Carbon Footprint Traction System Incorporated as Blockchain

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***Abstract*—This article tries to offer a solution to an environmental sustainability problem using a forward-thinking approach and tries to construct a carbon footprint tracking system based on blockchain technology while also introducing tokenization intertwined with the blockchain to make everyday use as accessible and effective as possible. This effort aims to provide a solid use case for environmental sustainability and lays the groundwork of a new generation social construct where carbon footprint is a valuable unit like money next to the other important tokenized attributes a person can possibly hold. The study proposes a blockchain-based solution to store the data. Through tokenization, the transacting and sharing is facilitated. As a result, carbon footprint data can be treated as a fungible utility token. The article tries to explain how and which blockchain technology offers an effective solution to challenges in global carbon tracking systems. In this context, a use case was proposed. The critical features of the blockchain-based platform are examined. In addition, the roles of parties and user interactions within the system are detailed. In conclusion, this article proposes the adaptation of blockchain technology together with smart contracts and tokenization to the management of carbon footprints.**

***Index Terms*—Blockchain, Carbon Footprint, CO2, Attribute Tracking, Tokenization, Utility Token, Data Sharing through Smart Contracts**

1. Introduction

There is a need for a multiuser, privacy-preserving tamper proof database that allows data governance and makes audit trailing possible. With the advent of Blockchain, such a database can be developed. The pivotal role of blockchain in ensuring tamper proof operations and preserving privacy has been substantiated by [1]. Furthermore, its application extends to multi-user environments, effectively enabling data sharing schemes as explained by [2]. The ability to conduct searches over encrypted records is another important functionality and how it is done is explained in [3]. Furthermore, the relevance of multi-stage processes in the context of blockchain databases, as discussed by [4], further underscores the versatility and complexity of such systems. This confluence of features marks a significant advancement in database technology, aligning with the requirements of modern data governance and audit trails.

Blockchain technology emerges as a potential solution where a common ”entity” such as carbon footprint traction is considered. Blockchain offers a promising avenue for building a database system that aligns with these critical requirements. In addition to these attributes, the blockchain-based database system offers the added advantage of enabling encrypted record searches. There are several tools in order to achieve this goal. This article will study a proposed construct for a carbon footprint ecosystem and why a blockchain based database and its associated token, smart contract-type tools are superior to the conventional database systems.

The carbon footprint becomes increasingly important for our civilization. There is too much effort being spent to track all goods' and products' carbon values. Every enterprise in the modern world has somehow started to keep track of their carbon footprints and try to become carbon neutral. This article suggests that it would be very hard to effectively overcome this complicated problem with conventional database systems.

The carbon footprint becoming a fundamental attribute, synonymous with price, of any item and service gives perfect room for the utilization of tokens to come in. In this way, a single blockchain can be the backbone of an entire database. Moreover, it will be very easy to keep track of all the goods and enterprises' footprints in a very effective way.

This article has studied the current availability of blockchains and how they can be of use. Prominent blockchains are elaborated in their practicality and effectiveness. Still, creating a well-governed consensus protocol is the biggest roadblock to get through and it is a matter to be concerned about in the blockchain world before serious real-life applications start taking place. The use of smart contracts as a privacy-preserving search method in blockchains is another topic to study.

This article primarily studied the general architecture of conventional systems and put forward the kind of properties that will be needed. This made understanding the main disadvantages of conventional systems a secondary concern. The reasons why they cannot serve as an effective tool for the newly proposed system with increasing requirements were investigated. A new system model was suggested, and the roles of each actor were tried to be defined in general in order to explain how they can be utilized in the future. Finally, an examination of available blockchains and their properties was done to decide on whether they can be of use or not. After this process, the best candidates for each proposed use case have been shortlisted.

2. Where we are?

In our context of carbon footprint, there are multi-faceted disadvantages inherent in current data management systems, in terms of the challenges they present in the realms of governance, control and optimization. These systems, while pivotal in managing large quantities of data, exhibit significant shortcomings that impede their efficiency and effectiveness.

From the complexities involved in data governance and audit trails to the infeasibility of deploying standardized control algorithms, these disadvantages manifest in various forms. Furthermore, reliance on less efficient off-line or manual audits, the tedious nature of data cross-checking, and the challenges associated with data replication further worsen these issues. The limitations in utilizing data for secondary purposes, such as data sharing for marketing or delivery optimization purposes are also noteworthy.

The Point of Sale (POS) System (here we use it as the entire system including the terminals at point of sale, credit card terminals, other components, Back Office systems, Database) is the pivotal component in modern business operations and encompasses several subsystems and fundamental functions designed to streamline the intricacies of retail transactions.

One of the primary functionality is detailed recording transaction i.e. Invoicing, These invoices include essential information such as the items or services purchased, corresponding prices, and applicable taxes. Invoicing ensures accurate and transparent documentation of sales transactions, enabling both business and customers to understand the specifics of their purchases.

Another main functionality is Stock/Inventory Management, a cornerstone in retail efficiency. This functionality is designed to oversee and control the inventory or stock of products within the business. This functionality enables real-time tracking of product quantities, efficient management of restocking processes, and immediate visibility into available stock levels. Effective Inventory Management through the POS system, together with back-office systems, is crucial for businesses to optimize their supply chain, prevent stockouts or overstocking, and ultimately enhance overall operational efficiency.

Customer loyalty programs are another significant aspect of the POS system. This subsystem is dedicated to cultivating and managing customer loyalty initiatives. It involves tracking customer purchases, implementing reward systems such as loyalty points, and facilitating promotional activities to improve customer retention and engagement. Customer Loyalty Programs not only incentivize customer purchases, but also contribute to building lasting relationships between the business and its clientele.

The POS system, with its associated components, is crucial in creating a smooth, customer-focused retail experience and equips businesses to effectively handle transactions and operations.

At the end of the process, the data collected through the POS system is fed into data entry terminals. Data entry can occur through various means, sometimes using bank POS machines and sometimes through communication with sales points via bank POS machines, ensuring the seamless flow of information within the data management ecosystem.

2.1. Main Properties of Current Database Systems:

Existing data infrastructure, for the most part, adheres to the conventional centralized database model. In this model, companies and organizations rely on a single central repository as the core of their data operations. This centralized approach streamlines government audits by providing an efficient oversight mechanism. However, the limitations of this model become glaringly evident when distinct organizations maintain separate databases, leading to data compartmentalization that inhibits cross-industry optimization. This challenge is particularly pronounced in sectors characterized by intricate logistical and supply chain dynamics, where the inability to share data hinders operational efficiency.

Centralized Databases: A predominant reliance on centralized databases is observed in most companies and organizations. While this architectural choice simplifies data management, it often results in notable environmental repercussions, particularly in terms of increasing the carbon footprint.

Governmental Audits and Central Servers: The prevalent method of conducting governmental audits through central servers requires further scrutiny. This practice plays a critical role in tracking and managing carbon emissions, and its efficiency and effectiveness are paramount in the context of environmental sustainability.

Similar Use Cases Across Industries: Various sectors, particularly within identical industries, frequently use comparable database systems. This uniformity presents different environmental challenges and opportunities, especially in terms of managing and mitigating the carbon footprint associated with these systems.

Decentralized Data Management: An emerging trend is the widespread adoption of separate databases by individual organizations. Such fragmentation impedes collaborative efforts towards optimization in critical areas such as logistics, deliveries, and supply chains. This in turn can lead to an increase in the overall carbon footprint due to inefficiencies and lack of coordinated action.

The Challenge of Isolated Systems: The isolated nature of these systems constitutes a significant obstacle in the pursuit of efficiency and sustainability. The absence of interconnectivity not only restricts data sharing, but also exacerbates the complexity of implementing effective measures to reduce the carbon footprint across industries.

2.2. Existing System Data Collection:

Central to these data systems is the precise collection of transactional data at various critical checkpoints. This pivotal process is executed through the deployment of a Data Acquisition System, seamlessly integrated into devices like 'Cash Registers' or 'POS Terminals.' These checkpoints, acting as pivotal nodes, systematically capture transactional data, thus constituting a fundamental component of the overall data lifecycle.

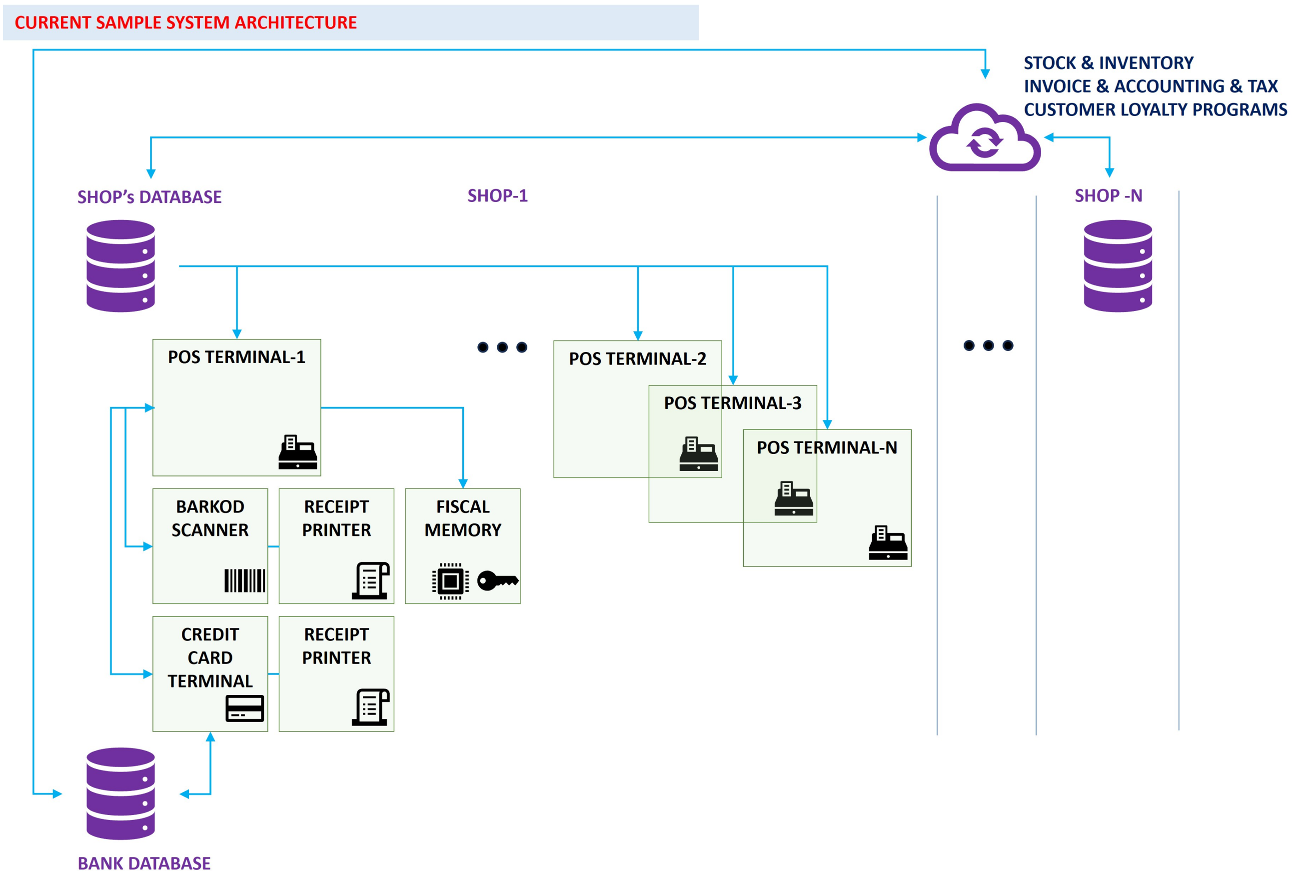

Figure 1. Current Sample System Architecture

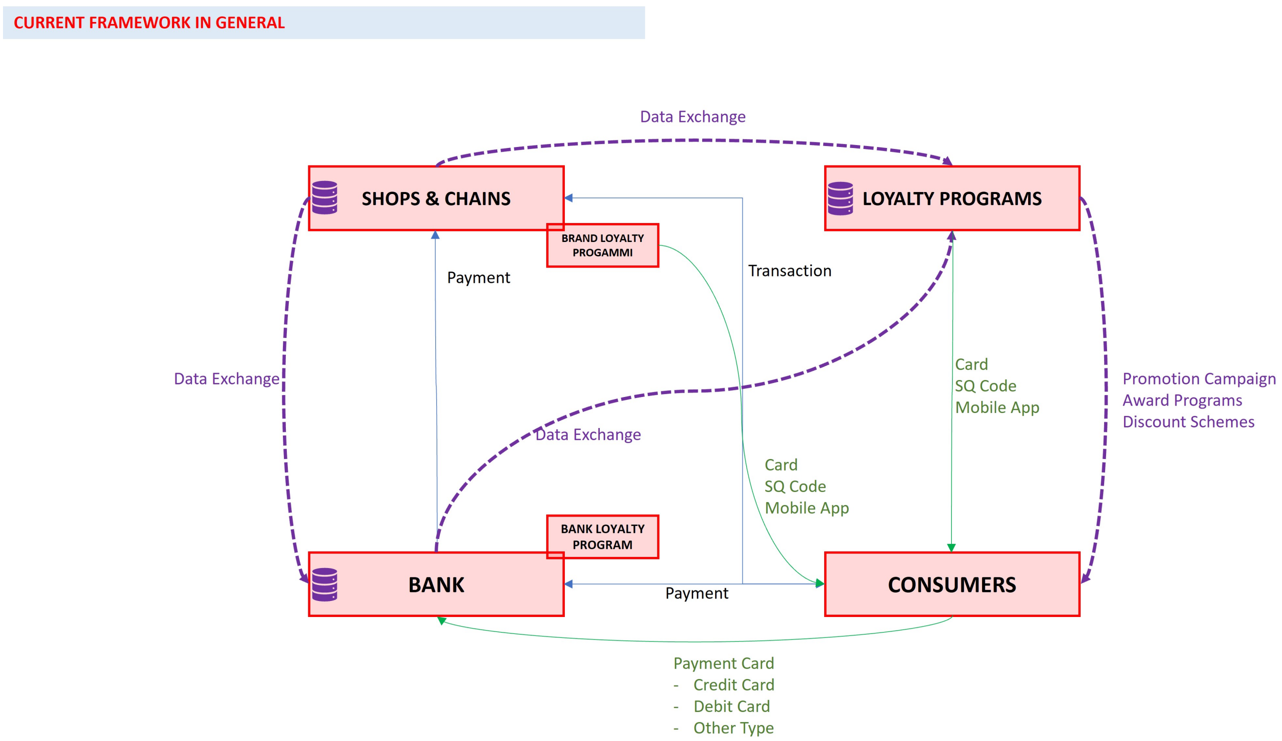

Figure 2. Current Frameork In General

The preservation of transaction records adheres to two primary methods. First, records may be stored in plain text, securely housed within hardware-protected memory or sealed memory chips, such as EEPROMs, to ensure accessibility while maintaining data integrity. Alternatively, in cases where data integrity is of paramount importance, encryption emerges as the preferred strategy. This cryptographic measure is particularly instrumental when information holds critical significance for subsequent audits, as is often the case in tax-related processes, safeguarding sensitive data from unauthorized access.

In summary, organizations are finding themselves navigating the intricate balance between data security, privacy preservation, and collaborative functionality in the ever-evolving landscape of data management. The pursuit of seamless multi-user capabilities, coupled with the establishment of robust governance structures and detailed transparent audit trails, propels the continuous transformation of data infrastructure. This changes how organizations navigate the complexities of contemporary data ecosystems.

2.3. What is Missing in Current Systems:

Difficulty in Data Sharing: Existing systems often face substantial challenges in data sharing, due to complexities in data formats and compatibility issues between various platforms.

Challenges in Managing a Common Database: Effectively managing a common database is a complex task, particularly with the need to ensure data integrity and implement robust security measures amidst various types of data.

Prevalence of Data Silos: Data silos, where information is kept isolated and replicated within different organizational segments, present a significant barrier to efficient data utilization and integration.

Complications in Multiuser System Design: Implementing or designing multiuser systems is fraught with challenges, especially in managing record access permissions, which require a delicate balance between accessibility, security, and privacy.

Privacy Concerns with Critical or Private Records: Handling records that are critical or private, such as in healthcare, involves intricate considerations. Ensuring the confidentiality and proper management of these sensitive records is a crucial aspect of these systems.

2.4. Main Disadvantages of Current Systems:

Data Governance and Audit Trails: The complexity of establishing robust data governance and creating effective audit trails in these systems is a significant challenge. This complexity arises from the intricate nature of the data structures and the high demands for accuracy and compliance in auditing processes.

- Infeasibility of Control Programs or Algorithms: Implementing control programs or algorithms in these settings often proves impractical. The limitations are due to the complex and varied nature of the data, which impedes the effective application of standardized algorithms or control measures.
- Reliance on Off-Line or Manual Audits: The necessity of resorting to offline or manual auditing methods highlights a key limitation. These methods are less efficient, more time-consuming and prone to human error, thus reducing the overall effectiveness of the audit process.
- Challenges in Data Cross-Checking: Cross-checking data within these systems is not only laborious, but also inefficient. The process is often hindered by the sheer volume of data and the lack of streamlined procedures for verification.
- Dependence on Z-Report-Like Checksum Auditing: The reliance on methods similar to z-report checksum auditing presents its own set of challenges. Such methods, while useful in certain contexts, may not provide the comprehensive oversight necessary for these complex systems.

Difficulties in Data Replication: Replicating data across these systems poses significant challenges, particularly in ensuring consistency, precision, and maintenance of data integrity during the replication process.

Limitations in Data Utilization: Utilizing this data for ancillary purposes, such as optimization of marketing or delivery, is fraught with difficulties. The data's structure and accessibility issues often make it unsuitable for such applications.

Complexities in Multi-Stakeholder Optimization: Optimizing these systems for multiple stakeholders is a complex undertaking. The diverse and often conflicting requirements of different stakeholders add layers of complexity to the optimization process.

3. Taking a Step Further: Blockchain-Based Database Advancements

The use of cryptographic protocols such as ”Public Key Encryption with Keyword Search” as elucidated in [5] simplifies the landscape of common database utilization and data sharing. This technology eliminates the intricacies associated with data access permissions, rendering database and data sharing accessible and straightforward.

Blockchain-Based Databases represent a cutting-edge solution in the realm of data management. One prominent attribute of this technology lies in its ability to ensure enhanced immutability through the continuous chaining of blocks, secured by cryptographic links. This intricate process guarantees that data remain impervious to tampering, thus establishing an immutable historical record. Beyond simply safeguarding the integrity of stored data, it fosters a profound sense of trust in the precision and reliability of the archived information.

Furthermore, Blockchain-Based Databases offer an innovative avenue for record sharing, achieved through the implementation of searchable attribute-based encryption. This sophisticated approach empowers data owners to encrypt records, specifying unique attributes. Authorized entities possessing corresponding attributes can then efficiently retrieve and interact with the encrypted data. This level of granularity in controlling data access not only augments privacy protection but also guarantees that only pre-designated individuals or entities possess the capability to engage with sensitive records. In essence, Blockchain-Based Databases present a significant step forward in the arena of data management, promising increased immutability and secure, tailored record sharing via attribute-based encryption.

1) **Enhanced Immutability through Cryptographically Chained Blocks:** The continuous chaining of blocks in a blockchain ensures an unparalleled level of immutability. The cryptographic link between blocks creates a secure and transparent historical record. This not only safeguards the integrity of the data against tampering but also provides an auditable and unchangeable history, instilling a high degree of confidence in the accuracy and reliability of stored information.
2) **Innovative Record Sharing Enabled by Searchable Attribute-Based Encryption:** The implementation of searchable attribute-based encryption (ABE) takes record sharing to a new level. This approach allows data owners to encrypt records with specific attributes, and authorized parties possessing matching attributes can efficiently search and access encrypted information. This fine-grained control over data access enhances privacy, ensuring that only designated individuals or entities can retrieve and interact with sensitive records.
3) **Decentralized Trust and Transparent Governance:** Going beyond traditional models, a Blockchain-Based Database embraces decentralized trust and transparent governance. The distributed nature of blockchain technology removes the need for central authorities, fostering trust among participants. Transparent and consensus-driven decision making ensures that database operations are collectively validated by the network, creating a system where trust is distributed and governance is democratic.
4) **Elevated Security and Trust:** The cryptographic foundation of the blockchain significantly increases security levels. Decentralized consensus mechanisms, coupled with robust encryption standards, create a secure environment resistant to malicious attacks. Participants can trust the system's integrity, knowing that the data is protected by advanced cryptographic measures and that any changes are subject to consensus verification.
5) **Smart Contracts Orchestrating Automated Processes:** The incorporation of smart contracts takes automation to new heights. These self-executing contracts, encoded within the blockchain, automate complex processes based on predefined conditions. This feature not only streamlines workflows, but also reduces the need for intermediaries, introducing a new era of efficiency, transparency, and reliability in business operations.

In summary, a Blockchain-Based Database extends the frontiers of data management, providing a robust foundation for unparalleled immutability, innovative record sharing, decentralized trust, enhanced security, and automated processes. This represents a significant step forward in reshaping how data is stored, shared, and governed, paving the way for a more secure, transparent, and efficient digital future.

In essence, the implementation of a common database with multiparty transaction recording transcends traditional data management practices, offering a robust solution that is efficient, versatile, and conducive to collaborative optimization in various dimensions of the industry.

Advancing further, the implementation of a common database with multi-party transaction recording simplifies data sharing, eliminating the need for data replication. This innovation not only enhances usability but also opens up various possibilities:

1) **No Replication of Data:** The shared database eliminates the redundancy seen in traditional systems, ensuring that data remain singular and authoritative. This not only minimizes the risk of inconsistencies but also streamlines data management.
2) **Versatility for Other Purposes:** Beyond its primary function, the shared database proves to be adaptable for diverse applications such as marketing and delivery optimization. The consolidated data serves as a valuable resource for extracting insights and refining operational strategies.
3) **Multi-Stakeholder and Sector-Wide Optimization:** The user-friendly nature of the shared database extends beyond individual use, facilitating collaboration among multiple stakeholders. This collaborative environment enables seamless engagement and shared insights, fostering optimization not only at the organizational level but also sector-wide.
4) **Data Exchange Across Industry Layers:** The interconnected nature of the database allows for the smooth exchange of data between different layers of industries. This inter-industry data exchange contributes to a more integrated and responsive business ecosystem.

3.1. One Solution May be;

Privacy-Preserving Blockchain-Based Database: The development of a blockchain-based privacy-preserving database presents a novel solution to the challenges identified in traditional data management systems. This approach takes advantage of the inherent security and transparency features of blockchain technology, offering a more secure and efficient means of handling data. In order to employ such a solution, we may need Development of a Blockchain-Based Database: The key to this solution is the careful design and implementation of a blockchain framework tailored for database management. This involves integrating advanced cryptographic techniques to ensure data integrity and confidentiality while maintaining the functionality and accessibility of the database.

1) **Implementation of End-to-End Encryption:** Each transaction within the database would be safeguarded with end-to-end encryption, ensuring that data remains secure from the point of creation to its final destination. This encryption plays a crucial role in protecting sensitive information

from unauthorized access and potential security breaches.

2) **Efficient Keyword Search Over Encrypted Data:** A significant feature of this proposed system is the ability to conduct efficient keyword searches over encrypted data. This functionality addresses the common trade-off between data security and usability, enabling users to effectively query encrypted information without compromising privacy.The research conducted by Jiang et al. (2019) [6] supports the feasibility of this solution, demonstrating how blockchain technology can be effectively utilized for creating a secure, privacy-preserving database. Their findings highlight the potential for blockchain-based systems to revolutionize data management practices, particularly in addressing privacy and security concerns.

3.2. Simpler and More Versatile Solution May be;

However instead of employing highly sophisticated cryptographic tools within conventional databases or blockchain-based databases, another efficient approach may be smart contracts or similar tools may be much more versatile and much more promising.

4. Adding Attributes to the Scheme

Embedding 'data collection and carbon credit payment terminals' within retail stores, resembling the POS terminals used for credit cards, and integrating blockchain technology can revolutionize the way transactions are conducted. This approach not only streamlines the process of carbon credit payments, but also ensures transparency and seamlessness, similar to the widely adopted credit card transactions in retail environments.

The integration of blockchain technology within this system architecture brings forth essential features such as immutability, transparency, and trust. Blockchain's decentralized and tamper-resistant nature guarantees that carbon footprint data and associated transactions remain unaltered, providing a reliable and secure foundation. This instills confidence in both consumers and businesses, creating an environment of trust in the integrity of carbon-related information.

Moreover, this innovative system directs consumers to be actively involved in the reduction of their carbon footprints. By making carbon credit payments and transactions visible and traceable through blockchain, individuals gain a clearer understanding of their environmental impact. This awareness created by the system can lead to more conscious and environmentally friendly choices, aligning with the global push for eco-friendly practices. In essence, the integration of 'data collection and carbon credit payment terminals' with blockchain technology not only enhances the efficiency of transactions in retail areas but also contributes to a broader societal goal. Encourages environmental responsibility and active participation in sustainable practices, reflecting a commitment to building a greener and more sustainable future.

The foundational structure of the system is built on blockchain technology, with the entire operation seamlessly integrated into a blockchain framework. The use of blockchain ensures a decentralized and secure environment for all transactions and data exchanges within the system. This architecture brings several advantages, including immutability, transparency, and enhanced trust in the integrity of carbon footprint data and transactions. The utilization of tokens and smart contracts further streamlines and standardizes data exchange processes, providing a robust and efficient mechanism for handling transactions. It also ensures the reliability of the entire system.

Within this blockchain-based system, all data exchanges are facilitated through tokens and smart contracts. Tokens serve as a digital representation of carbon footprint values, enabling users to make payments and engage in various environmental activities. Smart contracts, encoded within the blockchain, automate and enforce the terms of transactions, ensuring that they are executed securely and efficiently. This innovative approach not only enhances the reliability of data exchange but also promotes a decentralized and transparent ecosystem, aligning with the principles of sustainability and efficiency that underscore the entire system's design.

5. Details of System Structure and Roles of Main Stakeholders

The proposed system emphasizes the management of carbon footprints through smart contracts and blockchain tokens. The blockchain serves as an immutable ledger, precisely documenting carbon transactions to ensure traceability. This enables users to track their carbon footprint and token balance in digital wallets. Furthermore, it incentivizes environmentally friendly actions, such as reforestation or support for renewable energy, by providing additional carbon tokens. Blockchain integration ensures the dependability and transparency of this system, encouraging consumer participation in sustainability. The system includes Environmental Activity Validation and Token Rewards, where users earn tokens for verified green initiatives such as tree planting, recycling, or renewable energy adoption. Validaters, including environmental organizations, authenticate these activities and distribute rewards. This mechanism fosters sustainable behaviors and establishes accountability. Additionally, Carbon Tracking and Offset form the system's core, using blockchain to accurately and permanently record carbon transactions. Users gain insights into their carbon usage and token balances transparently. They can also partake in environmental activities to earn tokens. This holistic approach empowers individuals to manage their carbon impact while promoting collective responsibility for sustainability. Ultimately, the system operates as a comprehensive ecosystem linking producers and consumers via blockchain. Smart contracts and tokens ensure secure, transparent exchanges, with features like Activity Validation, Token Rewards, and Carbon Tracking advancing sustainable practices and awareness. Below are summaries of the Proposed System Stakeholder Roles.

5.0.1. The Role of The Producers. The proposed system relies on producers to establish their products' carbon footprints by adhering to the guidelines of the International Certification Institute (ICI). This process evaluates

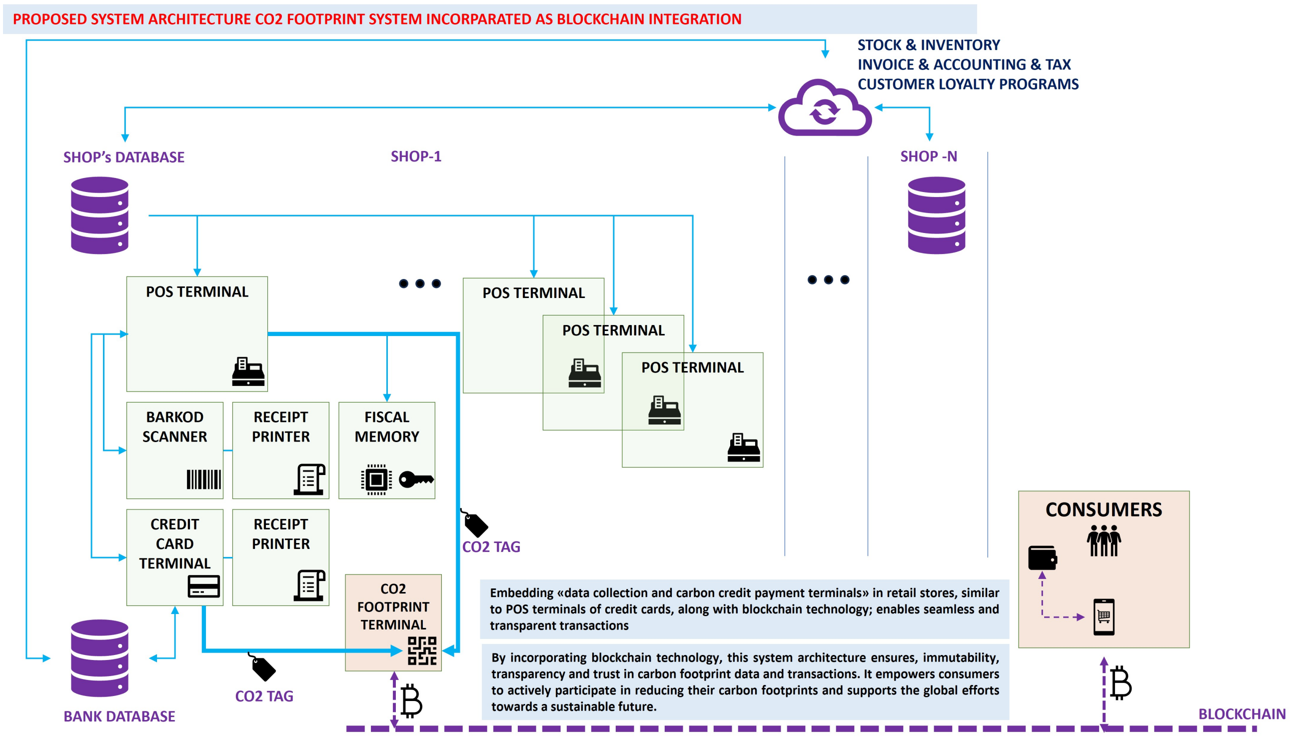

Figure 3. Proposed System Architecture Co2 Footprint System Incorparated As Blockchain Integration

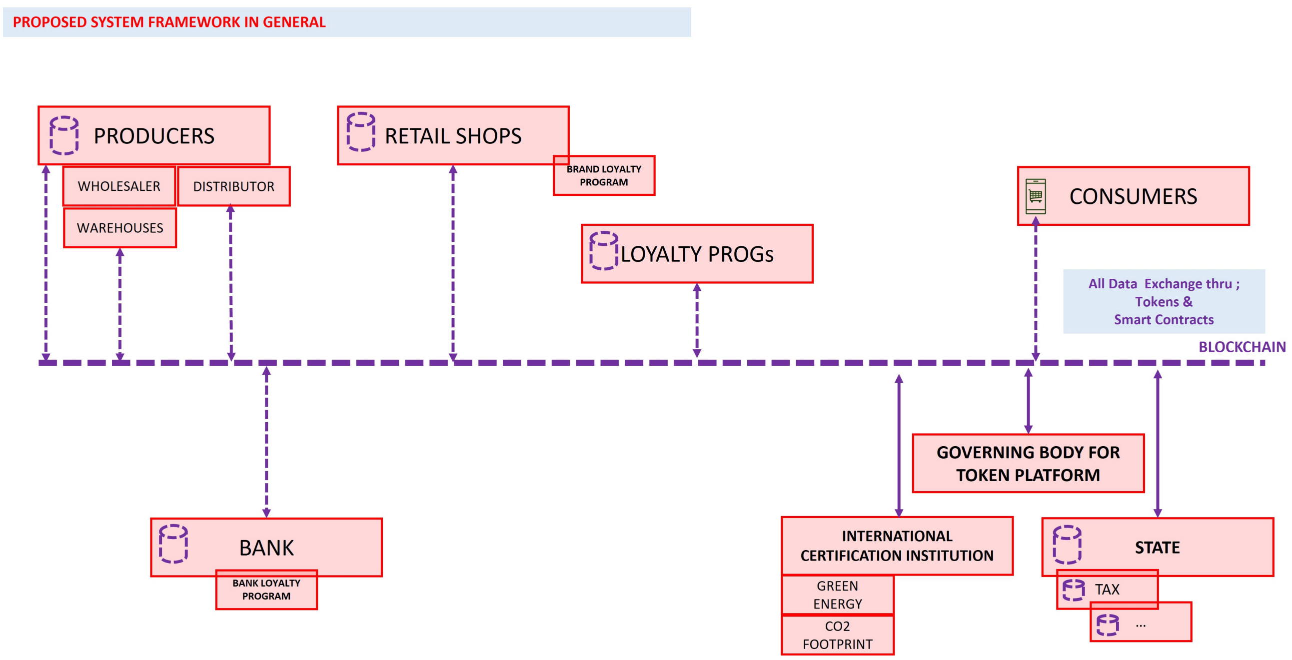

Figure 4. Proposed System Framework In General

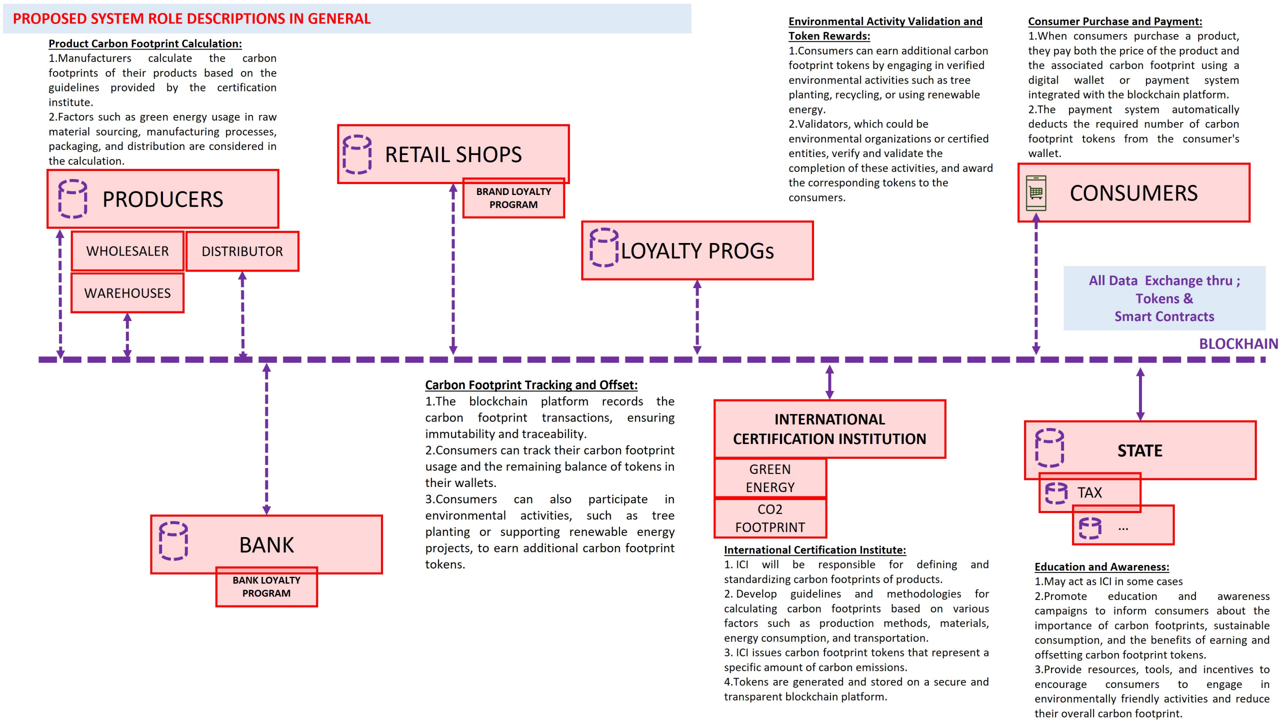

Figure 5. Proposed System Role Descriptions In General

aspects such as the use of green energy in sourcing, manufacturing, packaging, and distribution, aiming to deliver precise data on environmental impacts. Manufacturers calculate the carbon footprint of their products using ICI criteria, focusing on the integration of green energy across raw material extraction, manufacturing, eco-friendly packaging, and sustainable distribution to determine environmental impacts.

5.0.2. Role of International Certification Institution. The International Certification Institute (ICI) sets carbon footprint standards, develops calculation guidelines, and issues blockchain-traceable tokens representing carbon emissions.

1) Definition and standardization of carbon footprints by ICI
2) Development of guidelines and methodologies for calculating carbon footprints
3) Consideration of factors like production methods, materials, energy consumption, and transportation
4) Issuance of carbon footprint tokens by ICI
5) Generation and secure storage of tokens on a transparent blockchain platform

5.0.3. The Role of The State. The system uses blockchain to reward eco-friendly actions with carbon tokens, verified by environmental organizations, while also enabling carbon tracking and promoting sustainability education.

5.1. Role Description And Functions of the Governing Body

The regulatory authority enhances the carbon footprint token ecosystem's efficacy by controlling token issuance to reflect carbon emissions, maintaining a fixed supply, and regulating conversion rates to avert inflation. By partnering with carbon offset initiatives, it facilitates emission reductions, while blockchain technology guarantees transaction transparency and security. Furthermore, it fosters awareness via educational initiatives and collaborates with regulators to uphold the system's integrity. Main function are:

1) Token Issuance
2) Token Supply and Distribution
3) Token Conversion Rate
4) Token Redemption and Offset
5) Token Utility and Rewards
6) Token Burning
7) Carbon Credit Trading
8) Transparency and Auditing
9) Education and Awareness
10) Regulatory Compliance

5.2. Role Description And Functions For Consumers

In the proposed system, consumers are integral as they engage in the purchasing and payment process. Upon buying a product, they pay both the product price and its carbon footprint cost using a digital wallet or payment system linked to a blockchain platform. This system automatically deducts the needed carbon footprint tokens from

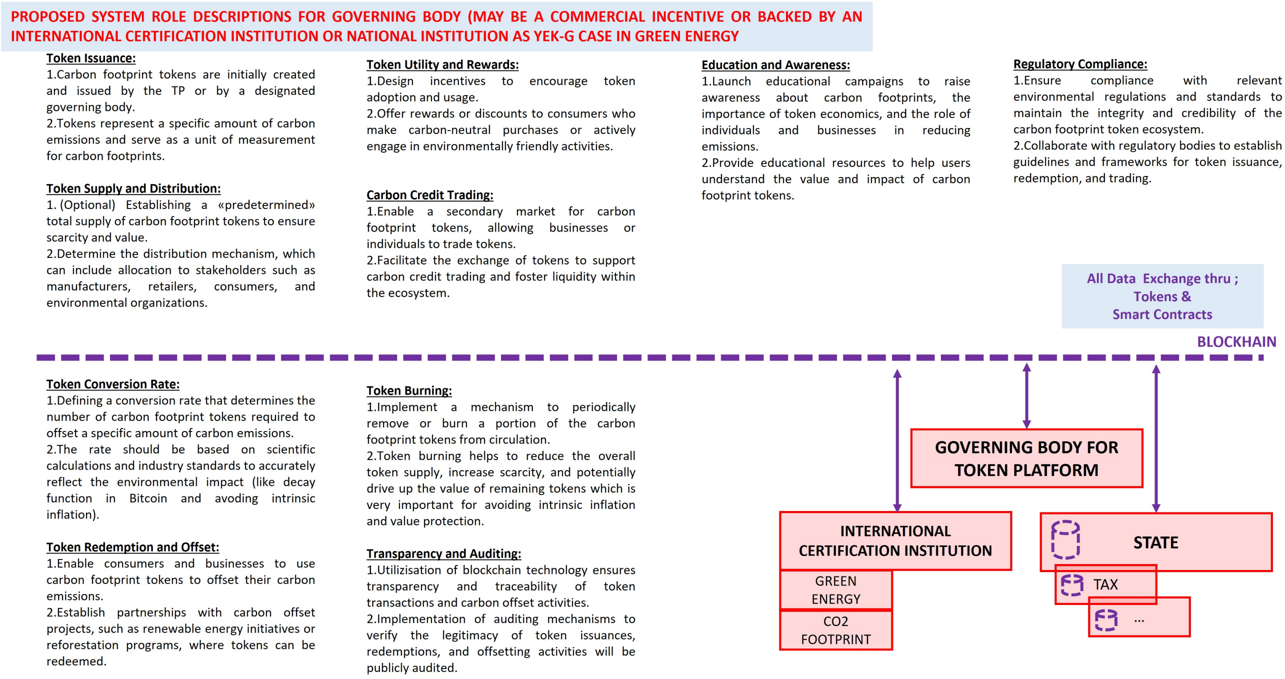

Figure 6. Proposed System Role Descriptions For Governing Body

the consumer's wallet, aiding in the tracking and offsetting of carbon emissions.

1) Environmental Activity Validation and Token Rewards
2) Carbon Credit Redemption and Offset
3) Consumer Purchase and Payment
4) Product Carbon Footprint Calculation
5) Carbon Footprint Tracking and Offset
6) Carbon Footprint Token Generation
7) Blockchain Platform Implementation

5.3. Role Description And Functions For Retail Shops

Retailers play a pivotal role in the carbon token ecosystem by engaging in data gathering and carbon footprint assessments. They utilize systems similar to POS to record the necessary product information to calculate carbon footprints per transaction. Integrated within retail operations, carbon credit payment mechanisms allow customers to utilize digital wallets to address carbon footprints along with their purchases. In addition, stores promote sustainability by involving consumers in validated activities such as tree planting and recycling, authenticated by entities such as environmental organizations or certified agencies. These validaters certify activities and allocate tokens, fostering environmental stewardship. At points of sale, both product costs and carbon footprints are concurrently computed, underpinned by blockchain technology that protects transaction records, carbon data, and credit transfers, ensuring the ecosystem's transparency and dependability. Furthermore, real-time reporting of carbon footprints and transactions offered by retailers enhances the understanding of the system, allowing stakeholders, both outlets and consumers, to generate detailed reports, thus increasing accountability and environmental awareness.

1) Data Collection and Carbon Footprint Calculation
2) Carbon Credit Payment Terminals
3) Environmental Activity Validation and Token Rewards
4) Consumer Purchase and Payment
5) Blockchain Integration
6) Reporting and Transparency

6. Suitable Blockchains

6.1. Overview

The choice of a blockchain platform for carbon footprint tracking and offset applications plays a pivotal role in shaping the efficiency, security, and scalability of the system. **For interoperability and global-level scalability of carbon footprint application, we will need a fungible Utility Token in a public blockchain.**

Each blockchain offers different features, and careful consideration is essential to align these features with specific project requirements. Here, we provide a brief summary of some prominent blockchain options and their considerations for use in carbon footprint management.

In the rapidly evolving landscape of blockchain technology, **Ethereum** comes to mind as its well-established ecosystem and robust smart contract capabilities. However, challenges related to scalability and transaction fees during peak demand periods are important considerations. **Hyperledger Fabric**, tailored for enterprise solutions, emphasizes privacy and scalability with its permissioned network and modular consensus protocols. Although suitable for permissioned environments, it may require a more complex setup compared to public blockchains.

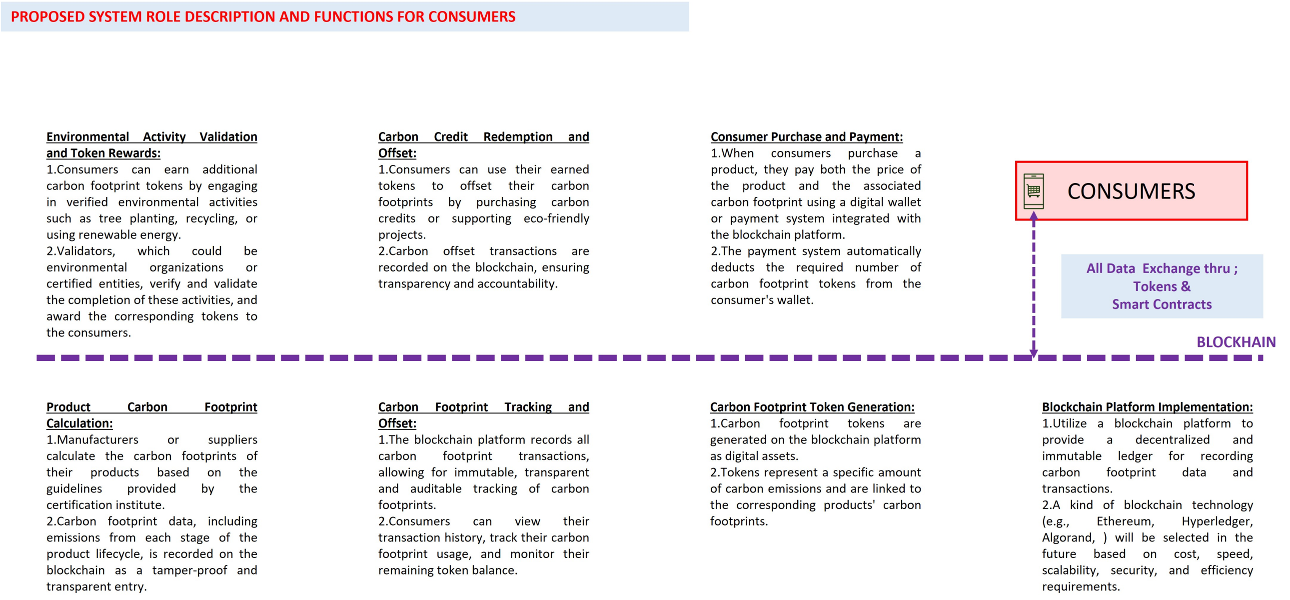

Figure 7. Proposed System Role Description And Functions For Consumers

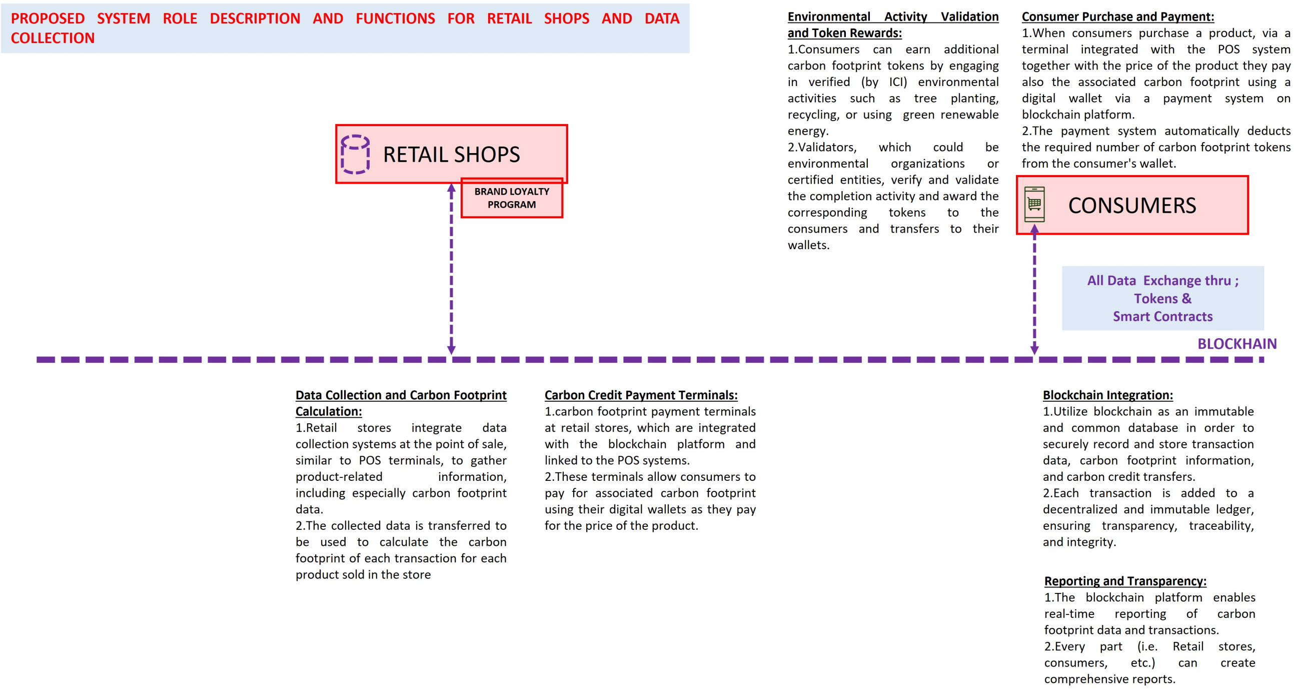

Figure 8. Proposed System Role Description And Functions For Retail Shops And Data Collection

In addition, for interstate or global-level applications, a hyperledger fabric may not be the best solution. **Algorand**, known for high throughput and rapid transaction finality, employs a pure proof-of-stake mechanism for enhanced energy efficiency. However, its relative youth in the blockchain space and the evolving support of the ecosystem are factors to consider. **Polkadot** focuses on interoperability and support for specialized functionality in parachains, offering scalability and customization. However, its complexity and the need for a well-defined ecosystem might impact ease of adoption. **Tezos**, with on-chain governance and formal verification, improves security and allows stakeholders to participate in protocol upgrades. However, its ecosystem may not be as extensive as more established platforms. **Avalanche**, recognized for its subsecond finality, provides a highly scalable platform with a unique consensus mechanism. Its approach to achieving decentralization and high throughput sets it apart, making it suitable for applications with stringent performance requirements.

6.2. Choosing the Right Blockchain

The landscape of blockchain technology offers a diverse range of platforms, each with its unique features and considerations. When selecting the most suitable blockchain for carbon footprint tracking and offset applications, project requirements, scalability, security, and ecosystem support play an essential role. Here is a summarized overview of the considerations for the six discussed blockchains.

1) **Ethereum:** With a well-established ecosystem and smart contract capabilities, Ethereum is a robust choice for projects that emphasize security and decentralization. However, scalability challenges and transaction fees during peak demand periods may impact its efficiency and cost-effectiveness.
2) **Hyperledger Fabric:** Tailored for enterprise solutions, Hyperledger Fabric prioritizes privacy and scalability with its permissioned network. Although suitable for permissioned environments, its setup may be more complex compared to public blockchains.
3) **Algorand:** Known for high throughput and rapid transaction finality, Algorand's pure proof-of-stake mechanism enhances energy efficiency. However, its relative youth in the blockchain space may influence adoption and ecosystem support is evolving.
4) **Polkadot:** Focused on interoperability and parachains, Polkadot offers scalability and customization. However, its complexity and the need for a well-defined ecosystem might impact ease of adoption.
5) **Tezos:** Boasting on-chain governance and formal verification, Tezos improves security. Although offering innovation, the ecosystem may not be as extensive as more established platforms.
6) **Avalanche:** With a new consensus protocol for high throughput and fast finality, Avalanche provides a flexible platform. Its recent entry into the blockchain space and customization complexity should be considered.

Other suitable candidates to be scrutinize would be Cardano, Stellar, EOS, or emerging blockchains like Hedera Hashgraph, Neo, Vechain, Nano, Solana.

In conclusion, the choice of the right blockchain for carbon footprint tracking and offset applications hinges on a careful evaluation of each platform's strengths, weaknesses, and alignment with project goals. Whether prioritizing decentralization, scalability, energy efficiency, or customization, a nuanced understanding of these blockchain options is crucial to ensuring the success and sustainability of carbon footprint management initiatives.

TABLE 1. BLOCKCHAIN COMPARISON

Blockchain	Type	Consensus	Smart Contracts	Interoperability	Governance	Energy Efficiency
Ethereum	Public	PoW to PoS	Yes	Limited	Decentralized	Moderate
Hyperledger Fabric	Permissioned	Pluggable	Chaincode	Limited	Configurable	Depends on Setup
Algorand	Public	Pure PoS	Yes	Limited	On-chain Voting	High
Polkadot	Heterogeneous	Nominated PoS	Yes	Yes	Referenda	Depends on Parachains
Tezos	Liquid PoS	LPos	Yes	Yes	On-chain Governance	High
Avalanche	Permissioned/Public	Avalanche	Yes	Yes	On-chain Governance	High

TABLE 2. SUMMARY OF TRANSACTION SPEED, FINALITY, AND TRANSACTION COST FOR DIFFERENT BLOCKCHAINS.

Blockchain	Transaction Speed	Finality	Transaction Cost
Ethereum	Moderate (15-45 seconds)	Probabilistic Finality	Variable, influenced by network congestion
Hyperledger Fabric	High (within seconds)	Depends on consensus algorithm	Low, suitable for enterprise solutions
Algorand	Very High (5 seconds)	Fast and Irreversible	Low, scalable and energy-efficient
Polkadot	High (within seconds)	Depends on relay chain and parachain consensus	Variable, influenced by relay chain and parachain mechanisms
Tezos	Moderate to High (15-30 seconds)	Depends on consensus	Adjustable through governance, generally moderate
Avalanche	Very High (few seconds)	Fast and Irreversible	Low, scalable and energy-efficient

7. Conclusion

This article has examined the necessity of using a blockchain-based database and its tools in carbon footprint tracking and management systems. And also Blockchain's Role in Carbon Footprint Management. Since carbon footprint is one of the basic attributes of the product, like price, it can be manageable if only we use a blockchain-based database system and its tools. We may not hold carbon footprint traction system with a conventional comparmantized data silos. It is an attribute of any product.

Other kind of such general attributes seem to come into our lives in the near future. All kind of such general attributes can only be manageable by token economics and blockchain-based systems. We may manage all such kind of applications with utility tokens.

Through an analysis of various blockchain architectures, including Ethereum, Hyperledger Fabric, Algorand, Polkadot, Tezos, and Avalanche, this research illuminates the potential of these platforms in addressing one of the intricate challenges of environmental sustainability.

Ethereum's Pioneering Role and Limitations: Ethereum comes to one's mind as a frontrunner in the realm of decentralized applications, offering smart contract capabilities essential for implementing secure and transparent carbon management systems. However, its scalability challenges and fluctuating transaction costs underscore the need for ongoing technological advances to enhance its efficiency in large-scale applications. Besides, Ethereum is self-contrary in such applications. The reason is that Ethereum became a storage of value and matter for market players instead of becoming a solution to real-life problems. Its price is increasing, so the cost of transaction. Therefore, in the short term Ethereum cannot be used as a tool for real-life problems.

Hyperledger Fabric's Enterprise-Grade Solutions: Hyperledger Fabric's permissioned blockchain architecture presents a tailored solution for state-level carbon management, prioritizing data privacy and scalability. The modular design of this platform offers a customizable approach, particularly suitable for complex organizational structures requiring stringent data control. However, we need a global solution. Hyperledger fabric eliminates data silos and comparison at company-level but only up to state-sized scales, which is not sufficient.

Algorand's Efficiency and Scalability: Algorand's pure proof-of-stake mechanism distinguishes itself with high throughput and rapid transaction finality, presenting an energy-efficient option for carbon footprint tracking. However, its long-term adoption and community support is questionable.

Polkadot and Tezos - Niche Innovations: Polkadot's focus on interoperability and Tezos's on-chain governance bring unique perspectives to blockchain applications on global level. These platforms offer specialized functionalities that can enhance collaborative efforts and community-driven initiatives in carbon footprint management. Polkadot seems to be one of the suitable solutions, but still has the transaction cost fluctuations.

Avalanche's Cutting-Edge Consensus Protocol: The Avalanche platform, with its novel consensus mechanism, offers a promising solution for high-throughput and rapid finality requirements in carbon footprint tracking. Its recent introduction to the market suggests a potential for significant impact, albeit with considerations for its evolving ecosystem. Among other blockchains, Avalanche seems to be the best candidate for such an application.

In brief we will need a governed global level, with very high finality and very low transaction costs.

Integrating Blockchain for Enhanced Environmental Stewardship: The integration of blockchain technology into carbon management represents a paradigm shift in how an attribute of a product is tracked, audited and shared. By providing immutable, transparent, and secure platforms, blockchain technology fosters a new level of trust and collaboration among stakeholders, including businesses, consumers, and regulatory bodies at the interstate and global levels. This technology enables more accurate tracking of carbon footprints, streamlines the carbon credit trading process, and facilitates the verification of sustainable practices.

Future Directions and Challenges: The future trajectory of blockchain in environmental sustainability hinges on overcoming current limitations, such as scalability, energy consumption, and integration of these technologies into existing infrastructures. Continued research and development are imperative to refine blockchain solutions, ensuring that they are not only technologically advanced but also accessible and practical for widespread adoption.

Policy Implications and Regulatory Frameworks: This research highlights the need for supportive policy frameworks and regulatory guidelines that encourage the adoption of blockchain technologies in environmental management. Policymakers and industry leaders must collaborate to establish standards and protocols that facilitate the seamless integration of blockchain into existing environmental management systems. Such collaborative efforts will be crucial in realizing the full potential of blockchain in driving sustainable practices and reducing global carbon footprints.

Concluding Remarks: This article studies the potential of blockchain technology as a building block, seeking feasible solutions to a growing global need. The capabilities of different blockchain platforms provide a rich spectrum of options for addressing the multifaceted challenges of managing carbon footprints. Blockchain technology seems to be a beacon of innovation, offering scalable, secure, and transparent solutions for a more sustainable future. This research contributes to the growing body of knowledge in this domain and lays the groundwork for future explorations of the synergistic potential of blockchain technology and environmental sustainability. Finality, energy efficiency, and transaction fees appear to be the most important features, but safety, security, and resilience come deep from the consensus protocol. Therefore, the most important concern remains the consensus protocol, and creating a well-governed one is actually the biggest challenge to overcome.

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