” who are incentivized to do so by transaction fees and crypto currency rewards. In case of permissioned blockchains the operators need to be identified, and there must be incentives for those to participate. In cases such as sustainability traceability, the node operators might be major companies, certification bodies or trade organizations in the supply chain and their motivation to operate the nodes could be the benefits they get to their business from the application or service fees.

Governance

A blockchain network is decentralized and not controlled by any individual entity. However, there is also a need for governance of the system. The system needs to be maintained, meaning that new versions of the software are developed and deployed. It may also be necessary to make corrections to the data on the blockchain, for instance in case of illegal activities.

Because of all these needs for coordination among the decentralized operators, there needs to be a governance process of the deployment.

Information Correctness

The information which is put on the blockchain must be correct for it to be useful. Any traceability solution, whether it be based on blockchain or not, must address this question. The transaction validation logic on the blockchain needs to contain rules about how data may enter the system, so that the validity of the data is tied to understood processes in the physical world. Certification, inspections, data sensors and other means of data assurance must be considered.

Energy Consumption

Bitcoin and many other public blockchains require much energy to operate. The purpose of this is to create a cost to protect the blockchain against attacks where someone tries to replace existing blocks to double spend currency.

There are alternatives to mining. For public blockchains there are now alternatives in the form of “proof of stake”, where there is instead a cost in the form of a large amount of capital which has to be bound, or “staked”, in the system for participation in the block generation process.

In a permissioned blockchain an alternative is to identify all participants and control access to participation. By monitoring the behavior of every participants, those who attempt to break the rules can be removed from the system.

Chapter Five – Research Studies about Blockchains and Traceability

There has been some research performed work in the academic community about using blockchain technologies for traceability and sustainability applications. Jay Jay Billings[35] describes how the information sharing and transaction validation properties of distributed ledgers make them applicable for storing and validating provenance data from workflows. This paper is written in generic terms and does not focus on any specific application area or industry.

Abeyratne and Monfared[36] propose an application of blockchains for tracking a supply chain. The authors propose that information of the products is recorded on a blockchain as the products move through the actors of a supply chain. The information they propose to store includes descriptions of the items, their locations and certifications of them. Each product is identified using a digital identifier. A smart contract is used to track the state of the item. The application logic in the smart contract is used to control how the ownership and other information of the item may change as the item moves through the supply chain. They illustrate their proposal with a hypothetical application for tracking the production of cardboard boxes, from wood, through paper, box production and finally to recycling.

Eljazzar et.al.[37] also propose using a blockchain for information sharing across a supply chain. In their case, they emphasize supply chain management issues such as information sharing for process optimization or demand forecasting.

Düdder and Ross[38] argue that blockchain is a technology suitable for a chain of custody system for timber. Illegal logging and trade in timber is a large problem globally and the authors argue that previous efforts to address the problem have failed because paper-based chain of custody systems are expensive, inefficient and easy to commit fraud in. They argue that if the chain of custody information is put on a blockchain, then the information is more secure and available in an efficient manner.

A Master's thesis by El Maouchi[39] proposes a traceability system on a blockchain which preserves the privacy of the actors through cryptographic protocols.

[35] Jay Jay Billings, "Applying Distributed Ledgers to Manage Workflow Provenance", retrieved from https://arxiv.org/abs/1804.05395

[36] Abeyratne, S.A. and Monfared, R.P, "Blockchain ready manufacturing supply chain using distributed ledger", retrieved from https://dspace.lboro.ac.uk/dspace-jspui/handle/2134/22625

[37] M. M. Eljazzar, M. A. Amr, S. S. Kassem, M. Ezzat, " Merging supply chain and blockchain technologies", retrieved from https://arxiv.org/abs/1804.04149

[38] Boris Düdder and Omry Ross, "Timber tracking: reducing complexity of due diligence by using blockchain technology ", retrieved from http://forskning.ku.dk/find-en-forsker/?pure=en/publications/id(6b471675-98c6-433e-ad78-30d99fb2184c).html

[39] Mourad El Maouchi, "DECOUPLES: A Privacy-Preserving Solution for Traceability in Supply Chains", retrieved from https://repository.tudelft.nl/islandora/object/uuid:f5be8c53-4251-4c6a-922d-d67b125fcd75

Chapter Six – Current use of Blockchains for Traceability and Sustainability

Use of blockchain technology for traceability is still in an early stage. There is much interest and many pilots and proof of concepts have been publicized. Some of the pilots have been successful and are in the process of being scaled up, but we have not found any examples of large-scale production deployments yet.

In this section we will give examples of uses of blockchain for traceability for other purposes than sustainability. Such examples are relevant since they provide examples of how to integrate blockchains with real world products and processes. We present examples of using blockchains for sustainability purposes in the next section.

The information in this chapter has been gathered mainly from public information provided by the projects themselves. We have not been able to do detailed technical analysis of the projects. One should be aware of that there is currently much hype about blockchains so there may be a commercial interest by some actors to promote their technology and services.

It should also be noted that there is currently a tendency when using blockchains for commercial projects to let the blockchain network be operated by a commercial cloud provider with only a small number of nodes, possibly managed by the single cloud service provider. In this case it can be debated what value blockchain technologies provide since the unique point about blockchains is their decentralized nature. In these cases, it might be simpler to just use a traditional database architecture. We have not been able to analyze these cases in detail, so the reader should be appropriately skeptical when reading about these examples.

Food supply chain traceability examples

There are several pilot projects around the world for using blockchain for tracking food in super market supply chains to the consumer. The motivations for these initiatives are to provide transparency about food sourcing to consumers and for more efficient product tracking and recall in case of food safety issues. The latter is a problem today because if there is an issue, then it is currently very labor intensive to trace the source of the problem, leading to a slow response and much product waste as a precaution. A recent example[40] of where it has been suggested a blockchain solution might have helped is an outbreak of E. coli in romaine lettuce in the US.

We have listed some examples of pilot projects in the food supply chain and provide links to press releases. We have not studied these projects in technical details.

Food sourcing or safety tracking requires an identity preservation chain of custody model. Cargill Turkey in the USA has implemented a pilot project for tracking turkey in the supermarket supply chain.[41] They use a blockchain to record turkeys and consumers can use an id code on the turkey to see from which farm the turkey was sourced.

[40] https://www.wired.com/story/the-fix-for-e-coli-outbreaks-could-be-the-blockchain/
[41] https://www.cargill.com/2017/honeysuckle-white-brand-leads-the-way-in-food-transparency

Walmart, IBM and multiple food suppliers across the world have been working jointly in several projects to use blockchain based solutions for food safety. For instance, they have successfully tracked mangoes.[42][43]

Carrefour has performed a pilot project for tracking chicken using blockchain technology and is in the process of expanding the system for other food products.[44]

UCOT has announced that they are working on a prototype for using blockchain for tracking milk formula products.[45]

Bureau Veritas have announced a blockchain solution for food traceability. Each product is marked with a QR code which allows consumers to see the full history of the product in the supply chain.[46]

Arc-net[47] is a startup company offering products and services for tracking food in the supply chain. There is little information available about their technology.

Eachmile[48] is a company with products for tracking food, such as fish and agricultural products, in the supply chain. The company is in the preparation phase for an initial coin offering for a utility token called Fishcoin.[49] The token is intended to be used to incentivize actors in the supply chain to capture data about fish in the supply chain. The idea is that the recipient of goods pays for chain of custody data with these tokens, thus incentivizing the collection of the data which is needed to track the fish. As this report is written, there is a craze in initial coin offerings and it remains to be seen if the utility coin concept has any sustainable bearing in the long run.

Other non-sustainability examples

Besides the great interest in the food supply chain, there are other uses of blockchain for traceability, which are not directly sustainability focused. These cases are about tracking goods for various reasons and as the food use cases, these also use an identity preservation chain of custody model.

GS1, IBM and Microsoft have announced that they are collaborating and looking to use of blockchain for supply chain tracking in conjunction with existing standards from GS1 and ISO. For instance, in the medical sector, there is an existing standard called EPCIS which provides item level tracking.

IBM and Maersk have performed a pilot project on tracking international shipping and the related documentation and are now expanding it into a commercial joint venture.[50]

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[42] https://www-03.ibm.com/press/us/en/pressrelease/53013.wss
[43] https://www-03.ibm.com/press/us/en/pressrelease/53487.wss
[44] http://www.carrefour.com/current-news/carrefour-launches-europes-first-food-blockchain-and-plans-to-extend-the-technology-to
[45] https://www.ucot.world/news/ucot-demonstrates-their-blockchain-traceability-product-to-leading-blockchain-organisation-blockchain-ventures/?lang=ko
[46] http://www.bureauveritas.com/home/news/business-news/blockchain-complete-food-traceability-solution?presentationtemplate=bv_master_v2/news_full_story_presentation_v2
[47] https://arc-net.io/
[48] https://eachmile.co/
[49] https://fishcoin.co/
[50] https://www-03.ibm.com/press/us/en/pressrelease/53602.wss

Safetraces is a company which is using a combination of blockchain and DNA bar codes for tracking bulk fertilizer. The motivation in this case is to aid in investigating illegal diversion, tax evasion, misuse, and adulteration of fertilizer.[51]

Another area where there are many ongoing initiatives, related to traceability, is trade and supply chain finance. Financing trade requires tracking of contracts, shipments and associated paperwork, which is done manually, in a costly, inefficient manner. There are many initiatives on this topic, but it is somewhat peripheral for our purposes, so in the interest of briefness, we do not explore this further.

Everledger Diamond and Jewelry Traceability

The company Everledger[52] provides a traceability application for diamonds.[53] The purpose is to track diamonds so that blood diamonds or stolen diamonds are prevented from entering the market.

Information about the service is available from news articles.[54,55]

The latest version of the service is based on the Hyperledger Fabric platform. They use an identity preservation chain of custody model. Each diamond has a physical, laser inscribed identity number on it and this number and other metadata, such as the physical characteristics of the diamond, are stored on the blockchain.

Each diamond is tracked through its value chain. To begin, the raw diamond is cut and polished. As this is done, the diamond is tracked, and each step is recorded with information about the process, such as who performed the work and pictures documenting the diamond. The Kimberley Process is scheme for certifying diamond mines and a copy of the Kimberley Process certificate is linked to the raw diamond on the blockchain. As the finished polished diamond is graded and certified for quality metrics, this information is also linked to the records.

The data is accessible through APIs, Application Programming Interface, and a Consumer User Interface. These interfaces allow traders and consumers to verify the identity and origin of diamonds. The service allows stolen diamonds to be recorded as stolen, so any attempted resale can be detected by checking the register.

Other Diamond and Jewelry Applications

Besides the offering from Everledger, there are two more recent, competing projects, not yet in production.

One is the TrustChain platform and consortium consisting of several jewelry and gold companies partnering with IBM.[56]

[51] https://www.agprofessional.com/article/blockchain-tech-applied-bulk-fertilizer-traceability
[52] https://www.everledger.io/
[53] https://diamonds.everledger.io/
[54] http://www.the-blockchain.com/2018/02/26/everledger-adds-diamond-provenance-protocol-blockchain-traceability-lineup/
[55] https://www.altoros.com/blog/a-close-look-at-everledger-how-blockchain-secures-luxury-goods/
[56] https://www.trustchainjewelry.com/

The Diamond company De Beers has also announced its intention to work for an industry wide diamond traceability system using blockchain technology.[57]

Provenance Traceability Pilots

The company Provenance[58] has built pilots for chain of custody applications, including several for sustainability tracking.

One of the pilots is a system for tracing of yellowfin and skipjack tuna from small scale fisheries in Indonesia.[59]

The system uses an identity preservation chain of custody model from the first mile. In the system, individual fishermen were certified by an NGO. When the fisherman caught a fish, the fish was registered on the blockchain using an SMS from a cellphone. As the fish is traded, the hand-overs were registered, and the fish could be traced through the supply chain so that its origin to a certified fishery could be verified. The system uses the public Ethereum blockchain platform.

Once the fish reach processing plants, they are transformed into products which can then be managed according to a mass balance chain of custody model. The project also explored marking consumer products with Near-field Communication, NFC, tags or QR codes.

Besides tracing tuna fish, Provenance have performed several other pilot studies. One pilot focused on tracing wool from shearing sheep to finished garments.[60] Other pilots focused on tracing organically produced[61] or co-op produced food[62] and providing a consumer accessible digital label which can be used to access the life journey of the food product.

Consensys Tuna Tracking Pilot

WWF in partnership with Consensys, TraSeable and Sea Quest Fiji have also done a pilot project for tracing tuna fish using blockchain.[63] The fish is tagged with a QR label and then tracked using a blockchain application.

Provenance Report on Rare Earth Elements for Tillväxtanalys

Of particular relevance to our project is a study[64] done by the company Project Provenance for Tillväxtanalys, for a Swedish government project. This study looks at blockchain and chain of custody models for sustainable sourcing of rare earth elements.

The report presents an overview of the rare earth element value chain and presents three alternative chain of custody and certification models.

[57] https://www.reuters.com/article/us-anglo-debeers-blockchain/de-beers-turns-to-blockchain-to-guarantee-diamond-purity-idUSKBN1F51HV
[58] https://www.provenance.org/
[59] https://www.provenance.org/tracking-tuna-on-the-blockchain
[60] https://www.provenance.org/case-studies/martine-jarlgaard
[61] https://www.provenance.org/case-studies/soil-association
[62] https://www.provenance.org/case-studies/co-op
[63] http://theconversation.com/how-blockchain-is-strengthening-tuna-traceability-to-combat-illegal-fishing-89965
[64] https://www.provenance.org/news/technology/transparent-global-rare-earth-element-system-using-blockchain

The first and simplest suggestion is to create financial certificates at the origin of the value chain at the mine. This presents a cost-effective solution since rare earth elements are fungible and it is costly to track them securely through the whole value chain.

A drawback of the first solution is that it can certify only practices happening at the source mine. Therefore, a second solution is to produce financial certificates at multiple points in the value chain. This has the benefit that more criteria can be certified since multiple processing stages in the value chain are covered.

The third presented option is to physically track and separate the certified materials through the value chain.

Provenance concluded in their report that physical tracking is currently not economically feasible and recommend further research in sustainability standards, certificate trading and how the state can advance the adoption of a solution.

RCS Global Report on Blockchain Traceability for Metal Supply Chains

The International Council on Mining and Metals, ICMM, have commissioned a report[65] from RCS Global.

RCS Global is an accredited audit and certification body and the report provides an overview of the use of blockchain technologies for traceability in metal supply chains. They point to the properties of blockchains, such as decentralization and immutability, and how these are beneficial for tracking minerals and metals in supply chain.

They sketch a solution where the movement of material is recorded across a supply chain and recommend the formation of a working group to form a small consortium of companies to run a pilot project.

[65] https://www.rcsglobal.com/wp-content/uploads/2018/09/ICMM-Blockchain-for-Traceability-in-Minerals-and-Metal-Supply-Chains.pdf