TraceMet Report:

Technical Development

TraceMet – Traceability for sustainable metals and minerals
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• Svemin, the industry organization for mines, mineral and metal producers in Sweden, is TraceMet's project owner and initiator.

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SWEDISH MINING INNOVATION

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TraceMet WP 3 Report

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Abstract

TraceMet WP 3 Report

This report presents the technical blockchain solution for mass balance accounting of metals and minerals in the TraceMet project. It explains the blockchain architecture and the transactions and their rules. Companies report their production and transfer of metals and minerals through an application to the blockchain. The companies also report the carbon footprint of their production and their use of recycled metals. With this information the blockchain can track the flow of the materials and its certified environmental measures across the whole value chain.

Key words: blockchain, certification, sustainability, chain of custody, raw materials

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Content

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Summary

This report describes the technical solution for a blockchain for mass balance accounting of certified metals and minerals in the TraceMet project.

A blockchain is a kind of decentralized database. In TraceMet we use it to keep accounts of how much certified materials businesses possess at their production facilities. We also record the accumulated carbon footprint of the materials and the content of recycled metals.

The mass balance accounts are maintained by having the businesses report when their production and the results of their calculations of the carbon footprint and recycled content values. As materials flow along the value chain, these movements are also reported to the blockchain as transfers of materials.

At the blockchain layer we have implemented transactions for the production and transfer reports. The transaction implementation includes validity rules and effectuation of them by modifying the mass balance accounts of the companies.

The blockchain transactions are logged in an audit log which can be viewed by auditors so the reported numbers can be audited against data at the companies to ensure the numbers reported to the blockchain are accurate.

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1 Introduction

This report describes the technical implementation of a blockchain based IT system for a mass balance-based chain of custody of certified metals and minerals. It is the result of work package 3 in the TraceMet project.

2 Blockchain Technology

Blockchain is a name for a kind of decentralized database. As a database, it stores information and can operate on that information using transactions. Figure 1 illustrates the structure of a blockchain.

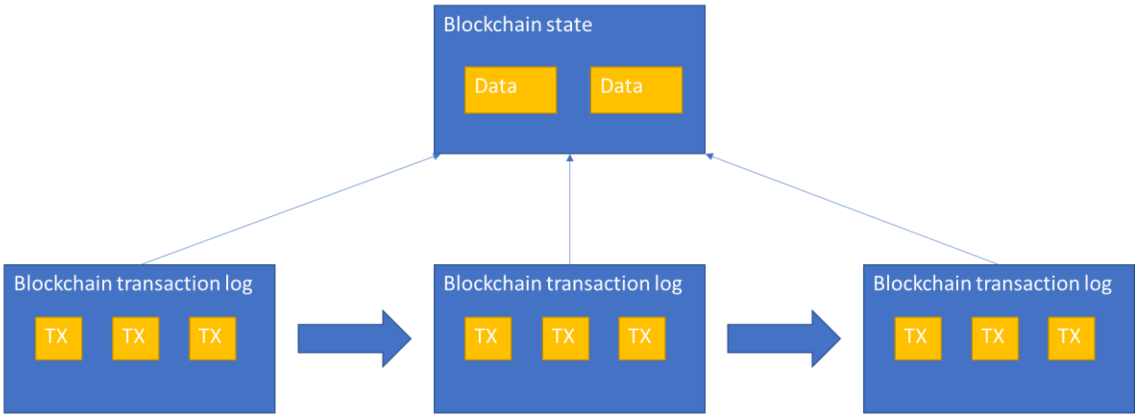

Figure 1 Blockchain structure.

The transaction log is typically organized in blocks. The transactions contained in the blocks operate on the data in the blockchain state. The transactions follow specified rules. For instance, a payment transaction might have a rule saying that the transaction is not valid if the sender of the payment does not have enough money to make the payment. The transactions also have effects. For instance, for a payment transaction the effect is that the sender's amount of money is reduced by the sent amount and the recipient's money is increased by it.

A blockchain is decentralized, meaning that there are multiple copies of the blockchain transaction log and state managed by independent operators. These copies are usually called "nodes". Each node will maintain the same state and validate the transactions in the same manner. A mechanism called "consensus" is used among the nodes to agree on the order of the transactions, their validity, and the current state.

There are many different ways to implement consensus, but basically in the end they all boil down to a majority of the nodes agreeing on the state of the blockchain. If we assume that the majority of the nodes are honest in their operation and that they validate and effectuate transactions correctly then any single node or minority group will be overruled by the honest majority if they try to cheat the system in some way.

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Usually there is some form of economic incentive built into the system which makes most nodes to prefer to be honest.

This tolerance against attempts to cheat makes a blockchain is useful when there are multiple parties that might not trust each other fully. In such a case it can be difficult to agree on a single operator of a traditional database since traditional databases can be controlled and modified by the operator. With a blockchain all parties get to validate the transactions to ensure that nobody is cheating.

Note that it is this decentralization which is the defining benefit of a blockchain. If there is already established trust into some operator of a traditional database, then it is more efficient to use a traditional database. A blockchain has much worse storage capacity and performance than a traditional database because of the large overhead the consensus mechanism causes. It is also more complicated to program, operate and control access to.

The motivation in TraceMet to use a blockchain has been that the metals and minerals industry is a global industry with many companies and countries involved, and not everyone might trust everyone else. The economic value from certification of the materials creates incentives for fraud. With a blockchain there is more transparency into the total supply of certified materials and how they have been accounted for.

3 The Pilot Architecture

Figure 2 shows the pilot system software architecture.

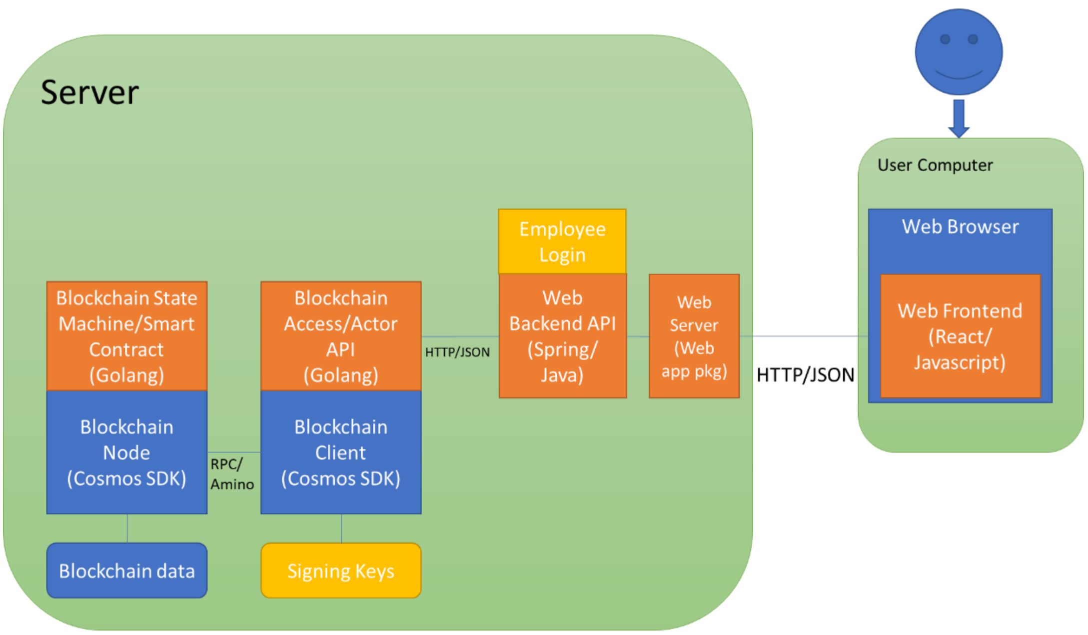

Figure 2 The pilot system software architecture.

The blockchain uses the Cosmos SDK[1] platform, which is based on the principle of building application specific blockchains, rather than a smart contract container. The

[1] https://cosmos.network/sdk

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blockchain state machine is implemented in the Go programming language. It defines the blockchain state, the transaction types and their validity and effects. The Cosmos SDK platform manages consensus over the blockchain network.

The Cosmos SDK blockchain platform is not based on so called "mining", or proof of work, which is energy intensive. Instead, it uses a voting-based consensus algorithm. Currently it is configured as a so-called proof of stake[2] consensus algorithm, which means that voting power is determined by deposits of a crypto currency. In short, the cost of electricity is replaced with a capital cost to make it difficult to gain a majority control of the system for cheating purposes. In the TraceMet pilot project this cost is purely fictional because there is value to the crypto currency which is used in the demo but could in a real deployment be a true cost of capital or represent share of ownership in the system. Alternatively, it could be changed into a proof of authority algorithm, which means that the node operators are identified, and each node gets one vote in the consensus process. In either case, there is no high electricity consumption from proof of work.

Since the chain of custody application is intended for enterprise use, it was decided that users should not have direct access to the signing keys which are used to perform transactions on the blockchain. The application uses a web wallet paradigm instead. This means that the signing keys are located at a blockchain client on the server and a web application is provided for the user. This web application can be built using standard enterprise software practices. The application controls the blockchain client and in this way the user can work with the blockchain. The backend application is written in Java using the Spring Boot[3] framework.

The user interface itself runs on the user's web browser. It is implemented in javascript using the React[4] and material-ui[5] user interface frameworks.

4 Chain of Custody

The fundamental function of the pilot software is to provide mass balance accounting on a blockchain.

Facilities represent locations of production or storage of materials. Facilities are associated with processes which may be associated with certifications which define reporting needs.

Materials are tracked in the form of lots. A material lot is described by its type and amount of material, its location, and any certified quantities of environmental measurements.

When businesses perform production, they consume materials which are transformed into production outputs. This production is reported by the businesses and the mass balance accounts on the blockchain are updated accordingly.

[2] https://blockgeeks.com/guides/proof-of-work-vs-proof-of-stake/
[3] https://spring.io/projects/spring-boot
[4] https://reactjs.org/
[5] https://material-ui.com/

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Some production might not require any input materials, such as for instance mining, which receives its inputs from nature, so the inputs cannot be accounted for on the blockchain.

When materials are transferred between locations, the transfer is reported by the businesses and the locations of the material lots are updated on the blockchain.

Finally, at the end of the raw materials value chain, manufacturing companies need to show evidence of having claimed materials from the blockchain. Claiming a material will remove it from the mass balance accounts and prevents double counting certified materials in manufacturing using certified materials.

5 Certified Quantities

The certification system is based on a mass balance chain of custody model and certifies two environmental quantities on the materials: a carbon footprint and the content of recycled metal. The blockchain application tracks these quantities along the value chain.

Material itself is tracked in lots. A lot has a type of material, the amount of material and the associated certified environmental quantities.

Reporting requirements for carbon footprint and recycled content is controlled by the certifications of the facility. In the system, there are definitions of the facilities. These definitions include the certifications of the facilities. When a facility has certifications, the system user interface will request the relevant values from the business user when a production report is provided.

5.1 Carbon Footprint

The carbon footprint is measured as kilograms of CO2 equivalents per ton of material. As the materials flow and are processed in the value chain, they accumulate carbon footprint contributions. The businesses doing the processing perform measurements and calculations to provide the contribution from their activities. These values are reported to the pilot software which stores them on the blockchain. At the end of the raw materials value chain, the system can present the accumulated contributions to the carbon footprint across the whole value chain.

The interpretation of a carbon footprint measure depends on the method of measurement, calculation and system boundaries, and it is desirable that this information is not lost. Therefore, carbon footprint measures are not simple scalar values and different measures are not added up or averaged.

The carbon footprint is a vector with three components: a numerical value, a reference to the certification standard and a reference to measurement system documentation. The table shows an example of a lot of 80 tons of copper with two measures of carbon footprint.

Material type	**Amount**	**CFP**
Cu	80 t	[1.875, “Standard A v1”, “https://..../1.pdf”]

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Material type	Amount	CFP
		[4.375, “Standard B v1”, “https://..../2.pdf”]

If a material lot is split as part of a transfer to another facility, the resulting lots all get the same carbon footprint value. For instance, if the previous lot is split into two:

Material type	Amount	CFP
Cu	30 t	[1.875, “Standard A v1”, “https://..../1.pdf”] [4.375, “Standard B v1”, “https://..../2.pdf”]
Cu	50 t	[1.875, “Standard A v1”, “https://..../1.pdf”] [4.375, “Standard B v1”, “https://..../2.pdf”]

It is not permitted to redistribute carbon footprint values between material lots, even if they follow the same standard and measurement method. This is because this would allow one to lower the footprint value of a material below its original certified value and the system cannot guarantee that the increased burden on the other lot is carried by someone else. In particular, the redistributed carbon footprint value can be destroyed from the carbon accounting entirely by selling the burdened material as non-certified, which case the accounted value is lost.

The following operations are possible on carbon footprint measures in the system.

Operation	Effect
Production process where all the input materials have certified carbon footprint values.	The aggregate values carry over to the output material lot. Any additional carbon footprint value from the production step is added also to the output lot.
Production process with any input materials with unknown carbon footprint value.	The output material lot has no certified carbon footprint value.
Split accounted material lot.	The split lots get the same carbon footprint value as the original lot which was split.

5.2 Recycled Content

A material lot may be certified with a percentage of recycled content of metal. The recycled metal content is a percentage from 0% to 100%. It is reported by the business, stored on the blockchain, and displayed to the users, but not otherwise used or modified by the blockchain.

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The recycled content measure is a vector with three components: a numerical value, a reference to the certification standard and a reference to measurement system documentation.

Note that the recycled content may have different values depending on how recycled materials are measured, for instance industrial recycling, vs consumer recycling. Thus, there may be multiple different measures of recycled content in the system and on any single material lot. These different values are calculated based on different definitions by the business.

For a production report, the newly provided measures are assigned to the produced lot and any measures on consumed materials are simply discarded in the transaction and not carried over to the produced lots.

A transfer report does not impact the measure of recycled metals. The transferred lots simply carry the measure to with them to the new facility inventory.

The following table lists the possible operations and behavior of the recycling measurement.

Operation	**Effect**
Production report for a process with no certified recycling measures in the facility definition.	The produced materials will not have any recycling measures. Any measures in the input materials are ignored.
Production report for a process with one or more certified recycling measures in the facility definition.	The produced materials will have recycling measures as defined by the certification of the facility process, with values provided by the reporting business. Any measures in the input materials are ignored.
Recycled materials enter chain of custody system.	Typically, recycled materials (scrap) are not tracked as they enter the chain of custody system, instead recycled materials are added as part of a production process and the measure of recycled material used is reported on the produced materials. If desired, scrap/recycled material can be traced in the chain of custody system by defining a process with no inputs, similar to mining. This process represents the entry point of recycled materials to the chain of custody system and has certified recycling measures in its facility certifications definition.

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6 Blockchain Information Structure

The blockchain state consists mainly of the material lots which form the mass balance accounts.

The content of **a material lot** is:

- Material type id
- Amount
- Certified carbon footprint values
- Certified recycled content values

The material lots are associated with the facilities to form inventories.

There are two main transaction types: a production report and a transfer report.

A **production report** consists of:

- Issuer
- Facility id
- Production process id
- Consumed material types and amounts (if any)
- Produced material types and amounts (if any)

The material descriptions include their certified environmental measures.

A production report is valid if it is issued by the owner of the facility, the facility has been certified for the reported process and the inventory of the facility contains enough materials to cover the reported consumption in the production report. When consuming materials from the inventory like this, the certified environmental measures are taken into account, so for the report to be valid, there must be enough materials in the inventory with the exact environmental measures, as specified in the production report.

The effect of a production report transaction is that the consumed materials (if any) are removed from the inventory of the facility and the produced materials are added. Carbon footprint measures are scaled and carried over from the consumed materials so that the total amount of carbon footprint is maintained. The carbon footprint measures provided in the production report are added to the produced material lot in the inventory.

Note that the claim operation in the user interface becomes a production report at the blockchain layer. A claim is in the technical sense simply a special case of a production process which has inputs but no outputs, thus causing the destruction of the reported input materials in the mass balance accounts.

A **transfer report** consists of:

- Issuer
- Origin facility id
- Destination facility id
- Material types and amounts

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A transfer report is valid if it is issued by the owner of origin facility and the facility inventory contains enough materials to cover the transferred material amounts.

The effect of a transfer report is that the transferred materials are removed from the inventory of the origin facility and added to the destination facility.

The transfer and production reports are also saved into an **audit log**. This audit log can be downloaded from the user interface and can be used by auditors to check that the numbers which are reported to the blockchain are plausibly correct with regard to physical production and transfers.

When doing a production report, it is possible to delay reporting of the environmental measure values. This will create a **pending report** on the blockchain. The pending report will be linked to the produced material lots and is tracked across the value chain. Later when the values are provided to the pending report, the blockchain will substitute the value to any material lot which references it.

7 Audit Logging

The audit logs contain a history of the transactions (production and transfer reports). They can be downloaded in two formats from the user interface, as JSON or CSV.

JSON stands for javascript object notation. It is a text-based data encoding format based on a key/value structure. Values can contain nested structures of keys/values, so data can be structured as trees. The JSON format contains all the details of the transactions.

JSON files can be read by people in any text editor or could be consumed by business intelligence tools or custom programs for search and analysis.

CSV stands for comma separated values. In this form data is encoded into a table consisting of rows of data separated by commas into columns. Since the CSV format is restricted to a table, the transaction details are separated into several files with different tables for different parts of the transactions.

CSV files can be viewed as text, or preferably imported into a program like Excel, which provides a nicer formatting of the tabular data.

The purpose of the audit logs is to provide a history of the reported materials and environmental values so auditors can compare these records with physical production and logistic records, to ensure that businesses report correct numbers to the blockchain.

8 User Interface

The focus in the project has been to validate the basic functionality of the mass balance chain of custody model. There is a simple user interface for this purpose. No integration with any industrial or logistical systems have been done yet.

Figure 3 shows the production report dialog. The user provides the facility and process of the production and the produced materials. I this example there are no consumed

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materials since the mined material comes from nature and is not accounted for on the blockchain previously. Figure 4 shows a production report for steel production, in which case there is a consumption of ore.

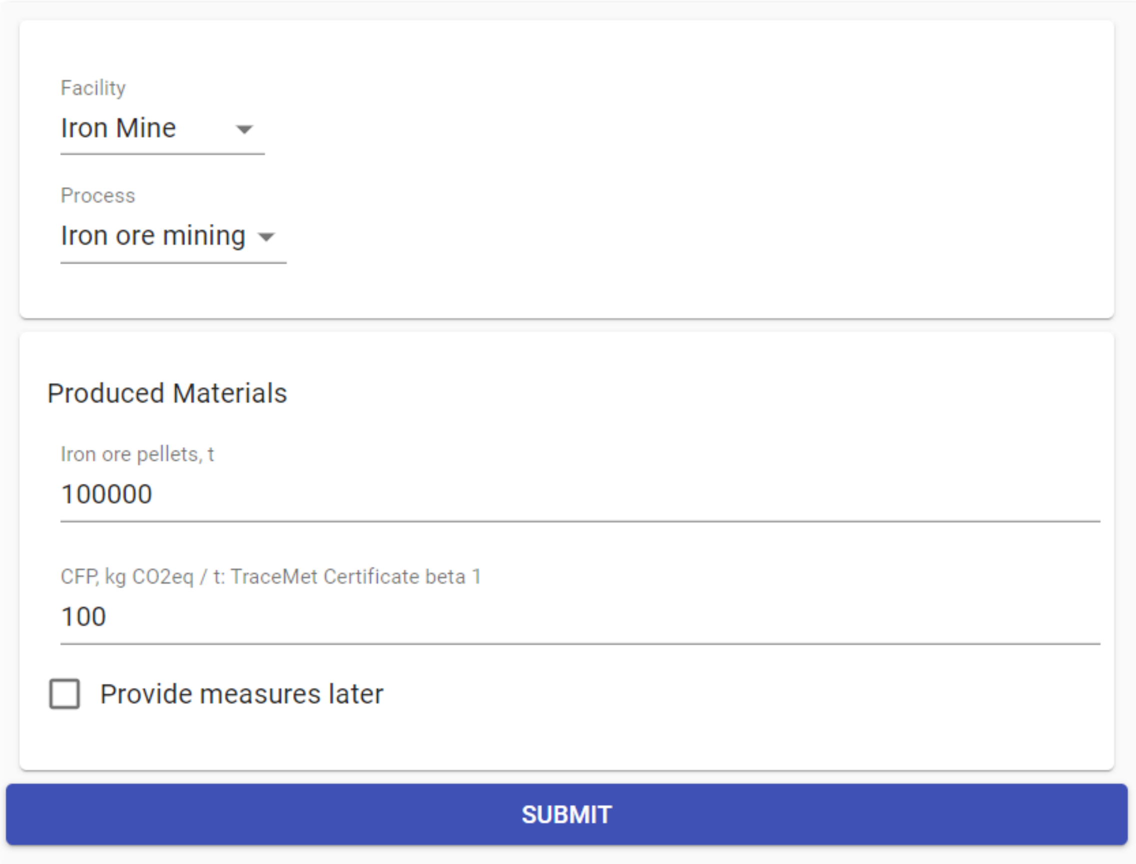

Figure 3 Production report dialog.

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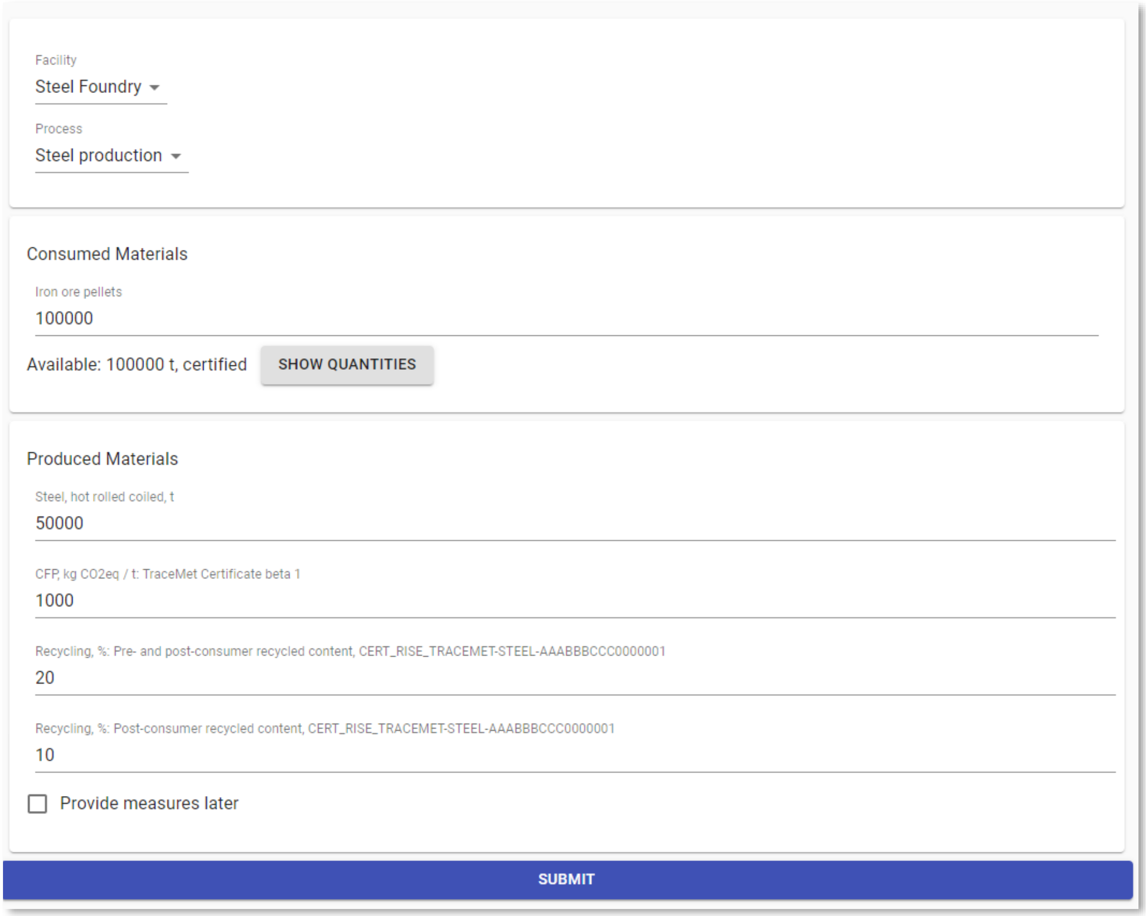

Figure 4 Production report with consumed materials.

Besides the amount of produced output, the production report will require the user to enter the values for the environmental measures for which the facility and process has been certified.

Figure 5 shows the dialog for making a transfer report. The user provides the origin and destination facilities and the amount of materials to transfer of each kind of material of the inventory of the origin facility.

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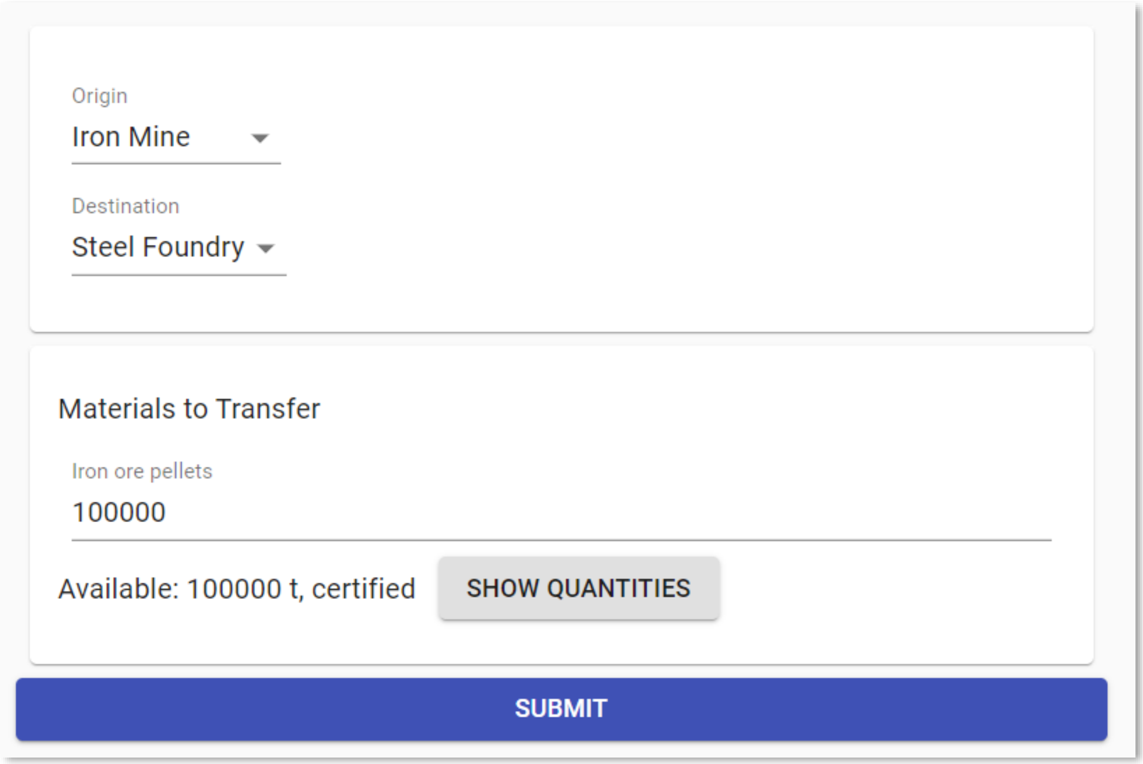

Figure 5 Transfer report.

Figure 6 shows the inventory of a business. By clicking on the “view” button in the Measures column, the certified environmental measures of the material will be shown, as is illustrated in Figure 7

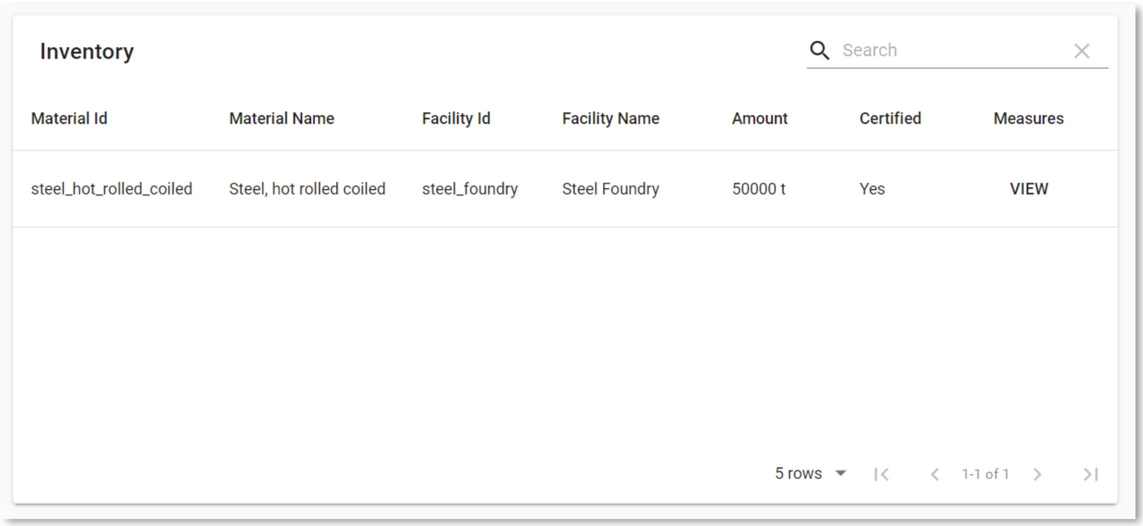

Figure 6 Display of inventory.

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Certified Quantities

Quantity	Value	Unit	Standard	Documentation
Carbon footprint	200	kg CO2eq / t	TraceMet Certificate beta 1	https://web.siteaddr.ess/specific_public_version_of_certified_document_unique_ID
Carbon footprint	1000	kg CO2eq / t	TraceMet Certificate beta 1	https://web.siteaddr.ess/specific_public_version_of_certified_document_unique_ID
Recycled content	10	%	Post-consumer recycled content, CERT_RISE_TRACEMET-STEEL-AAABBBCCC0000001	DOC_STEELCO_TRACEMET-STEEL-AAABBBCCC0000001
Recycled content	20	%	Pre- and post-consumer recycled content, CERT_RISE_TRACEMET-STEEL-AAABBBCCC0000001	DOC_STEELCO_TRACEMET-STEEL-AAABBBCCC0000001

Figure 7 Certified environmental measures of a material.

9 Scalability and Future Development

The implementation has been done with software quality in mind, so that the pilot system can be developed into a production system if desired. However, the focus in the project has been the certification system and how the blockchain shall treat the certified measures for carbon footprint and recycled content. To keep development costs down, many practically important aspects have been deferred for later implementation.

The system is configurable so additional materials and processing steps can be added, but this is for now done by text configuration and there is no user interface in the software for this. Besides the user interface, it would be necessary to define who may perform this configuration in which manner since a blockchain is a decentralized system. Likewise, there is no management of organizations and user accounts in the current version.

If additional types of environmental measures are desired, then it is necessary to define the rules of behaviour in a mass balance certification scheme for them. If the behaviour is similar to the carbon footprint or recycled content measures already implemented, then the code for these may be re-used for easy implementation of the new measures. However, if their behaviour is different, then the required transaction validation and effectuation code must be implemented on the blockchain.

Within the TraceMet project the focus has been the happy paths in the user stories. This works for a pilot or a small-scale deployment but for scaling up it will be necessary to handle alternative flows and error conditions. Examples of this include reversing incorrect data entry or transactions and recovering from encryption key loss or compromise. Likewise procedures for data migration in software upgrades and business continuity have not been considered yet.

The Cosmos SDK blockchain state is represented as a key/value database. This means that code must be written to manage the storage and indexation of the data in the blockchain state. Some of the state is currently managed with simplistic algorithms which perform linear searches instead of using an index, but this can be fixed by updating the implementation. Optimizations in general are best done through profiling of realistic data scenarios and has been left for later, and it is expected that the system can scale to a good performance.

In a large-scale deployment with frequent data entry, it may become desirable to replace some of the manual user interfaces with integration to external systems for automation of data entry and transactions.

The user interface should be subjected to usability studies and refined based on the results and user feedback as it is deployed for real use.

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