Principles for Blockchain-Based Emissions Reporting

Brief / February 2022

Authors

Authors

Charles Cannon, Shannon Hughes, Marc Johnson, Emily Long, and Paolo Natali

Authors listed alphabetically. All authors from RMI unless otherwise noted.

Contacts

Paolo Natali, pnatali@rmi.org
Charles Cannon, ccannon@rmi.org

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Charles Cannon, Shannon Hughes, Marc Johnson, Emily Long, and Paolo Natali, *Principles for Blockchain-Based Emissions Reporting*, RMI, 2022, https://rmi.org/insight/principles-for-blockchain-based-emissions-reporting.

About RMI

RMI is an independent nonprofit founded in 1982 that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and NGOs to identify and scale energy system interventions that will cut greenhouse gas emissions at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing.

About Climate Intelligence

Climate Intelligence is the program within RMI focused on making greenhouse gas emissions more visible, transparent, and readily traceable with objective data. Our mission is to determine where the world's most carbon-intensive industries truly stand in their emissions footprint, and to provide sector-specific guidance and leading-edge technology to enable significant climate action wins in this decisive decade.

Executive Summary

To confront the challenges of climate change and a carbon-intensive economy we must address the environmental impact of the products we use daily. Achieving this requires a new approach to tracking greenhouse gas (GHG) emissions so that stakeholders will be able to make purchasing decisions based on environmental performance. This new approach should be informed by systems and processes already in place, as well as bringing in new elements to add credibility, comparability, traceability, and accountability.

Today, environmental disclosure is based on annual sustainability reports and the emerging ecolabeling of products. The information behind these disclosures is not always available, and the format of that data varies widely. In our recent brief *Improving and Simplifying Carbon Accounting*, we outline the changes needed to improve the quality of climate disclosure and recommend that disclosures be based on primary data exchanged at the product level. Existing reporting tools are static, based on PDFs and spreadsheets, and are not suitable for moving emissions information through complex supply chains. Without a high level of accuracy and traceability, climate disclosures will not be useful for a company or consumer trying to purchase low-carbon products.

The objective of this brief is to define the opportunity and propose a path forward to transform climate disclosures, by introducing a blockchain-based technical architecture that will more comprehensively track and trace emissions throughout supply chain operations. The components of this system will be based on the following principles and are explored in greater technical detail in the appendix of this brief:

1. **Name it.** Define emissions information; use content addressing for secure, easily identified data.

2. **Own it.** Set and maintain ownership; a blockchain removes the intermediaries.

3. **Record it.** Create verifiable audit trails to keep emissions data connected to products.

4. **Trade it.** Standardize units of trade to make climate-friendly products accessible.

By introducing the foundations of our technical architecture, this brief aims to provide practitioners with the information needed to build data systems that are compatible with one another and collectively capable of transforming climate-related information into climate action.

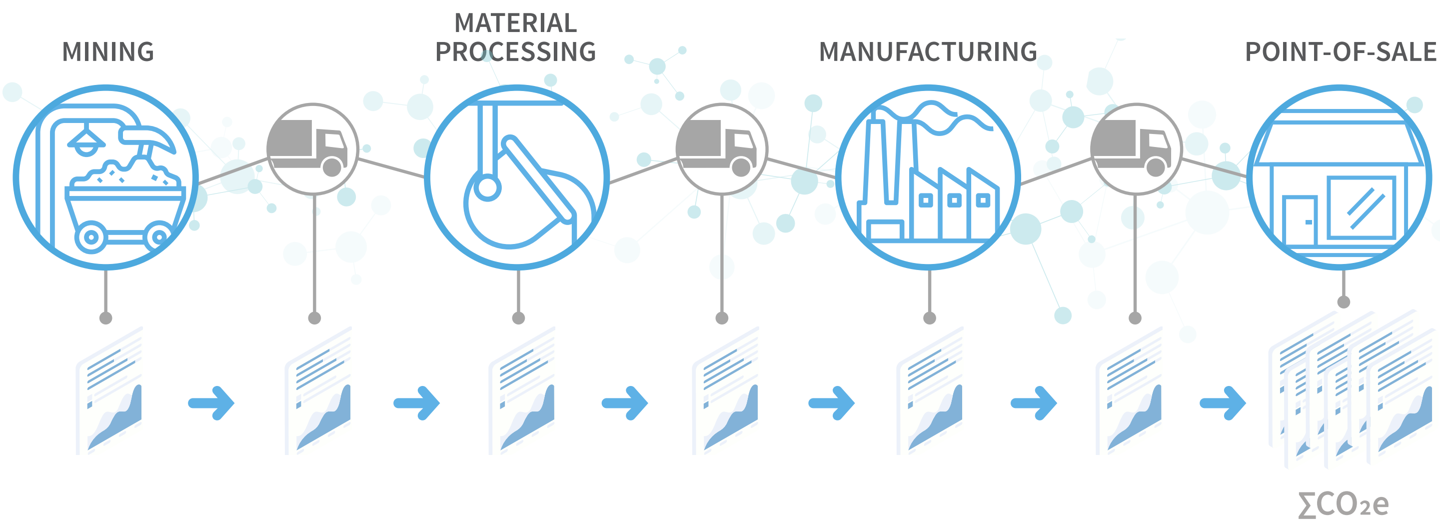
To influence supply chain decisions that will decarbonize industries, we need a way to report and track all emissions as they move from asset to product, and from company to company. This process is currently not a simple matter of summing up suppliers' and customers' direct emissions. Instead, the emissions of a particular product are the proportion of those emissions that have been emitted to produce the product that you bought ("embodied carbon") or that are a consequence of the product that you've sold ("downstream carbon"). The confusion leads to strategic action feeling challenging or impossible.

The best way past this roadblock is to track emissions as they travel at the product level, allowing more climate-friendly purchase and process decisions. Representing emissions digitally on a blockchain allows supply chain partners to make primary emissions data readily available and to share it with the next participant in the chain—making actual emissions totals accessible to multiple companies (see Exhibit 1). With these emissions totals in hand, companies will be able to make more informed procurement decisions to lower their supply chain, or Scope 3, emissions. These efforts on primary data exchange at the product level are already well under way, and it is our goal to integrate improved guidance and tools with existing solutions.

Exhibit 1

Tracking and tracing emissions across a supply chain

Representing emissions digitally on a blockchain allows supply chain partners to make primary emissions data readily available and to share it with the next participant in the chain.



Where Blockchain Meets Procurement Practice

This brief will articulate how the most efficient solution for digital tracking and exchange of emissions is **a standard, open-source, blockchain-based technical architecture** that offers ways to share a cornerstone and become more comparable. We foresee a system in which every emission has its own "digital twin" originated at the source and flowing through the supply chain attached to the commodities, and then the products, that are accountable for it. A "digital wallet" for each product will represent its emissions, and the facilities receiving intermediary products will see a trace of the product emissions flowing through—which in aggregate represent the supply chain (Scope 3) emissions associated with each entity in a supply chain. Digitizing emissions data and integrating it with existing procurement practices can serve as a cornerstone for any tracking system, exchange, or repository of information involving GHG disclosures.

Creating this system will be an iterative and collaborative process based on the principles stated in the executive summary above. RMI is creating a foundation that allows for markets and traceability solutions to be built in lockstep with the demands of technology providers and consumers.

This process gives substance to data, turning unorganized information into meaningful intelligence that drives market activation. A standardized technology infrastructure will transform a system currently being questioned for its veracity and complexity into a robust, verifiable marketplace.

The solution we have defined will require strong working relationships with industry for several reasons:

- It requires users to interact with a secure and private Web application, rather than self-calculating emissions and reporting via Excel spreadsheets and PDFs.
- It employs a blockchain-based architecture and user-centric data model, as opposed to the traditional client/server model where data becomes siloed in individual enterprise database systems.
- This system elevates transparency of data while maintaining a user's preferred level of data privacy.
- Instead of estimating figures by using generalized emissions factors, our solution rests on tracking activity-level data to calculate product-level emissions footprints.

This solution creates more easily verified reporting, allows greater transparency into industrial emissions, and limits failure potential—three characteristics that are essential for a new emissions-tracking system to function efficiently and effectively. Transforming how corporations report GHG will not be easy, as it requires a new set of processes and data interactions. It is our intention to build a team and platform that publish resources for corporations and developers alike to iterate and improve on implementation.

Why Primary Data Is So Important

Current emissions accounting methods don't provide information useful for driving procurement decisions to lower supply chain emissions. The GHG Protocol states that its Corporate Value Chain (Scope 3) Standard "is not designed to support comparisons between companies based on their scope 3 emissions."[1] The key to making comparisons viable is to have supply chain emissions based on primary data instead of averages and assumptions. Using more primary data is widely accepted as desirable. Reporting frameworks (notably the World Business Council for Sustainable Development's Pathfinder Framework) emphasize this by requiring disclosure of the amount of primary data used. To increase the amount of primary data, companies should focus on what is actionable: getting primary data from direct suppliers and providing quality data to customers. If every member of a supply chain did this, a product's carbon footprint could be based entirely on primary data, and the accuracy of corporate-level reporting would also improve.

Four Principles for Blockchain-Based Emissions Reporting

We now have the technology that allows us to accurately represent and account for emissions along complex supply chains. The foundation of this vision is the creation of an open-source, blockchain-based technical architecture that defines how a digital attribute is created, its basic format, and how it is represented in the accounts of each player along the supply chain.

This system is fully digital from the beginning, built on the best original source data available, and constantly updated and evolving to include additional primary inputs.

To increase the veracity of data inputs, documentation or validation (which exists in ISO standards or other relevant sector-specific guidance) should be linked to every associated process step that occurs along a supply chain, enabling a tracking system that collects and stores information. Third-party validation will remain a key aspect of supply chain emissions reporting, improved by automated smart contracts, built right into the blockchain.

The unit of trade for the GHG attribute of any given product is a standard amount of embodied carbon dioxide equivalent (CO_2e), so that there is a level of comparability across products. Each product will have further relevant attributes attached to it—geographic origin, share of primary data used, and other data points found on a standard bill of lading.

This approach will enable supply chain actors to verify GHG and environmental, social, and corporate governance (ESG) data, while improving transparency for consumer goods or the goals of the Paris Agreement.

This technical architecture takes shape when designed around the following principles:

1. Name it. Clearly define emissions information; use content addressing for secure, easily identified data.

Today, the standard way information is stored and accessed over the internet does not provide end-users with much visibility on how that information has changed throughout its life cycle. There are many cases in which the "state" of data and content changes, and those changes may not be noticeable to the end-user. The ability for data service providers to effortlessly change the state of information has utility in many applications, but for environmental data, we need to know exactly where, when, how, and by whom emissions are generated.

Using content addressing—a process facilitated by cryptographic hashing to identify and retrieve data—affords supply chain actors a way to continuously verify the integrity of data.

One form of content addressing that could be used in this system is a content identifier, or CID. A content identifier doesn't indicate where the content is stored, but it forms an address based on the content itself.

In this way, **CIDs function like fingerprints for data**. Supply chain actors could use such a fingerprint as a unique and succinct name to point to the emissions data or GHG attributes of a specific product, process, or activity within a supply chain. Refer to the appendix for more information on content identifiers.

2. Own it. Set and maintain ownership; a blockchain removes the intermediaries.

Securely sending information over the internet is a foundation of online commerce, logistics, trade, and other sensitive transactions. Among the primary components needed to facilitate the secure transfer of information are access control mechanisms. For blockchain-based solutions, DIDs (decentralized identifiers) and VCs (verifiable credentials) are used to ensure that only verified users have access to exchange information.

A DID is a new type of identifier that enables verifiable, decentralized digital identity. A DID refers to any subject (e.g., a person, organization, thing, data model, etc.) as determined by the controller of the DID. VCs "represent statements made by an issuer in a tamper-evident and privacy-respecting manner."[2] VCs allow for the digital watermarking of claims data through public key cryptography and other techniques to preserve privacy (explored in greater detail in the appendix). The effect of this is not only that physical credentials can safely be turned digital, but holders of such credentials can selectively disclose specific information from this credential without exposing the actual data.

The combination of CIDs for individual data points, an encrypted transport layer for communication among peers, and DIDs and VCs for authentication will enable supply chain actors and devices to confidentially transmit and exchange data with one another directly. These components enable us to transmit information in a "trustless" manner, meaning there's less need to trust independent actors because the technology itself allows you to check the validity of the information.

3. Record it. Create verifiable audit trails to keep emissions data connected to products.

There are many existing and proven solutions for developing a transaction network and event logging system when data is stored and shared with CIDs and DIDs. A benefit of using a blockchain-based transaction network is that it is not hosted on any particular server by any particular company. Changes to the state and record of data can be made transparent and readily available as a part of the network design. Blockchain is itself just a technology and does not force any design parameters. In fact, the decentralized nature of blockchain lends itself to a broader range of solutions:

- Intermediate production steps within a single corporate boundary can be more easily recorded, bringing measurement closer to the point of production.
- Data permissions can be more seamlessly shared with auditors who will need access to the primary data underneath product- or asset-level emissions claims.
- Companies can produce annual sustainability reports by aggregating tokens into a wallet that avoids double counting and facilitates more timely aggregation of data.
- A public layer of access could bolster claims in a sustainability report or contribute to nationally determined contributions as a part of the Paris Agreement.

Record keeping of environmental reporting has been an arduous and inconsistent task to date—within one company, let alone an entire sector or geographic region. A new technology is not going to be adopted overnight, and there are provisions for filling in missing data along a supply chain. That said, tokenizing emissions information does not necessitate a software subscription, and interacting with some of the solutions that are currently available is as easy as navigating to a Web page. (More open-source resources can be found in the appendix.) By using blockchain, creating a record of environmental data for a product is nearly automatic and shows how better records can accelerate low-carbon procurement.

4. Trade it. Standardize units of trade to make climate-friendly products accessible across supply chains.

For GHG attributes to be tradable, digital records of GHG emissions should be represented by a standard unit of embodied carbon. Each certificate should have a unique identifier (a CID) that forms the basis of a token (or digital twin) that will be attributed to a specific batch of product, company, and geographic boundary by existing carbon accounting standards and supplemented by sector-specific guidance (via the COMET Framework, an effort to harmonize and support existing carbon accounting methodologies across sectors using more comparable methods and primary data).

By agreeing to a common unit across different types of products, validation of GHG information will be more straightforward, and companies can assign value to CO_2 more easily. There are a number of token standards that can represent single units of GHG emissions or a larger combination of information gathered across a supply chain. Our recommendations on which specific token standards should be used to represent GHG emissions in supply chains can be found in the appendix.

The way blockchain-based platforms create these tokens (and specifically non-fungible tokens, or NFTs) is primarily through the use of smart contracts, which are computer programs intended to automatically execute, control, or document relevant events and actions according to the terms of a contract or an agreement.

The digital twin of the standardized unit of emissions will contain all relevant information that is needed for the recipient to assess the key attributes of the emissions.

Conclusion

The supply chains necessary to build a sustainable energy future are complex. When you add GHG and other climate attributes, that complexity increases. It is important to maintain the appropriate amount of complexity to drive climate action, and to communicate and exchange that information in its simplest terms.

Using blockchain for these functions brings unparalleled transparency, traceability, and tradability to supply chain operations. By acting as an orderly and secure record of the events and interactions that occur, blockchains can create a verifiable end-to-end audit trail and chain of custody among actors as supply chain operations take place.

The immutable nature of blockchains enables tracking of the entire lineage of commodities and products and their associated attributes from cradle to grave, mine to metal, or source to sale. This feature also provides producers, shippers, consumers, and regulators with the ability to share verifiable claims to improve confidence and authenticity of the commodities and products in question.

The ability to construct comprehensive audit trails, which can be monitored to ensure that processes occur as expected (or alert key stakeholders of any exceptions), can also act as the beginning of verified data collection upon which additional calculations, methodologies, and products can be built, including automated emissions reporting, proof of compliance, insurance, and verified carbon credits.

Our vision is to use blockchain technology for recording emissions transactions and interactions across supply chains. The technology is available. The will to take action is growing, and the incentive for succeeding is nothing less than our ability to continue to survive and thrive on a livable planet. As the barriers to building and adopting such a system tumble, we are forging ahead, working to provide resources for partners and practitioners near and far to advance this vision. As these open-source resources are published, reshaped, and implemented at scale, a robust market for low-carbon products will likely surface, connecting climate data to climate action at the pace needed to achieve a clean, prosperous, zero-carbon future for all.

Technical Appendix

1. Clearly define emissions information; use content addressing for secure, easily identified data.

The standard model for Web applications and services on the modern Web is that of the client/server architecture, in which many clients (remote processors) request and receive service from a centralized server. Having a single server hosting the database of usernames and passwords, and managing what levels of access individual users and computers have on a specific network, is a major advantage of client/server architecture. The benefits of this approach are further seen through the client/server architecture's ability to scale in a cost-effective and relatively secure manner.

One of the most important differences between the architecture of the centralized Web (Web 2) and that of the decentralized Web (Web 3) is the way we identify and retrieve data. URLs (uniform resource locators) are the primary addresses we give one another for data on the centralized Web. These are useful, as they make it possible for individuals to make links and connect data. However, URLs are based on the location where data is stored, not on the contents of the resources stored there. This is called location addressing, and it presents us with a plethora of problems.

Through the domain name, URLs indicate which authority we should go to for the data. Under the standard client/server architecture of Web 2, the links referencing the data are location-based, and the data itself is centralized on a server owned by a service provider. This centralization makes the task of finding and retrieving the data we are seeking rather trivial. However, ultimately the contents of a file hosted on the centralized server have no direct relationship with their location-based addresses. This location-based addressing creates a confusing mess of data that is saved multiple times at different URLs, making it difficult to attribute ownership or tell which items are duplicates or originals.

Conversely, on the decentralized Web, individuals can all host one another's data, with a different kind of linking that's more secure, making it easier to trust. This new form of linking, called content addressing, is facilitated by cryptographic hashing, and it liberates us from reliance on centralized service providers.

Cryptographic hashing takes data of any size and type and returns a single, fixed-size "hash" that represents it. A hash is a string of characters that can be thought of as a unique name for the data. These hashes and the notion of storing data via content addressing are more secure because each hash is unique. This approach to securely identifying and verifying the integrity of data provides a higher level of transparency and enables independent actors to trust the information that's shared.

The data underlying these efforts to digitize supply chain information will be imperfect at the beginning, but it is our expectation that the transparency created, combined with the evolving needs of market actors, will create a self-reinforcing cycle that improves the quality of data over time.

2. Set and maintain ownership; a distributed ledger removes the intermediaries.

The inherent verifiability of systems that use a content-addressed architecture,[3] such as the InterPlanetary File System (IPFS),[4] provides a high level of confidence in the integrity of information and data sets, which traditional client/server architectures using location-based addressing simply cannot. CIDs are based on the content's cryptographic hash,[5] which means supply chain actors can simply assess the cryptographic proof that a file's hash has remained the same, so they know with certainty that the file has not been edited or tampered with.

To facilitate access control functions, RMI's partner firm, the Energy Web Foundation, has developed an Identity and Access Management (IAM) Client Library for authentication and authorization that uses DIDs (decentralized identifiers) and VCs (verifiable credentials) to ensure that only verified users have access to the applications they are interacting with.

The standard way that information is transferred on the Web is the Transport Layer Security (TLS) protocol,[6] but there are additional protocols, such as libp2p,[7] that support upgrading a connection provided by the transport layer into a securely encrypted channel. That upgrade provides a higher level of verifiability, transparency, and fault tolerance among independent actors.

The combination of CIDs for individual data points, an encrypted transport layer for communication among peers, and DIDs and VCs for authentication enables supply chain actors and devices to confidentially transmit and exchange data with one another directly, in a trustless manner, without relying on a centralized service provider.

3. Create verifiable audit trails to keep emissions data connected to products.

The ability to construct comprehensive event audit trails, which are currently consumed by monitoring processes to ensure process consistency, can also act as the beginning of verified data collection upon which additional calculations, methodologies, and products can be built, including automated emissions reporting, proof of compliance, insurance, and verified carbon credits.

Using a blockchain-based solution for recording transactions and interactions across supply chains can act as a decarbonization decision-making matrix that verifies the who, what, when, where, and why of supply chain emissions in a bottom-up fashion.

An event logging system for supply chain emissions could borrow features of other supply chain platforms, such as the Morpheus.Network.[8]

To fulfill the tasks of a transaction network and event logging system, there are many open-source implementations of blockchain frameworks available. In the Ethereum ecosystem, these include GETH,[9] OpenEthereum,[10] Nethermind,[11] and Quorum.[12] Many other frameworks and implementations, including Polkadot[13] and Substrate,[14] also fulfill the requirements for the immutable event logger and audit trail envisioned for this proposed solution.

4. Standardize units of trade to make climate-friendly products accessible across supply chains.

Something that is composable means that it has the ability to combine things, parts, or elements.[15] In the context of a composable token, it should be able to represent more than one digital asset. Multiple tokens can be composed into a single ERC-998[16] token that can represent either a group of similar assets (ERC-20[17] tokens), an assortment of unique assets (ERC-721[18] tokens), or a combination of both, which can then be traded in a single transaction.

As such, a single ERC-998 token can be regarded as a portfolio of digital assets or, in other words, a single asset can be digitally represented by the sum of its parts using an ERC-998 token. For the purposes of creating GHG attributes that are tradable, ERC-998 tokens can act as a bundle of GHG attributes in a modular, adaptable, extensible, collapsible, and transposable manner.

For the purposes of this proposed solution, the data schema of any one digital GHG attribute should build on the schema of a standard ERC-721 token, where the data structure contains information related to the who, what, when, where, and how the event took place, the data that was collected, and how the embodied CO_2e was calculated.

The data schema of any one digital GHG attribute should build on the ERC-721 standard because it is intended to only represent a parcel of embodied emissions and, as such, should be its own distinct digital asset. Additionally, to ensure that the digital GHG attribute follows our Accounting Principles,[19] the digital GHG attributes should seek to conform to the data schema for Location Metadata in ERC-721,[20] which is based on ISO 6709[21] and was recently submitted to the Ethereum Improvement Proposal process by the Ernst and Young Blockchain Team.[22]

Lastly, any one material or any one complete supply chain operation should follow the data schema of a standard ERC-998 token and should seek to implement the ERC998ERC721TopDown interface.[23]

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