Exploring the Future of Granular Carbon Tracking with Blockchain

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Abstract

Environmental, Social, and Governance (ESG) reporting is increasingly crucial for companies dedicated to sustainable and ethical practices. This conceptual paper delves into the challenges of ESG reporting, with a specific focus on granular carbon emissions tracking. It explores the potential of leveraging blockchain technology to enhance the accuracy and transparency of carbon data. The need for granular tracking of carbon emissions, particularly Scope 2 and Scope 3 emissions is emphasized because these emissions are not directly controlled by the reporting company and vary widely depending on external factors. By examining current blockchain infrastructures, this paper investigates the feasibility of developing a framework for tracking carbon emissions throughout a product's entire lifecycle—from raw material extraction to end-of-life disposal. Such a system would enable real-time carbon accounting, facilitating timely corrective actions and informing policy decisions.

Keywords: Blockchain, ESG, Carbon Accounting

1. Introduction

In the global push toward sustainability, the demand for precise and transparent Environmental, Social, and Governance (ESG) reports has risen dramatically. While the social and governance components of ESG play vital roles in broader corporate responsibility, it is the environmental aspect—specifically, carbon emissions data—that has the most direct and critical impact on corporate accountability and climate policy.

At the heart of this is the granularity of carbon emissions data. Accurate, detailed tracking of emissions at every stage of corporate activity is essential for producing reliable reports; without which these reports risk becoming an exercise in greenwashing. However, the collection and application of granular carbon data is inherently challenging, particularly for Scope 2 and Scope 3 emissions due to their indirect nature.

Scope 2 emissions are generated from the consumption of purchased electricity, steam, heating, and cooling by a company. The variation in these emissions arises from the different energy sources (renewable like wind and solar, or non-renewable like coal and natural gas) used to produce this purchased energy, which in turn affects the intensity of carbon emissions. This variability necessitates accurate tracking and reporting for genuine environmental accountability. Scope 3 emissions encompass all other indirect emissions within a company's value chain and are far more complex due to their origins in a wide range of upstream and downstream activities, such as transportation, manufacturing by suppliers, and product disposal by consumers.

The diversity of these supply chain interactions, coupled with differing environmental standards across regions and companies, leads to significant variability in emissions transparency and reporting standards (Lyon & Maxwell, 2011; Talbot & Boiral, 2018; Boiral & Heras-Saizarbitoria, 2020). As a result, obtaining consistent, comprehensive, and accurate data for these emissions are particularly challenging, requiring robust tracking systems and cooperation among all parties involved verifying complex data from numerous sources.

Addressing these challenges is imperative not only as a step towards achieving net-zero but also for driving informed investment decisions within the corporation. Companies that engage in granular tracking of emissions enjoy significant advantages, such as substantial cost reductions. McKinsey research has highlighted a notable link between granular resource efficiency and financial performance, finding that resource usage can impact operating profits by up to 60%. Additionally, there is a growing market demand for sustainability which can drive top-line growth. For instance, according to the 2022 UOB ASEAN Consumer Sentiment study, 34% of millennials and Gen Zs in Singapore are willing to pay more for sustainable products. This shift in consumer preferences is a clear

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indicator that sustainability can enhance brand value and market positioning.

Given the complexities and the significant role of granular carbon data in shaping sustainable practices and policies, the goal is to develop a scalable, blockchain-enabled framework designed for enhancing the accuracy, transparency, and verifiability of granular carbon emissions data. This paper is the first in a series which will fit into a larger design science research paper.

2. Background

2.1 Current State of Carbon Tracking

Monitoring, Reporting, and Verification (MRV) systems are pivotal for effectively managing and reducing greenhouse gas emissions within various environmental frameworks, including national and international climate change policies (Singh et al., 2016). The MRV process helps ensure the accuracy of emissions data, supports compliance with environmental regulations, and aids in the assessment of progress towards climate goals. There are two primary methods for MRV: Direct monitoring and remote sensing.

Direct monitoring involves the physical measurement of emissions at their source. This method typically uses sensors and meters installed directly on emission sources such as industrial equipment, vehicles, or within infrastructure systems like power plants. The key advantage of direct monitoring is the precision and reliability of the data it provides. Since it measures emissions as they occur, it can offer real-time insights and detailed quantification necessary for effective regulation and control. However, the challenges with this method include the high costs associated with installing and maintaining sensors, the need for technical expertise in interpreting data, and potential issues with sensor accuracy or malfunction.

Remote sensing, on the other hand, utilizes satellite, aerial, or drone technologies to detect and measure emissions from a distance. This method is particularly useful for monitoring large areas or difficult-to-access locations. It can cover vast regions such as forests, oceans, or sprawling industrial complexes, providing a broader picture of environmental impact. Remote sensing is advantageous because it minimizes the need for physical access to emission sites, which can reduce costs and logistical complexities. It's also beneficial for tracking changes over time, such as the progression of deforestation (Mitchell et al., 2017) or the effects of policy interventions on air quality. The challenges with remote sensing include the dependency on weather and atmospheric conditions, which can affect the accuracy and consistency of data. Moreover, the resolution of the data may not always be as high as that obtained from direct monitoring, and there can be delays in data processing and analysis.

Despite the advances in MRV technologies through direct monitoring and remote sensing, several systemic challenges hinder the effective management of emissions data across sectors. Two significant issues are siloed data and the multitude of software and platforms used in emissions tracking.

Siloed Data: One of the most persistent problems in environmental data management is the issue of siloed data. Many companies operate their MRV systems in isolation, centrally organizing their data without provisions for integration with external systems. This lack of interoperability leads to difficulties in aggregating and comparing emissions data across different organizations or sectors. Siloed data systems can result in inefficiencies and inaccuracies in broader environmental assessments and hinder collaborative efforts to address climate change at a regional or global scale.

Multitude of Software and Platforms: Furthermore, the diversity of software solutions developed to assist with emissions data management adds another layer of complexity. Organizations might choose from a wide array of software, ranging from enterprise-level systems that integrate emissions data with other financial and operational metrics, to niche products that focus exclusively on environmental reporting. While this variety allows organizations to find solutions tailored to their specific needs, it also creates a fragmented landscape where data standards and formats may not align. This fragmentation can complicate the processes of data exchange and consolidation, making it challenging to obtain a cohesive view of emissions impacts and trends.

Both siloed data and the plethora of software options underscore the need for more standardized and unified approaches to environmental data management. Addressing these challenges is crucial for enhancing the effectiveness of carbon emission data tracking and this is where blockchain would be able to play the perfect part.

2.2 Data Providers and Reporting Standards

On top of the many software out there, several major data providers play pivotal roles in the ESG space as well. These organizations gather, analyze, and distribute information that assists stakeholders in making informed decisions regarding climate change and sustainability practices. These include:

- Carbon Disclosure Project (CDP)
- Sustainalytics
- MSCI - Morgan Stanley Capital International
- Refinitiv
- Bloomberg
- S&P Global Trucost

It is also no surprise that the landscape of compliance and reporting standards for greenhouse gas emissions and sustainability practices is complex and varied. Governed by several key frameworks globally, each contributes in a unique way to standardize and enhance environmental accountability.

Starting off we have the Greenhouse Gas Protocol which serves as a comprehensive, global standardized framework to measure and manage carbon emissions from various sectors. Developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), this protocol is widely used for carbon emissions reporting. However, the broader climate reporting ecosystem still lacks full harmonization. Different regions have adopted specific standards, like the European Union Emissions Trading System (EU ETS) in Europe and the Greenhouse Gas Reporting Program (GHGRP) in the US, reflecting regional priorities and economic structures.

Global Reporting Initiative (GRI) 305 helps organizations worldwide report on their carbon emissions and reduction efforts. This standard promotes transparency in environmental impacts, enabling comparisons across different organizations and industries.

Sustainability Accounting Standards Board (SASB) provides industry-specific standards that guide public corporations in disclosing financially material, sustainability information to investors, including metrics on energy use and carbon emissions, tailored to the specific realities of various industries. The Task Force on Climate-related Financial Disclosures (TCFD) develops voluntary, consistent climate-related financial risk disclosures to help organizations communicate with stakeholders about how they assess and manage climate-related risks and opportunities. ISO 14064 offers an international standard for quantifying, monitoring, reporting, and verifying carbon emissions, part of the ISO 14000 family of environmental management standards. It provides a structured framework for organizations to measure and manage their carbon footprint.

Additionally, countries like Australia and Canada have established their own national programs, such as Australia's National Greenhouse and Energy Reporting Scheme (NGERS) and Canada's GHG Reporting Program. Each of these frameworks and national programs indicates the variation in climate reporting standards worldwide, contributing to a fragmented global approach. While this diversity in standards reflects local needs, it underscores the challenge of achieving a globally unified strategy for tracking and reducing carbon emissions, highlighting the necessity for greater international coordination and standardization in environmental reporting.

2.3 Literature Review

The integration of blockchain technology into supply chain management has garnered significant attention for its potential to enhance sustainability initiatives, especially in the context of carbon emissions tracking. Researchers like Chang and Chen (2020) reviewed the ongoing developments and potential applications of blockchain within supply chains. They emphasize its pivotal role in enhancing transparency and accuracy throughout the supply lines and how it has the technical capabilities to share this information. Leveraging these features once it has been integrated into the supply chain will be crucial to how we can track indirect Scope 2 and Scope 3 emissions as it is this aspect that would ensure emissions data are verifiable and consistent across different stages of the supply chain.

Adding to this discourse, Kouhizadeh and Sarkis (2018), along with Saberi et al. (2019), have highlighted blockchain's potential to ameliorate sustainability practices within supply chains, particularly its role in augmenting data integrity and fostering stakeholder trust. These enhancements are pivotal for developing trust and reliability in environmental reporting and for the broader adoption of sustainable practices.

Furthering this exploration, Esmaeilian et al. (2020) delve into how blockchain could revolutionize sustainable supply chain management in the era of Industry 4.0. Their research suggests that blockchain supports more reliable ESG reporting by facilitating the

secure and transparent exchange of information. This capability is vital for the circular economy and sustainable supply chain practices, as it enhances the integrity of sustainability claims and ensures compliance with environmental standards. Additionally, Paliwal, Chandra, & Sharma (2020), and Queiroz, Telles, & Bonilla (2020) have provided systematic reviews on blockchain applications in supply chain management, underscoring its utility in facilitating sustainable practices through enhanced traceability and transparency. These features are instrumental in ensuring that environmental impacts are meticulously tracked and managed.

Central to these discussions is the perspective offered by Bakarich, Castonguay, and O'Brien (2020), who posit that blockchain is exceptionally well-suited to providing reliable tracking and custodial support for sustainability information. They argue that broader adoption of blockchain technology could lead to the inclusion of higher-quality data, thereby fostering the development of a uniform standard across industries. Such a standard would be instrumental in enhancing traceability and accountability mechanisms within supply chains. This could significantly enhance the traceability and accountability mechanisms within supply chains, as noted by Manupati et al. (2020) and Min (2019), ultimately making supply chains more resilient and sustainable by mitigating risks and enhancing operational efficiency.

3. Conceptual Idea

3.1 Modular Framework Design

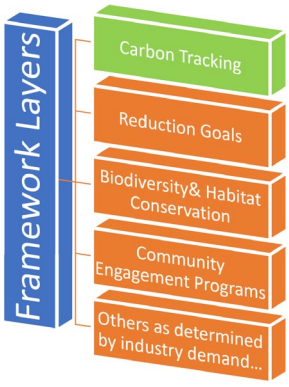

Figure 1. Visualization of Layers

Stepping back, while much of this discussion has centered on granular carbon tracking, the modular framework is part of a much larger vision—a comprehensive, all-in-one system for ESG reporting. Designed with flexibility in mind, the framework can expand to incorporate additional components such as reduction goals, biodiversity and habitat conservation, and community engagement programs (as shown in Figure 1). This modularity allows the system to evolve and address the full spectrum of ESG impacts. It provides businesses and stakeholders with a unified platform for managing and tracking their sustainability initiatives to make better decisions.

At the core of this system is granular carbon tracking which serves as the foundational component within the broader ESG framework. The primary goal of this tracking component is to address the key challenges highlighted in the previous sections, which can be summarized into three main objectives:

- Enhancing the *accuracy, transparency* and *immutability* of emissions data.
- Improving *interoperability* across different data sources and emission reporting systems to ensure consistency.
- Providing a solution that is *scalable* across industries and adaptable to varying data demands.

The granular carbon tracking layer would operate at every stage of a product's lifecycle, from raw material extraction to end-of-life disposal, ensuring precise tracking of carbon emissions. At each step, a tokenized system records the carbon footprint generated. For instance, when energy is consumed to produce one kilowatt of power, an energy token is minted, encapsulating the emissions from its generation. As the lifecycle progresses, such as during the production of a raw materials like metal, the energy tokens are burned and their carbon data is aggregated into a new material token, representing the cumulative emissions of the energy inputs used in creating one gram of metal. As the product moves through subsequent stages, such as assembling a pen, the carbon emissions from all components (e.g., plastic, metal, ink) are collated into a single product token. This final token, representing the pen, contains the emissions data from all prior tokens, ensuring a transparent record of its total carbon footprint. The burning mechanism at each stage provides a reliable and immutable way to track emissions, ensuring that the entire carbon lifecycle of a product is preserved within the final token, facilitating robust reporting and decision-making for both companies and stakeholders.

The feasibility of this tokenized carbon tracking system lies in the inherent features of blockchain

technology, which make it uniquely suited to handle such complex, multi-stage processes.

3.2 Blockchain Key Features

Within the suite of intrinsic features blockchain offers there are three key features that are particularly beneficial to a granular carbon tracking system:

Transparency: Blockchain provides unparalleled transparency, making it an ideal technology for the granular tracking of carbon emissions. Each transaction and data entry on a blockchain is recorded on a decentralized ledger that is accessible to all participants in the network, which may include regulators, companies, and environmental watchdogs. This visibility ensures that all stakeholders can see and verify the data on carbon emissions from various sources in real-time. For instance, emissions data from a specific factory can be tracked from its initial recording to its inclusion in broader regulatory reports. This level of transparency fosters trust among stakeholders, enhances regulatory oversight, and enables more accurate reporting and monitoring of emissions.

Immutability: Once data is entered into a blockchain, it cannot be altered or deleted making the records tamper-proof. This immutability is crucial for maintaining the integrity of carbon emissions data, which must remain unaltered once reported to ensure accuracy and prevent manipulation. For example, if a company reports its quarterly emissions, this data is permanently recorded and can be audited by external parties to verify compliance with environmental standards and regulations. This feature is particularly important in contexts where financial or regulatory incentives might otherwise motivate the alteration of data.

Security: Each block in the chain is linked to the previous one via cryptographic hashes, creating a secure chain of data that enhances the overall security of the system. This security is essential for sensitive environmental data, such as carbon emissions, which could be targeted for breaches or theft. Secure blockchain systems ensure that emission data is not only protected from external threats but also from insider threats, providing a robust foundation for a carbon tracking system that stakeholders can trust.

With smart contracts, processes such as the aggregation of emissions data and the burning of tokens can be automated, reducing human error and ensuring real-time processing. The decentralized nature of blockchain also ensures that these carbon tokens and their data are securely preserved, creating a scalable solution for managing carbon emissions across industries while maintaining data integrity.

4. Blockchain Choice

When considering the blockchain infrastructure for granular carbon tracking, there are several well-established chains in the web3 space. We will discuss five chains in particular, Ethereum, Arbitrum, Algorand, Polkadot and Hyperledger Fabric. Given the nature of granular carbon tracking, which would need to handle a potentially massive volume of transactions as tokens are minted, burned, and transferred throughout the lifecycle of countless products, the scalability and throughput of the blockchain platform become critical considerations.

4.1 Ethereum

Ethereum, as a leading public, open-source blockchain platform, has carved a niche for itself in the realm of digital ledger technology, particularly due to its robust support for smart contracts and decentralized applications (dApps). This platform has become one of the most widely adopted blockchain infrastructures globally, supported by a large, active, and innovative developer community. This extensive adoption and support are a testament to Ethereum's flexibility, reliability, and advanced technological capabilities.
Ethereum was the first blockchain platform to popularize smart contracts, which are self-executing contracts with the terms of the agreement directly written into code. Ethereum’s smart contracts are powered by Ethereum Virtual Machine (EVM), which executes the code globally across the network. The ability to run smart contracts has made Ethereum the backbone of many applications across various industries, from finance to gaming.

In the context of material tracking, this translates to a range of functionalities: from verifying the authenticity of materials, documenting their lifecycle events, to ensuring compliance with stringent sustainability standards. These smart contracts operate on predefined rules and execute automatically when conditions are met, ensuring accuracy, reducing human error, and enhancing efficiency in the tracking process.
Ethereum's decentralized nature, a hallmark of public blockchains, brings forth significant advantages in terms of transparency and trust. This transparency is crucial in material tracking, as it allows all stakeholders to verify the authenticity and sustainability of materials without relying on a central authority. This level of trust is essential in building confidence among various parties involved, from suppliers to end-users.

Furthermore, Ethereum's ERC standards, such as ERC-20 (for fungible tokens) and ERC-721 (for non-fungible tokens), are pivotal in the tokenization of assets. This capability is particularly beneficial in representing sustainable materials on the blockchain. Tokenization enables these materials to be uniquely identified, tracked, and traded, creating a more efficient and transparent supply chain. It also opens up possibilities for innovative economic models, such as incentivizing sustainable practices through token rewards.

4.2 Arbitrum

Arbitrum is a layer 2 scaling solution for Ethereum that aims to improve its scalability and reduce costs while ensuring the security of the main Ethereum blockchain. It is designed to execute Ethereum-compatible smart contracts at a lower cost and faster pace than can be achieved directly on Ethereum's mainnet.

Utilizing a technology called Optimistic Rollups to achieve its scaling benefits, it essentially bundles (or "roll up") a large number of off-chain transactions into a single transaction. After executing these transactions off-chain, they submit the new state to the Ethereum mainnet. By moving the bulk of computation and storage off-chain, Arbitrum can offer significantly lower transaction fees compared to Ethereum's mainnet, while also enabling a much higher throughput. This makes it an attractive option for applications with high transaction volumes that would otherwise be too costly or slow on the main Ethereum network.

Arbitrum is particularly suited for applications that require high transaction throughput and more extensive computation than what Ethereum’s mainnet can economically support.

4.3 Algorand

Algorand is a blockchain platform that stands out for its focus on speed, security, and scalability, which are critical factors for widespread adoption of blockchain technology. It was created by Silvio Micali, a professor of computer science at MIT and a recipient of the Turing Award, often referred to as the "Nobel Prize of Computing."

Algorand uses a pure proof-of-stake (PPoS) consensus mechanism, which is designed to address the three main challenges in blockchain technology: security, scalability, and decentralization. In Algorand's PPoS, the network ties its security to the honesty of the majority of its economy, and only a minimal amount of computation is needed to maintain this security, making it energy-efficient. One of the main features of Algorand is its high transaction throughput and low latency. Algorand can process many transactions quickly, akin to large payment processing companies, making it a suitable platform for widespread adoption and everyday use. It achieves this while ensuring that blocks are finalized without the risk of forking, which can be a major issue in other blockchain environments.

In Algorand, every token holder is randomly and secretly selected to participate in the consensus process, and the selection is proportional to their stake in the network. This method of selection ensures that the network remains decentralized and secure, as there is no centralized group of validators, which can be a point of vulnerability.

4.4 Polkadot

Polkadot is a network protocol designed to connect multiple specialized blockchains into a unified network. A core feature of Polkadot is its ability to enable different blockchains to communicate and share information in a secure manner. This interoperability is facilitated through Polkadot’s central chain, known as the Relay Chain, and various parallel chains or "parachains." Each parachain can have its own tokens and be optimized for specific use cases, but still interact with other blockchains on the network, allowing for a high degree of flexibility and customization.

Unlike traditional blockchains that process transactions one at a time, Polkadot allows multiple transactions on multiple chains (parachains) to be processed in parallel. This parallel processing capability significantly increases the overall capacity of the network and reduces bottlenecks associated with other blockchains. Security is pooled and shared across the network where the Relay Chain provides security to all connected parachains, which means that individual chains do not need to provide their own security. This shared security model helps smaller blockchains benefit from the same level of security as larger ones, without the need for extensive mining or staking power on each chain.

Polkadot uses a nominated proof-of-stake (NPoS) consensus mechanism, which involves validators who secure the network and nominators who delegate their DOT tokens to trustworthy validators. Validators are responsible for adding new blocks to the Relay Chain and parachains, while nominators help secure the

network by selecting trustworthy validators, incentivizing network integrity and performance.

4.5 Hyperledger Fabric

Hyperledger Fabric, hosted by the Linux Foundation, is a permissioned blockchain platform tailored for enterprise applications, offering enhanced privacy and scalability features. Its design is particularly suited for businesses seeking a high degree of control over their network operations and data privacy. It offers a distinctive modular architecture that allows network designers to plug in their preferred components and configurations to suit their specific needs. This modularity extends to all fundamental aspects of the blockchain network, including consensus mechanisms, membership services, and transaction handling.

Unlike many blockchain solutions that broadcast transactions to all nodes, Fabric supports private transactions and confidential contracts through its "channels" feature. Each channel represents a private blockchain overlay, allowing a subset of network participants to transact privately among themselves. Smart contracts are referred to as "chaincode." These contracts are deployed onto the blockchain and executed within a container environment (like Docker), which isolates them and enhances security.

All participants have known identities in Fabric as network participants are issued digital certificates via a Membership Service Provider (MSP), which adds a layer of security and operational management not available on permissionless blockchains. This is particularly important for enterprises that need to comply with regulatory audits and governance standards.

Hyperledger Fabric is widely used across various industries for applications that require stringent privacy and permissioned access, including supply chain management, healthcare, finance, and identity verification. Its flexible and modular architecture makes it well-suited for complex business networks where diverse stakeholders are involved in the processes.

5. Consensus Mechanism Choice

The effectiveness of a blockchain platform is not only determined by its infrastructure but also by the underlying consensus mechanism it employs. This mechanism plays a pivotal role in how transactions are verified and added to the blockchain, impacting the network's overall efficiency, security, and scalability. The selection of an appropriate consensus mechanism is a critical decision when it comes to implementation. Each consensus algorithm offers a unique blend of attributes, balancing efficiency, security, energy consumption, and scalability.

5.1 Proof of Work (PoW)

The original consensus mechanism used by Bitcoin, is known for its high security but is also the most energy-intensive. The computational work required to validate transactions under PoW ensures a high level of security but at the cost of slower transaction speeds and significant energy consumption. This makes PoW less suitable for carbon tracking where sustainability and efficiency are key concerns.

5.2 Proof of Stake (PoS)

Presents a balance between energy efficiency and decentralization. In PoS, the validation of transactions is based on the economic stake of the participants, making it a greener alternative to PoW. It's generally more scalable and faster than PoW, making it a good fit for public blockchains where diverse stakeholder engagement is crucial. The design of PoS also allows for greater decentralization by enabling a larger number of validators to participate in network consensus, provided they hold a stake. This encourages broader participation and reduces the risk of centralization, which can be an issue in PoW systems where large mining pools dominate the network.

5.3 Pure Proof of Stake (PPoS)

A consensus mechanism that selects validators randomly and secretly from its pool of token holders, proportionate to their holdings, through a cryptographic lottery. This process, which does not require significant computational power, ensures low barriers to entry and prevents centralization, fostering greater security and decentralization. PPoS guarantees immediate transaction finality without the risk of forks, enhancing the network's security and stability. Additionally, it's energy-efficient compared to PoW systems, supporting a high transaction throughput with minimal environmental impact. This scalability and efficiency are what makes Algorand a standout for its broad range of applications.

5.4 Nominated Proof of Stake (NPoS)

NPoS is the consensus mechanism employed by Polkadot to secure its network, designed to optimize both security and decentralization. In NPoS, the network divides roles into validators, who are responsible for

producing blocks and validating parachain blocks, and nominators, who delegate their stakes to trustworthy validators to support the network's security. The selection process for validators is based on the amount of stake delegated to them, both their own and that from nominators, maximizing network security by ensuring that validators have a large collective stake. This system not only facilitates high network integrity through shared security risks and rewards (including penalties for misconduct known as slashing) but also promotes a decentralized and fair governance structure by allowing a broad base of token holders to participate in the network's operational security and decision-making.

5.5 Practical Byzantine Fault Tolerance (PBFT)

Designed to ensure system reliability and fault tolerance in distributed networks, even in the presence of malicious or faulty nodes. It operates through a three-phase protocol involving pre-prepare, prepare, and commit stages to facilitate consensus without the extensive computational overhead seen in mechanisms like Proof of Work. PBFT is especially effective in permissioned blockchain environments where participants are known and verified, making it well-suited for applications requiring high throughput, low latency, and stringent data integrity, such as in financial services and distributed databases. This efficiency and reliability, combined with a requirement for less than one-third of the nodes to be non-faulty, make PBFT a preferred choice in trusted environments needing robust fault tolerance.

5.6 Proof of Authority (PoA)

PoA is a consensus mechanism where approved accounts, known as validators, validate transactions based on their identity and reputation rather than computational power or financial stakes. This approach makes PoA highly energy-efficient and capable of achieving higher transaction throughput and quicker block times, ideal for networks that require fast consensus and finality. PoA is particularly well-suited for permissioned blockchain networks where trust and identity are paramount, such as in supply chain management or corporate blockchain applications, offering a balance between efficiency, control, and reduced risk of malicious behavior.

6. Which Chain and Consensus Mechanism?

Table 1. Comparison of Blockchains

	Ethereum	Arbitrium	Algorand	Polkadot	Hyperledger Fabric
Market Cap	$310.57 Bln	$2.17 Bln	$1.09 Bln	$6.55 Bln	-
Real Time TPS	11.58 tx/s	17.86 tx/s	9.05 tx/s	0.04 tx/s	-
Max Recorded	63.34 tx/s	896 tx/s	5,716 tx/s	112 tx/s	2544 tx/s (benchmark)
Block Time	12.04 secs	0.25 secs	2.9 secs	6.01 secs	-
TTF	16 mins	16 mins	0 sec	1 min	-
Consensus Algo	PoS	PoS	PPoS	NPoS	Custom
Language	Solidity	Solidity	Python	Rust	Go

Source: https://coinmarketcap.com/ | https://chainspect.app/dashboard (over 30d period) (accurate as of September 2024*)*

The choice of blockchain and the corresponding consensus mechanism for our project remains undecided and will be a critical aspect of the ongoing design and development process. In the next phase of the research progress, we will conduct a thorough investigation into various blockchain platforms and consensus mechanisms to identify the most suitable option that aligns with our specific requirements for security, scalability, and efficiency. This evaluation will involve detailed analysis and experimentation to ensure that the selected technology optimally supports our objectives. As a preview, we have selected a few key variables such as transactions per section (TPS), block time and time to finality (TTF) in the above Table 1 showcasing the differences between them. It is interesting to note that there is not much readily available information on Hyperledger Fabric. This is likely due to the blockchain being enterprise orientated and highly customizable.

The next step will entail an exploration of the potential trade-offs and benefits of different blockchain solutions to determine the best platform for a granular carbon tracking system. Furthermore, as the technology continues to mature, we can expect even more innovative and newer chains to enter the space combined with the possibility of interoperability across chains presents exciting opportunities for creating a more integrated and cohesive system.

7. Conclusion

The intersection of technology, ESG, and supply chain is on the cusp of a new digital transformation. Kotsantonis and Serafeim (2019) delve into the intricacies of ESG data quality through a mixed-methods approach, utilizing case studies and surveys with investment professionals. Their findings highlight critical issues in ESG data quality, particularly the discrepancies that can mislead stakeholders and result in misinformed decisions. Having better data allows for more informed decision-making, enabling better capital allocation to more promising sustainable opportunities. This resonates with the challenges in carbon data reporting identified by Bebbington and Larrinaga-González (2008) in their work. Through a documentary analysis of compliance reports and structured interviews with corporate accountants within the EU Emissions Trading Scheme, they uncover significant inconsistencies in how carbon emissions are reported and verified, advocating for stricter regulatory frameworks to ensure transparency and reliability in carbon reporting—key for effective carbon trading.

Moreover, the complexities of carbon trading and environmental reporting present notable challenges within the sustainability sphere. Bebbington and Larrinaga-González have called for more reliable and transparent mechanisms in carbon trading, a sentiment echoed by Ju et al. (2022) who propose a blockchain-based system for tracing carbon footprints. This system could potentially furnish a more credible and efficient framework for carbon trading markets, aligning with the goals of ESG reporting by offering a verifiable ledger of emissions and reductions that could address the transparency and trust deficits observed in traditional carbon markets.

These papers show how companies that actively measure and report their carbon emissions gain a competitive edge by demonstrating awareness of their carbon-related risks and readiness to set science-based targets to reduce emissions. This reporting is crucial, especially for Scope 3 emissions, which include indirect emissions from activities such as purchasing goods and services, transportation, and employee commuting. With granular, transparent carbon data, companies can track the entire lifecycle of a product, identify high-emission stages, and implement targeted reductions. This granular data is invaluable not only for the company itself but also for others in the supply chain, enabling them to integrate this information into their own sustainability reports and strategies. For instance, when a manufacturer provides detailed emissions data, companies further down the supply chain can use this information to bolster their own efforts towards achieving net-zero targets—a crucial commitment as Scope 3 emissions can account for up to two-thirds of a company's emissions but remain challenging to manage due to their indirect nature.

By incorporating blockchain which we have explored in this paper within organizational systems, it can potentially mark the next step towards the future of granular carbon tracking, transforming how we monitor and manage our carbon footprint which will lead us to our global net zero goal.

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