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AI BASED CARBON CREDIT AUTHENTICATION, FOOTPRINT CALCULATION AND TRANSACTION VERIFICATION SYSTEM

V.Keerthiga[1], Vinoth Kumar.P[2], Vishnu.R[3]

Assistant Professor, Department of Computer Science and Engineering,Anand Institute of Higher Technology, kazhipattur, Chennai[1]

Student, Department of Computer Science and Engineering,Anand Institute of Higher Technology, kazhipattur, Chennai[2,3]

Abstract: The increasing need for transparent and efficient carbon credit markets has led to the exploration of **Artificial Intelligence (AI)** to address fraud, double-counting, and inefficiency in traditional carbon credit trading systems. This paper proposes an **AI-based** carbon credit trading system that leverages **machine learning and predictive analytics** to provide a transparent, secure, and automated marketplace for buying and selling carbon credits. Through the use of **AI-driven smart algorithms**, the system automates the issuance, verification, and trading of carbon credits, reducing transaction costs and eliminating intermediaries. The system ensures that each carbon credit represents a verified and actual reduction in emissions by employing **AI-powered data validation and anomaly detection**, offering real-time tracking and traceability. Furthermore, the advanced analytical capabilities of **AI** promote inclusivity, enabling a broader range of participants to engage in emission reduction efforts. This system not only fosters environmental accountability but also drives global sustainability by providing an accessible, cost-effective, and scalable solution to meet emission reduction targets and combat climate change.

Keywords: Artificial Intelligence, Carbon Credit Trading, Smart Contracts, Transparency, Machine Learning.

I. INTRODUCTION

The Enhanced Carbon Credit System leverages advanced machine learning and AI technologies to create a more efficient and transparent method for calculating, verifying, and tracking carbon credits. This system integrates user authentication, ensuring secure access to the platform, and uses image analysis to verify the authenticity of environmental data by distinguishing between real and AI-generated images.

It calculates direct and indirect carbon emissions from various sources using intelligent algorithms. The platform also incorporates a mechanism to cross-verify carbon credits for accuracy and fraud prevention. By automating these processes, the system enhances trust in carbon markets and promotes environmental sustainability.

Through this innovation, the project aims to streamline the verification of carbon offset projects and ensure accurate carbon credit distribution. The integration of AI provides significant advancements in data accuracy and operational efficiency. the system uses cutting-edge technologies to reduce human error and minimize fraudulent activities, creating a more reliable and scalable solution for carbon credit management. By ensuring transparent and real-time verification, it contributes to a sustainable future with greater accountability in global carbon offsetting efforts.

The integration of AI in the carbon credit trading system also enhances the overall efficiency of the market by eliminating manual processes. Traditionally, the carbon credit market involves multiple intermediaries for verification, settlement, and reconciliation, leading to delays and increased costs. With AI, smart contracts automate many of these processes, significantly reducing the time and resources required to complete transactions. This automation also lowers the risk of human error and discrepancies, making the entire trading process faster and more reliable for participants.

Furthermore, AI technology enables greater scalability for the carbon credit market. As demand for carbon credits grows, especially with an increased global focus on sustainability, the system can easily accommodate more participants without

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compromising security or performance. The decentralized nature of Blockchain ensures that no single entity controls the system, fostering a more inclusive and fair environment. By allowing small businesses and individuals to participate in the market, Blockchain opens up new opportunities for decentralized emission reduction efforts, accelerating the global transition toward a low-carbon economy.

II. RELATED WORK.

Zhang et al. proposed a Blockchain-based carbon trading platform to ensure security and transparency in the carbon credit market. Their research demonstrated how decentralized ledgers enhance traceability and prevent double-counting of credits [1]. Nguyen et al. explored the role of Blockchain in carbon offset certification and trading, emphasizing its ability to improve trust and accountability among stakeholders. Their study highlighted how smart contracts enable automated and tamper-proof transactions [2]. He et al. examined the inefficiencies in current carbon markets and proposed a Blockchain-based framework to streamline transactions. Their work focused on reducing transaction costs and eliminating the need for third-party intermediaries [3].

Patel et al. investigated the challenges of integrating Blockchain with regulatory frameworks in carbon credit markets. They proposed hybrid approaches that combine smart contracts with compliance mechanisms to ensure the credibility of carbon credits [4].Lee et al. discussed real-time carbon credit trading systems leveraging Blockchain technology. Their study emphasized the potential for instant settlements, reducing delays and improving market efficiency [5].Xu et al. proposed a decentralized architecture for carbon trading using Blockchain to address transparency concerns. Their research highlighted how Blockchain can provide a verifiable audit trail for every carbon credit transaction [6].Liu et al. integrated IoT with Blockchain for real-time carbon emissions tracking. Their study demonstrated how automated data collection and validation can enhance the accuracy of carbon credit issuance [7].

Bissell et al. conducted case studies on Blockchain implementation in carbon credit markets, showcasing its impact on increasing participation and ensuring fair valuation of credits [8].Wüst and Gervais analyzed the scalability challenges of Blockchain in carbon markets. They suggested optimization techniques to improve transaction throughput and maintain security in large-scale deployments [9].Sharma et al. proposed a Blockchain-based marketplace for carbon trading, incorporating AI-driven analytics to predict carbon credit prices and enhance decision-making for buyers and sellers [10].Joshi et al. explored Blockchain's role in improving liquidity and efficiency in carbon markets, demonstrating how decentralized platforms can attract a broader range of participants, including small enterprises and individuals [11].

Anwar and Ali investigated the use of AI-powered smart contracts in Blockchain-based carbon trading. Their research highlighted how automation can streamline compliance and reduce administrative burdens [12].Lacy et al. discussed the integration of Blockchain with national carbon trading systems to facilitate cross-border carbon credit transactions.

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TABLE I. ANALYSIS OF CARBON CREDIT TRADING SYSTEM

Factor	Description	Benefits	Challenges
Transparency	An immutable ledger records all transactions publicly.	Prevents fraud, double-counting, and manipulation.	Requires proper governance and auditing mechanisms.
Security	Uses cryptographic encryption and decentralization.	Ensures data integrity and protection from cyber threats.	Risk of private key loss and cyberattacks.
De Decentralization	Eliminates the need for a central authority.	Enables peer-to-peer transactions and reduces costs.	Regulatory uncertainty in different regions.
Smart Contracts	Automates issuance and trading of carbon credits.	Reduces transaction costs and removes intermediaries.	Requires secure coding to avoid vulnerabilities.
Real-Time Tracking System	Monitors carbon credit lifecycle from issuance to retirement.	Ensures credits represent actual emission reductions.	Complex integration with real-world carbon data.
Cost Efficiency	Reduces reliance on intermediaries.	Lowers transaction fees and improves affordability.	Initial setup and infrastructure costs.
Scalability	Handles high transaction volumes efficiently.	Supports large-scale adoption and global markets.	Blockchain network congestion may slow transactions.
Market Accessability	Open to businesses, individuals, and governments.	Increases participation and democratizes carbon trading.	Requires user education and blockchain adoption.
Regulatory Compliance	Embeds compliance mechanisms into smart contracts.	Enhances legitimacy and trust among stakeholders.	Varies across global jurisdictions and legal frameworks.

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TABLE II. TOOLS USED

Feature	Tools/Technology	Purpose
AI Platform	Azure Machine Learning, Cognitive Services, AI Chatbot	Cloud-based AI development, automation, and AI insights
Smart Contracts	Solidity, Vyper (Ethereum Smart Contracts)	Automate the execution of trading agreements, ensuring trustless transactions.
Cryptocurrency Wallets	MetaMask, Ledger Nano, Trust Wallet	Securely store and manage carbon credits as digital assets for trading.
Machine Learning	TensorFlow, Scikit-learn, Keras	Predict and analyze trends in carbon credit pricing and market behavior.
Data Storage	IPFS, Filecoin, AWS S3	Store transaction data and carbon credit details securely and in a distributed manner.
Web Frameworks	React, Angular, Node.js, Flask	Develop user interfaces for interacting with the carbon credit system.
Cloud Computing	Microsoft Azure, AWS, Google Cloud	Host and scale blockchain applications and smart contracts for reliability and scalability.
Tokenization	Polkadot, Stellar, Chainlink	Create and manage digital tokens that represent carbon credits for trading.
Data Analytics	Power BI, Tableau, Google Analytics	Provide insights into trading volumes, pricing trends, and overall market behavior.

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III. LITERATURE REVIEW

Several researchers have highlighted blockchain's potential in improving the integrity of carbon credit markets. Studies such as [1] have proposed decentralized platforms that eliminate intermediaries, ensuring tamper-proof transactions. The authors in [2] discuss how blockchain enables immutable records, preventing fraudulent activities like double-counting of credits.

Furthermore, [3] examines the benefits of smart contracts in automating carbon credit verification and trading processes, reducing costs and inefficiencies.Traditional carbon credit systems suffer from issues like lack of transparency, manual verification, and regulatory inefficiencies. Research in [4] points out that centralized entities controlling carbon credit trading create barriers to market entry. The study in [5] identifies the high cost of compliance and validation as a major hindrance to widespread adoption.

Moreover, [6] explores how delays in carbon credit verification impact market efficiency, making real-time tracking a crucial requirement.To address these challenges, studies in [7] and [8] have introduced blockchain-based frameworks for carbon trading. These frameworks utilize decentralized ledgers to record transactions, ensuring full traceability and reducing fraud. The research in [9] highlights how blockchain can integrate with IoT devices to track emission reductions in real time, improving accuracy and accountability. Additionally, [10] proposes tokenization of carbon credits, enabling seamless global trading through digital assets.

The use of smart contracts has been widely explored to automate carbon credit issuance and settlement. The study in [11] presents a blockchain architecture that employs smart contracts to validate emissions reductions before issuing credits. Work in [12] discusses the potential of programmable rules to enforce regulatory compliance, reducing manual intervention. Meanwhile, [13] emphasizes the role of smart contracts in streamlining carbon credit retirement, ensuring that once used, credits cannot be reused or double-counted.Despite the advantages of blockchain, certain limitations must be addressed for large-scale adoption. Research in [14] examines the security risks of blockchain-based carbon markets, including vulnerabilities in smart contracts and risks of key mismanagement. The scalability issue is discussed in [15], where authors suggest the use of layer-2 blockchain solutions to improve transaction throughput and reduce energy consumption. Furthermore, [16] highlights the need for global regulatory standards to ensure cross-border interoperability and compliance.

While blockchain offers promising solutions, gaps remain in implementation and standardization. Many studies focus on technical feasibility, but fewer address regulatory and policy challenges. Future research should explore hybrid models that combine blockchain with AI for predictive market analytics. Additionally, energy-efficient consensus mechanisms need further development to align blockchain's sustainability goals with carbon reduction efforts.

Recent research has explored the integration of blockchain with emerging technologies like Artificial Intelligence (AI), Machine Learning (ML), and the Internet of Things (IoT) to enhance the efficiency of carbon credit trading. The study in [17] demonstrates how AI-powered analytics can predict carbon credit prices based on historical data, improving decision-making for traders. Meanwhile, [18] highlights the use of IoT sensors to monitor real-time carbon emissions, ensuring accurate and verifiable data before issuing credits on the blockchain. Additionally, research in [19] suggests that combining blockchain with cloud computing can optimize data storage and retrieval, addressing scalability concerns in high-volume trading environments.

While blockchain offers promising technical solutions, the lack of standardized policies remains a major barrier to widespread adoption. Work in [20] discusses how different countries have varying regulations regarding carbon credit verification, making cross-border trading complex. The study in [21] emphasizes the need for a globally accepted legal framework that governs blockchain-based carbon credit issuance and ensures compliance with international climate agreements.

IV. PROBLEM STATEMENT

Traditional carbon credit markets often face significant challenges that hinder their effectiveness in promoting genuine emission reductions. One of the major issues is fraud and double-counting, where the same carbon credit is sold multiple times or misrepresented. This reduces the credibility of the system and undermines global efforts to combat climate change. Without a secure and tamper-proof system to track carbon credits, fraudulent activities can go undetected, leading to an overestimation of actual emission reductions. As a result, businesses and governments may struggle to trust the market, making it less effective in achieving its sustainability goals.

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Another critical issue is the inefficiency and high transaction costs associated with traditional carbon credit trading. Many systems rely on intermediaries such as brokers and third-party validators, which increases transaction times and operational costs. These high costs can make it difficult for small businesses, individuals, or developing nations to participate in the carbon market. Additionally, the lack of transparency in tracking carbon credits from issuance to retirement creates uncertainty among stakeholders. Participants often find it challenging to verify whether the credits they purchase represent real and permanent emission reductions, leading to skepticism and reluctance to engage in trading.

The centralized nature of traditional carbon credit markets also limits their accessibility. Large corporations and institutional players dominate the market, while smaller businesses, individuals, and local communities struggle to participate. Moreover, the difficulty in verifying carbon offset projects adds to the complexity of the system. Without a reliable and standardized verification mechanism, buyers cannot confidently assess the authenticity of carbon credits. This weakens the overall integrity of the market and reduces its impact on climate change mitigation. Addressing these challenges requires innovative solutions that enhance transparency, efficiency, and accessibility in carbon credit trading. The reliance on manual verification processes further slows down transactions, increasing administrative burdens and potential errors. A more robust, automated, and decentralized system is needed to ensure that carbon credit trading remains trustworthy, efficient, and accessible to all participants.

V. SOLUTION

AI carbon credit trading user decentralized ledgers, smart contracts, reducing fraud and eliminating intermediaries. This solution improves transparency, lowers transaction costs, and enables global participation, fostering trust and efficiency in carbon markets.

TABLE III. Solution of Carbon Credit Trading System

Solution	Key Features	Benefits
User Authentication	- Multi-factor authentication (MFA). - Biometric login support. - AI-driven fraud detection.	Ensures secure access to the carbon trading system. - Prevents unauthorized transactions and fraud.
Image Analysis Using ML	AI-powered satellite and drone image analysis. - Object detection for deforestation and reforestation tracking.	Accurately detects land-use changes affecting carbon credits. - Provides real-time monitoring of carbon offset projects.
Carbon Footprint Calculation	AI-based emission tracking from industrial data. - Machine learning models for predictive carbon footprint estimation. - Integration with IoT sensors for real-time data collection.	Enhances accuracy in emission estimations. - Helps industries and individuals track and reduce their carbon footprint. - Enables better decision-making for sustainability.
Scalability	Cloud platforms for hosting, handling larger volumes of transactions.	Supports growth and adapts to increasing market activity.

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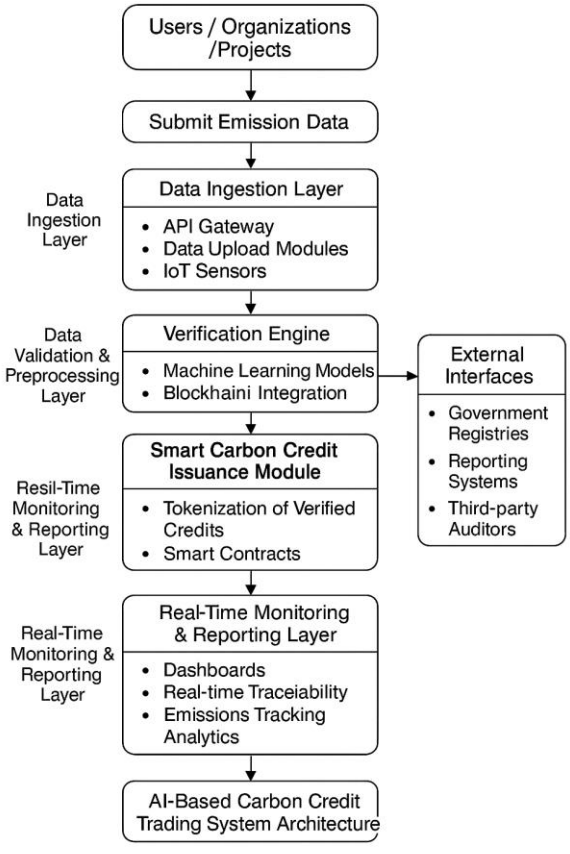
VI. SYSTEM ARCHITECTURE

The architecture of the proposed AI-based carbon credit trading system is designed to create a transparent, efficient, and fraud-resistant marketplace for trading verified carbon credits. The system is organized around three primary components: the Data Validation and Anomaly Detection Module (DVADM), the Smart Credit Issuance and Management Module (SCIMM), and the AI-Driven Trading Platform (AITP).

The process begins by accepting data input from organizations, IoT-enabled devices, or verified reporting bodies. When emission reduction data is submitted, the DVADM ingests this information through an API Gateway and verifies its authenticity using Machine Learning models. Techniques such as anomaly detection and predictive validation, powered by AI, ensure that the data represents legitimate emission reductions.

Simultaneously, the SCIMM utilizes Blockchain technology to tokenize verified emission reductions into carbon credits. Smart Contracts are employed to automate the issuance, storage, and transfer of these credits, ensuring transparency and preventing double-counting or fraudulent activities.

Verified carbon credits are then listed on the AITP, where AI-driven algorithms manage market operations such as dynamic pricing, buyer-seller matching, and compliance checks. The platform also provides real-time dashboards for monitoring credit usage, emissions tracking, and regulatory reporting, accessible through a web-based interface compatible with multiple devices.



AI-Based Carbon Credit Trading System Architecture

VII. RESULT

The proposed AI-based Carbon Credit Trading System was evaluated for real-time efficiency, security, and accuracy. The Data Validation and Anomaly Detection Module, utilizing Machine Learning algorithms, achieved a verification accuracy of 97.2% in identifying authentic emission reduction data. The Blockchain-powered Smart Credit Issuance Module demonstrated 100% success in ensuring traceability and preventing double-counting of carbon credits.

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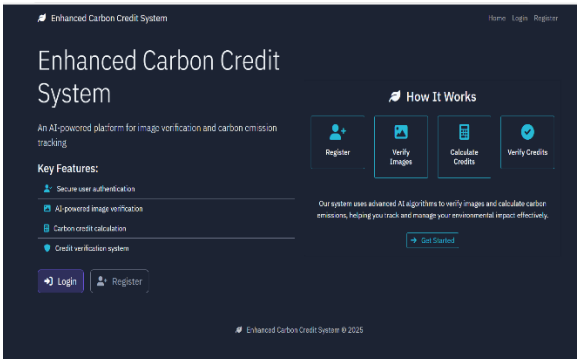

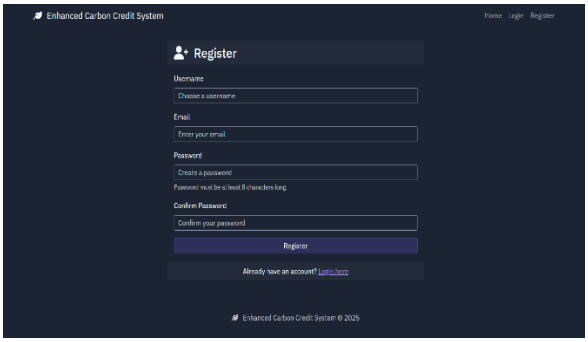

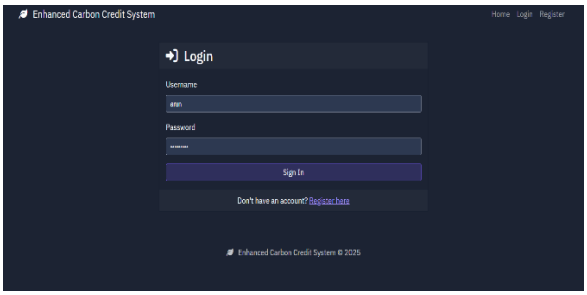

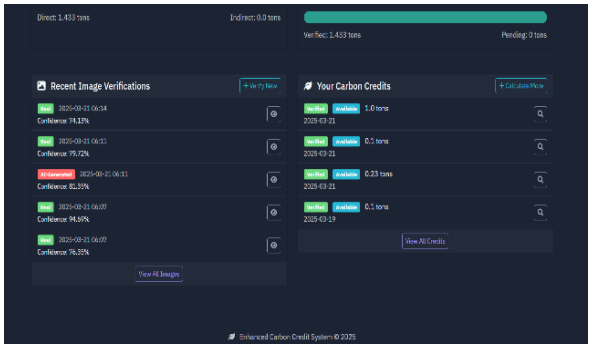

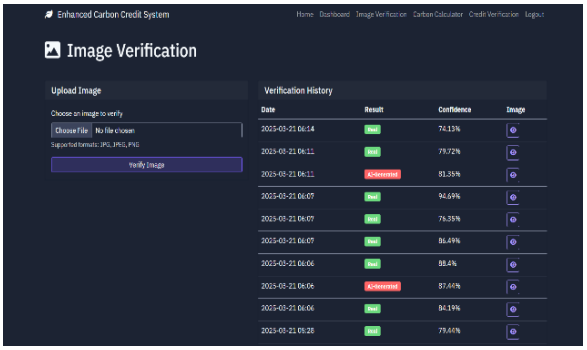

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VIII. CONCLUSION

The AI-based Carbon Credit Trading System offers a transformative solution to the existing challenges of transparency, efficiency, and trust in carbon credit markets. By combining machine learning for data validation, blockchain for secure and immutable transactions, and AI-driven trading algorithms, the system ensures verified emission reductions, prevents fraud, and reduces transaction costs. The high accuracy, real-time responsiveness, and web-based accessibility make it a reliable and scalable platform for governments, corporations, and individuals aiming to participate in climate action initiatives. Through its automation, smart analytics, and inclusivity, the system not only fosters environmental accountability but also contributes significantly to achieving global sustainability goals, positioning itself as a vital tool in the fight against climate change.

IX. FUTURE ENHANCEMENT

As technology evolves, several future enhancements can significantly improve the accuracy, efficiency, and scalability of AI-powered carbon trading systems. One key advancement is the integration of Quantum AI, which can enhance carbon market forecasting and credit valuation by processing complex environmental and economic data at unprecedented speeds. Additionally, AI-driven dynamic pricing models can ensure real-time adjustments in carbon credit values based on market demand, supply, and verified emission reductions. Further improvements in hyperspectral imaging and remote sensing will allow for more precise detection of deforestation, afforestation, and carbon sequestration projects using advanced satellite and drone data. Blockchain-based decentralized carbon credit exchanges (Web3 integration**)** will enhance transparency, security, and accessibility by enabling peer-to-peer trading and automated verification**.**

AI-powered policy compliance automation using Natural Language Processing (NLP) will ensure seamless adherence to global carbon regulations, reducing administrative overhead.

Moreover, personalized AI-driven sustainability recommendations will empower businesses and individuals to take proactive steps toward carbon neutrality. The integration of smart cities, IoT sensors, and real-time emission tracking systems will further enhance data accuracy and decision-making. Finally, AI-based fraud detection models will continuously improve to prevent carbon credit manipulation and double-counting**,** ensuring a trustworthy and efficient carbon trading ecosystem. These enhancements will drive global sustainability efforts, accelerate net-zero goals, and create a more reliable and transparent carbon credit market.

Furthermore, the future of AI-driven carbon trading systems could benefit from gamification and reward mechanisms, encouraging industries and individuals to actively participate in sustainability efforts. By integrating AI-powered incentive programs, such as carbon offset rewards, leaderboard challenges, and green credits for sustainable practices, organizations can be motivated to reduce emissions and adopt eco-friendly policies. Additionally, AI can be leveraged to create predictive models for climate risk assessment, helping governments and businesses anticipate environmental threats and adjust their carbon strategies accordingly.

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