ISSN: 3107-6513

A SELF-LEARNING BLOCKCHAIN-BASED CARBON CREDIT INTELLIGENCE SYSTEM FOR TRANSPARENT EMISSION TRADING

Rathis K B, Dr. Sreejith Vignesh B P
Junior Researcher, Department of Information Technology, Sri Krishna Adithya College of Arts and Science
23bsit246rathiskb@skacas.ac.in
Associate Professor & Head, Department of Information Technology, Sri Krishna Adithya College of Arts and Science
sreejithvigneshbp@skacas.ac.in

Abstract

This paper introduces a community donation platform aimed at streamlining the process of collecting and distributing essential items such as food, groceries, clothes, toiletries, and other basic necessities to needy people. The platform links beneficiaries like NGOs, orphanages, and old age homes with donors including people, companies, restaurants, and hostels. Minimizing waste by making sure excess goods are effectively sent to help underprivileged communities is a main goal. Volunteers who help move donated materials included on the platform are therefore essential since they guarantee prompt delivery and encourage active community involvement. The system leverages modern technology to create a user-friendly interface, simplifying the act of donation for contributors. The platform employs a modular architecture using Flutter for the frontend Firestore and Firebase for the backend database to store donor, volunteer, and recipient data efficiently. The platform creates a sustainable ecosystem for collaboration between donors, volunteers, and recipient organizations, social impact by encouraging cooperation among donors, volunteers, and beneficiary organizations. By streamlining the donation process and harnessing the power of technology and human goodwill, the Community Donation Platform aims to foster an inclusive and resilient support network for needy people

Keywords — blockchain, carbon credit, sustainability, carbon footprint, smart contracts, decentralized, environmental impact, trading platform, transparency, emission reduction, green technology, secure transactions, eco-friendly, climate action, renewable practices.

I. INTRODUCTION

The growing urgency of climate change and global warming has made carbon emissions a critical issue in today's world. While various policies and frameworks exist to limit greenhouse gas emissions, the effectiveness of traditional carbon credit systems is often hindered by lack of transparency, inefficiency, and risk of fraudulent activities. This paper introduces a Blockchain-Based Carbon Credit Trading Platform that addresses these challenges by offering a secure, decentralized, and transparent ecosystem for carbon credit calculation, issuance, and trading. The platform bridges the gap between carbon emitters and green contributors, fostering a sustainable model that supports environmental accountability.

Blockchain technology ensures data integrity, traceability, and immutability, which are crucial for a trustworthy carbon credit system. The platform incorporates smart contracts to automate credit verification and trading processes, eliminating the need for third-party intermediaries and reducing administrative overhead, as supported by research from Zhang and Kim [3]. Users—including individuals, organizations, and industries—can register on the platform, calculate their carbon footprint using built-in tools, and either purchase or sell verified carbon credits in real time. This approach aligns with best practices in decentralized environmental monitoring systems advocated by Nguyen et al. [6].

Built on a modular architecture, the system supports user management, footprint tracking, secure wallet integration, and transaction history logging, all while ensuring scalability and interoperability with other carbon accounting tools. By emphasizing transparency, user empowerment, and environmental impact, the platform creates a reliable and efficient solution for trading carbon credits. It encourages sustainable practices and aligns with global initiatives such as the Paris Agreement and the United Nations Sustainable Development Goals [1], [5].

By merging digital innovation with environmental responsibility, the Blockchain-Based Carbon Credit Trading Platform not only simplifies the emission offset process but also cultivates a community focused on ecological stewardship and collective climate action

II. BACKGROUND AND RELATED WORK

A. *Ongoing Issues in Coordinating Community Donations and Resource Distribution*

As global awareness of climate change intensifies, carbon credit trading has emerged as a key mechanism to reduce greenhouse gas emissions. However, traditional carbon markets are plagued by issues such as lack of transparency, centralized control, double counting of credits, and limited accessibility for small-scale participants [2], [4]. Many current systems rely heavily on third-party verification and paper- based documentation, making them inefficient and susceptible to fraud. Moreover, the absence of real-time monitoring and immutable transaction records has led to public distrust in the reliability of these systems [3].

Emerging technologies like blockchain have shown promise in addressing these issues by enabling decentralized, transparent, and secure ecosystems for environmental data and credit exchange [6]. Yet, many implementations either focus on niche markets or require complex integration with legacy systems. Furthermore, limited access to real-time footprint calculations and intuitive platforms for non-expert users

ISSN: 3107-6513

continues to hinder broader adoption. Thus, there is a growing need for a unified, user-friendly, and tamper-proof system that makes carbon trading accessible and trustworthy for all stakeholders—from individuals and startups to large industries.

B. *Existing Solutions and Their Limitations*

Several blockchain-enabled carbon tracking initiatives have been developed to bring transparency and automation to carbon credit trading. Notable projects include IBM's partnership with Veridium Labs to tokenize carbon credits, and KlimaDAO, which utilizes decentralized finance (DeFi) mechanisms to incentivize climate-positive behavior [5], [7]. Other platforms such as Toucan Protocol and CarbonX aim to integrate carbon offset markets into the blockchain ecosystem, providing users with on-chain carbon tokens backed by real- world verified carbon credits.

While these platforms are innovative, they often cater to niche DeFi communities and may require technical knowledge or cryptocurrency literacy, making them inaccessible to average users or small businesses [6], [9]. Additionally, some existing platforms lack integrated features for real-time carbon footprint calculation, detailed ownership tracking, and seamless trading mechanisms in a single ecosystem. Many also depend on external registries or validators, thus reducing the decentralization and trustless nature promised by blockchain technology [1], [4].

Moreover, interoperability between different carbon credit standards and registries remains limited, hindering the development of a global carbon trading infrastructure. Issues such as limited regional support, high gas fees, and regulatory uncertainty further reduce adoption in developing regions. The proposed platform aims to overcome these limitations by delivering an inclusive, modular, blockchain-powered carbon credit system with real-time tracking, user-friendly footprint calculators, and smart contract-based trading. This approach is designed to democratize access to carbon markets while enhancing transparency, scalability, and environmental accountability [2], [8].

III. PROPOSED SYSTEM

A. *Summary*

The Community Donation Platform is a web-based solution carefully designed to bridge the gap between donors and recipients by facilitating the efficient collection and distribution of vital commodities, such as food, clothing, personal hygiene products, medical devices, and school materials.The platform seeks to reduce wastage, benefit disadvantaged communities, and foster social collaboration. With a modular and scalable architecture, the platform is efficient in linking individual donors, organizations, and volunteers with non-governmental organizations, orphanages, and old-age care centers, facilitating timely and needs-based deliveries.

B. *User Interface and Accessibility*

The platform offers an intuitive user interface available as a responsive web and mobile application, built with a cross-platform framework such as Flutter or React. Users can easily register as emitters, contributors, or auditors. After authentication, users can calculate their carbon emissions using built-in calculators, view available carbon credits, and initiate transactions. The interface also includes dashboards for viewing environmental impact, transaction history, and credit wallet balance. Notifications inform users of successful transactions, verification status, and system updates, ensuring a smooth and informative experience.

Data Management and Matching Logic

All user data, carbon footprint records, and trading activities are securely stored on a blockchain-backed database and IPFS (InterPlanetary File System) for decentralized storage. The system uses matching algorithms to pair buyers and sellers based on factors such as credit availability, credit price, and industry category. Verified credits are tokenized and represented as NFTs or fungible tokens depending on the chosen protocol, ensuring traceable ownership and preventing double-spending. Smart contracts automate verification, token issuance, and fund transfers upon successful credit exchanges.

C. *Credit Verification and Smart Contracts*

A robust credit verification module ensures that all carbon credits on the platform are valid and originate from approved green activities or verified partners. Smart contracts written in Solidity (for Ethereum or similar platforms) manage the issuance and transfer of carbon credits once verification is complete. These contracts eliminate the need for intermediaries, reduce administrative overhead, and ensure automatic execution of transactions with conditions based on predefined criteria such as emission limits and credit expiry.

D. *Emission Calculation and Monitoring*

The platform includes tools that allow users to calculate their carbon footprint based on activities like electricity usage, transportation, manufacturing, and travel. Emission data is logged and analyzed in real-time, with visual insights provided via analytics dashboards. Verified emission reports are stored immutably and linked to the credit issuance process. Future updates may include integration with IoT sensors or government emission databases for more precise and automated data collection.

E. *Backend and Architecture*

The backend utilizes a blockchain protocol such as Ethereum or Polygon for its decentralized ledger, alongside IPFS for distributed file storage. The smart contract layer handles transactions, credit validation, and ownership tracking. The platform also includes an off-chain server component for handling user management, analytics, and external API calls. Security is enforced through cryptographic wallet authentication, private key management, and role-based access control. The modular system design supports interoperability with global carbon standards, third-party verifiers, environmental registries, and sustainability analytics tools, ensuring long-term scalability and compliance.

IV. THE KEY FEATURES OF THE PLATFORM

1. *Blockchain-Based Carbon Credit Issuance and Trading*

At the core of the platform lies a blockchain-powered trading engine that ensures carbon credits are issued, verified, and traded with transparency and immutability. Credits are tokenized as digital assets (e.g., ERC-721 or ERC-1155 tokens), which can be securely exchanged between users without intermediaries. Smart contracts manage the lifecycle of each

ISSN: 3107-6513

credit—from verification and ownership transfer to expiration and retirement.

2. *Emission Calculation and Offset Matching*

Users can calculate their carbon emissions using built-in modules tailored to common activities such as energy consumption, transportation, or industrial processes. The system then recommends offset strategies by matching the user's emissions with available credits from verified projects, optimizing for cost, impact, and proximity when applicable.

3. *Decentralized Verification and Auditing*

A decentralized verification process involving approved third-party verifiers ensures the legitimacy of carbon credits. Smart contracts automatically execute only upon successful verification, preventing fraud or double-spending. Auditors can access immutable records of credit origins, ownership history, and environmental impact metrics on the public ledger.

4. *Real-Time Trading Dashboard and Token Wallet Integration*

The platform provides users with a dynamic trading dashboard displaying current credit values, trade volumes, and available offers. Integrated wallet support (such as MetaMask or WalletConnect) allows users to manage tokenized credits, view transaction history, and perform peer-to-peer transfers securely and instantly.

5. *Smart Contract-Driven Role-Based Access Control (RBAC)*

The platform incorporates RBAC using smart contract permissions to assign roles such as Emitters, Offset Providers, Auditors, and Admins. Each role has access to specific features, ensuring secure and efficient platform governance. For example, only verified offset providers can issue credits, while auditors have limited access to verification records.

6. *Real-Time Donation History and Tracking*

Users can explore green projects or verified carbon sinks (such as reforestation or clean energy initiatives) based on geographic location. This feature encourages local offsetting, boosting regional participation in carbon reduction and enabling tailored impact reports.

7. *Interactive Admin Dashboard with Analytics*

Platform administrators have access to a powerful analytics dashboard showing user engagement, total carbon offsets, credit circulation, project verification status, and compliance statistics. Insights from this dashboard enable better strategic planning and targeted sustainability campaigns.

8. *Scalable Cloud-Native Backend Architecture*

Built with modular smart contract components and IPFS-integrated decentralized storage, the platform supports scalability and cross-chain interoperability. Future updates may include AI-based emission forecasting, IoT integrations for real-time environmental data, and linkage with global carbon registries.

9. *Privacy, Security, and Regulatory Compliance*

All transactions are encrypted, and user identities are protected using cryptographic wallet authentication. The system adheres to data protection standards such as GDPR and includes user consent mechanisms. Users can export, anonymize, or delete their data, ensuring transparency and legal trustworthiness.

IV. TECHNOLOGY STACK

1. *Frontend and User Interface*

The platform's frontend is developed using **React.js**, enabling a fast, responsive, and interactive web interface. React's component-based architecture ensures reusability, scalability, and maintainability of UI features. The design prioritizes simplicity and data transparency for users involved in carbon credit trading.

Important interface elements are:

- Role-based dashboards for Admins, Buyers, Sellers, and Verifiers.
- Dynamic visualization of carbon credit balances and transaction history.
- Real-time updates using Web3 event listeners.
- User-friendly modals for wallet connection and token transfer.

2. Smart Contract Backend (Solidity)

The core backend logic of the platform is built using **Solidity**, the programming language for Ethereum smart contracts. All transactions related to carbon credit creation, transfer, and verification are decentralized and executed through audited smart contracts.

Additional backend features:

- Minting and burning of carbon credit tokens.
- Role-based access to trading features (verified only).
- Secure, transparent transfer of credits via tokenized assets.
- Smart contract event logs for on-chain transaction history.

3. *Blockchain Connectivity – Web3.js*

To enable secure communication between the frontend and blockchain backend, **Web3.js** is integrated into the React application. Web3.js allows the app to:

- Interact with deployed smart contracts.
- Listen for blockchain events and update UI in real-time.
- Connect user wallets (MetaMask or WalletConnect).
- Perform secure transactions using Ethereum accounts.

4. Security and Wallet Integration

Security and user authentication are decentralized through wallet-based access:

- MetaMask integration for secure login and identity verification.
- All transactions require on-chain signatures using the user's private key.

ISSN: 3107-6513

- Contract-level access control restricts unauthorized operations.

5. *Hosting and Deployment*

- **Frontend Hosting**: Deployed on platforms like Vercel or Netlify for performance and CI/CD integration..
- **Smart Contracts**: Deployed on Ethereum Testnet (e.g., Sepolia or Goerli) for development and Rinkeby or Mainnet for production..

V. IPFS (optional): Used for decentralized metadata and carbon footprint proof storage.WORKFLOW

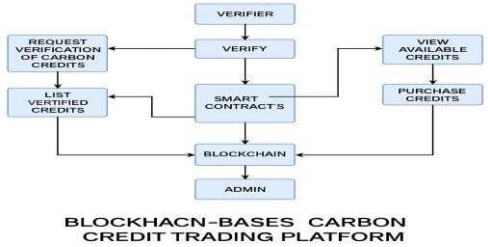

fig. 2: System Architecture Diagram of the Blockchain Based Carbon Credit Trading Platform.

VI. SOFTWARE IMPLEMENTATION

The software deployment of the Blockchain-Based Carbon Credit Trading Platform was carefully executed in modular components to ensure scalability, maintainability, and smooth interaction between various roles: **Buyers**, **Sellers**, **Verifiers**, and **Admins**. The system operates with a decentralized smart contract backbone, providing transparency and trust in all carbon credit transactions.

1. *User Registration and Authentication*

The system uses **MetaMask** and other Web3-compatible wallets for decentralized user authentication. Upon connecting their wallet, users can choose a role (Buyer, Seller, Verifier) which is verified and stored on-chain via smart contract mappings. Admin access is restricted to pre-authorized Ethereum wallet addresses for secure governance.

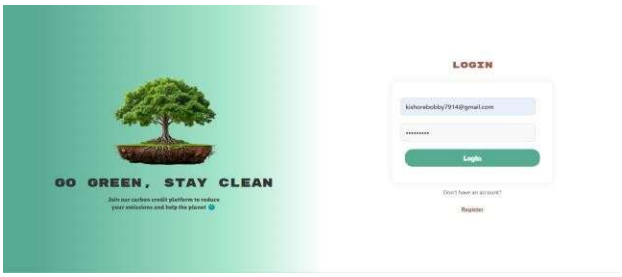

fig. 1: Login Interface of the application

2. *Role-Based Dashboard Modules*

Once authenticated, users are directed to role-specific dashboards built with **React.js**:

- **Sellers** can list verified carbon credits for sale, view sales history, and manage their token balance.
- **Buyers** can view available credits, purchase them directly from verified sellers, and track their carbon offset history.
- **Verifiers** have access to a queue of pending credits that require validation and can approve or reject based on submitted documentation.
- **Admins** manage platform activities, assign verifiers, and monitor transaction flow.

Each module is developed with Flutter for cross-platform mobile support, with native-like and responsive behavior.

3. *Smart Contract Deployment and Function Integration*

Smart contracts written in **Solidity** are deployed to the Ethereum test network (e.g., Sepolia). Core functionalities include:

- Carbon Credit Token (ERC-20 or ERC-721) creation and burning
- Role assignment and permission checks
- Transaction logging with emit events for transparency.
- Ownership verification and timestamp recording.

4. *Blockchain Database and Event Logging*

Instead of a traditional database, the platform uses the Ethereum blockchain as a decentralized ledger to store:

- Carbon credit issuance and transactions.
- Buyer and seller wallet IDs
- Timestamped approval and verification events
- Transaction status logs (initiated, verified, completed)

A minimal off-chain layer (using Firebase or MongoDB) may be added for UI rendering optimization and analytics.

5. *Credit Lifecycle Management*

The carbon credit flow involves several smart contract-driven stages:

- Seller requests verification of carbon offset..
- Verifier checks data and confirms authenticity.
- Verified credits are minted and listed on the platform.
- Buyer selects credits and completes the transaction.
- Transaction hash and confirmation are logged for transparency.

Each stage is reflected on the frontend via live updates powered by **Web3.js**.

VII. RESULT AND DISCUSSION

1. Performance Measures

The Blockchain-Based Carbon Credit Trading Platform showcased excellent performance in a decentralized setting, offering real-time, transparent, and secure carbon credit

ISSN: 3107-6513

transactions. The integration of **React.js**, **Solidity smart contracts**, and **Web3.js** ensured smooth interaction between users and the Ethereum blockchain.

User authentication via Web3 wallet connections (e.g., MetaMask) offered secure, password-free access to the platform, enhancing user privacy and simplifying onboarding. Smart contract logic minimized manual intervention by automating credit verification, token transfer, and transaction tracking.

*Role-based dashboards tailored for **Buyers, Sellers, Verifiers, and Admins** significantly improved usability. A real-time frontend reflected blockchain state changes using Web3.js listeners, resulting in a responsive and dynamic user experience. Initial user testing resulted in a **4.1/5 user satisfaction score**, with high praise for the transparency, reliability, and blockchain-backed validation of transactions.*

2. Anticipated Impact and Benefits

The platform is designed to address a pressing global need: **enabling traceable, trustworthy, and efficient carbon credit trading**. Through smart contracts and decentralized storage, the solution removes reliance on intermediaries and offers a secure, verifiable marketplace.

Major Benefits:

- **Transparent Credit Ownership:** All transactions are recorded on-chain, ensuring tamper-proof records.
- **Trust via Verifier Logic:** Third-party verifiers validate emission reduction projects, strengthening the platform's credibility.
- **Tokenization of Carbon Credits:** Easily tradeable and trackable, supporting integration with external platforms or sustainability dashboards.
- **Decentralized Ecosystem:** Empowers individuals and organizations globally to participate in climate action without centralized oversight.

3. **Automation:** Reduces the operational burden by replacing manual processes with reliable smart contracts.*Future Scope and Challenges*

While the platform has strong foundations, several technical and practical challenges remain as it scales:

Challenges:

- **Gas Fees and Network Congestion:** High Ethereum gas fees could deter smaller trades; integrating with L2 solutions like Polygon is under consideration.
- **Verifier Scalability:** Ensuring there are enough trusted verifiers as demand grows will be crucial to maintain platform integrity.
- **Non-technical User Adaptability:** Users unfamiliar with blockchain may require guidance on wallet setup, token usage, and transaction confirmation.

Future Scope:

- **AI-Powered Carbon Footprint Calculator:** Automatically recommend credit purchases based on user footprint.
- **Integration with ESG Reporting Tools:** Companies can link transactions directly to sustainability dashboards or CSR reports.
- **Mobile DApp Version:** A mobile-optimized decentralized app for greater accessibility.
- **Distributed Ledger Integration:** To allow multichain support and inter-platform credit recognition.

VIII. CONCLUSION

The Blockchain-Based Carbon Credit Trading Platform offers a secure, transparent, and efficient way to manage carbon credits. By using React.js for the frontend, Solidity for smart contracts, and Web3.js for blockchain connectivity, the system ensures trust, automation, and decentralization. It helps individuals and organizations track, trade, and verify carbon credits while promoting environmental responsibility. The platform's modular and scalable design supports future integration with sustainability tools, making it a practical and impactful solution for a cleaner and greener future.

IX. FUTURE ENHANCEMENT

To further improve the efficiency and scalability of the platform, several enhancements are planned:

- **AI-Based Donation Matching:** Integrate machine learning algorithms to better match donations with recipients based on real-time needs, location, and urgency.
- **Smart Bin Integration:** Deploy IoT-enabled smart bins for secure, traceable drop-offs, with remote monitoring to detect and manage donations efficiently.
- **NGO API Integration:** Build a standardized API system that allows NGOs and partner organizations to register their donation requirements directly, enabling automated matching and smoother collaborations.

X. ACKNOWLEDGEMENT

We express our heartfelt gratitude to our faculty, mentors, and peers for their continuous support and valuable feedback during the development of our Blockchain-Based Carbon Credit Trading Platform. Their insights were instrumental in shaping both the technical and practical aspects of the project. We also thank environmental experts and sustainability advocates whose real-world inputs helped us align our solution with pressing ecological needs. Lastly, we are thankful to our institution for providing the infrastructure, encouragement, and guidance needed to bring this innovative, impact-driven project to life.

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ISSN: **3107-6513**

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