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CarbonChain: A Blockchain-Enabled Decentralized Marketplace for Verified Carbon Credit Trading and Emission Reduction

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***Abstract*— The carbon offset market is an essential component in the mitigation of climate change globally [1], [2], [23]; however, its efficacy is often thwarted by inherent inefficiencies, lack of transparency, and issues of trust. The issues of fraudulent credit creation, double counting, lack of registry, and long settlement times [3], [4], [10] have been prevalent in the carbon market, which is primarily being driven by the centralization of the trade system that is based on multiple actors in the system In this paper, an outline for the development of a decentralized carbon credits trading market based on blockchain technologies is discussed. The proposed trading market utilizes smart contracts and carbon credits in the form of blockchain tokens to provide automated, secure, and transparent trading without the need for centralized supervision [11], [12], [24]. The unchangeable records maintained in the blockchain ledger provide secure traces for the validation of emission reductions, while cryptographic tools help in securing confidential trade between peers. The analysis conducted in this paper provides an understanding of how blockchain technology can greatly increase market efficiency.**

***Index Terms*— Blockchain, Carbon Credit Trading, Transparency, Decentralized Marketplace, Smart Contracts.**

I. INTRODUCTION

The global carbon offsetting market is one of the most important tools in the reduction of climatic changes [15], [19]. This is because the market enables organizations and individuals to offset the carbon units they emit and contribute to the reduction of greenhouse gases in the atmosphere. Despite the importance of the market, the market faces numerous challenges that hamper the success of the market [3], [4]. Some of the factors include fraudulent activities, duplication of offsets, and the lack of verification processes for the offsets. There is also a lack of clarity with respect to the sale and retirement of the offsets. Centralized nature of the existing carbon trading markets also seems to be one of the primary reasons for these inefficiencies [17], [20]. In addition to being potential points of failure, these centralized registries and middlemen also contribute to higher costs, delayed finality of transactions, and less market accessibility. The lack of trust among trade participants also gets further fuelled by the transparency issues associated with these centralized markets, wherein errors or manipulations can prove to be undetected for an unreasonably long time.

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II. Literature Survey

A. Blockchain in Environmental Systems

Nakamoto (2008) and Tapscott & Tapscott (2016) highlighted blockchain's ability to provide decentralized, tamper-proof records. Their studies show that blockchain improves transparency and trust [1], [12], [20], but they do not specifically address its implementation in carbon credit trading systems.

B. Issues in Traditional Carbon Markets

Hamrick and Gallant (2017) identified major problems in carbon markets [3], [15], including fraud, double counting, and lack of transparency due to centralized intermediaries. However, these studies fail to propose an automated or decentralized solution.

C. Smart Contracts for Automation

Buterin (2013) introduced smart contracts on Ethereum, enabling automated transactions [11], [17]. Later studies showed that smart contracts reduce transaction delays and costs, but limited attention was given to their role in managing the complete carbon credit lifecycle.

D. Tokenization and Decentralized Governance

Hassan and De Filippi (2021) discussed DAOs as transparent governance models, while the World Bank (2022) explored tokenized carbon credits [8], [24]. These works lack a unified framework combining decentralization with regulatory compliance, which this project addresses.

III. Proposed System

The growing difficulties of traditional carbon credit trading systems have focused attention on a set of new technologies, among which blockchain represents a potent solution [6, [21]. At the core of blockchain is a decentralized, immutable ledger that transparently records transactions across nodes in a network, with security and tamper resistance guaranteed. This technology obviates the need for centralized intermediaries, hence reducing transaction costs and times of settlement, while at the same time increasing participants' trust. Ethereum and Solana play an especially significant part in this transformation. As one of the most mature and widely adopted blockchain platforms, Ethereum allows the development of smart contracts-human agreements, expressed logically in code and self-executed when certain conditions are met. Smart contracts automatically trigger transactions upon fulfilment of the conditions laid down in the contract and, without human intervention, ensure strict adherence to pre-agreed provisions; thus, they are ideal for applications in carbon credits verification and trading. Solana is another blockchain with high transaction speeds and low transaction costs that can help address scalability issues-issues often seen in blockchain-based applications. With Ethereum and Solana combined, there is now a well-rounded blend of security, functionality, and efficiency that can be achieved by the non-profit, decentralized markets of carbon offsetting. As it has already been stated, besides those efficiency gains, there are other advantages linked to the use of decentralized ledger technology. First of all, it must be said that those same decentralized platforms offer an immutable trail of audits regarding each and every aspect of those carbon credits, from issuance through trade and retirement, which can be accessed by any party involved [22], [23].

IV. Results

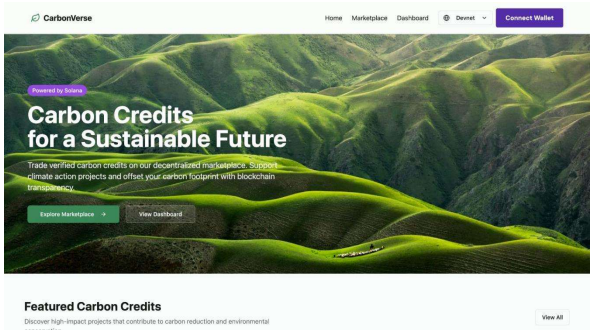

Fig.1. Home page

The Carbonchain system, which was proposed, has been successfully implemented through the application of blockchain technology and smart contracts. This system has been designed to facilitate secure issuance, trading, and retirement of carbon credits without the need for intermediaries. During testing, it was observed that the system has been successful in efficiently executing transactions between wallets belonging to participants, and all data has been recorded on the blockchain ledger.

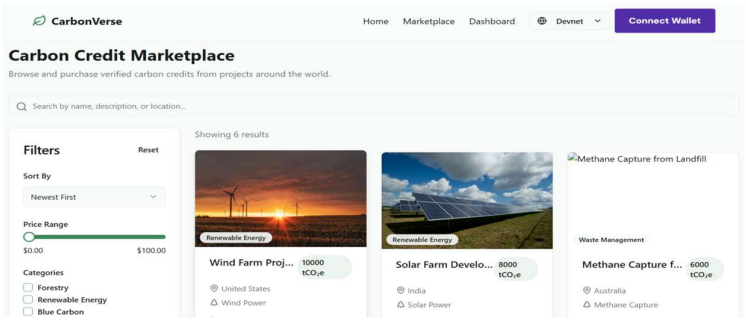

Fig. 2. User Interface of CarbonCredit Marketplace

TABLE I. COMPARISON BETWEEN TRADITIONAL MARKET AND CARBONCHAIN

Feature	Traditional Market	CarbonChain
Transparency	Low	High
Transaction Time	Hours/Days	Seconds
Fraud Risk	High	Low
Trust Mechanism	Requires intermediaries	Blockchain-based trust
Record Keeping	Centralized databases	Immutable blockchain ledger

V. CONCLUSION

This work presents a blockchain-based decentralized marketplace aimed at improving the efficiency, transparency, and reliability of carbon credit trading systems. Traditional carbon markets have serious limitations, like centralized control, delayed transaction settlements, high operational costs, and a greater risk of fraud and double counting. The proposed solution tackles these issues by using blockchain technology to enable secure, transparent, and real-time carbon credit transactions. The combination of smart contracts and decentralized ledgers ensures permanent record- keeping, automatic transaction execution, and verifiable tracking of carbon credits throughout their lifecycle. Besides its operational advantages, the proposed platform shows strong potential for growth and long-term use, reflecting the rising global focus on environmental sustainability and ESG compliance. By making it easier to access carbon markets and enabling reliable measurement and verification of carbon reductions, the system supports responsible environmental efforts and encourages broader market involvement. Overall, the proposed blockchain-enabled carbon credit trading platform effectively achieves its goals by offering a secure, efficient, and transparent alternative to traditional systems. The results show that decentralized technologies can significantly contribute to promoting sustainable environmental practices and creating a more accountable, globally measurable framework for carbon offset trading.

FUTURE SCOPE

Although the technology possesses great potential to bring improvements to the carbon offsetting market, some issues require remediation to unlock the full potential of the technology. One of the key issues that have been forthright regarding the technology is its scalability, especially when the user base continues to increase. Nevertheless, research and development work being conducted to develop Layer 2 and high-throughput blockchain networks is encouraging. The application of artificial intelligence and machine learning also offers tremendous opportunities. The technology could enable the automation of validation and verification processes for carbon offset projects. It would not only ease the process but ensure that there are hardly any delays in the issuance of credits. Machine learning could enable the detection of fraud in the system. Looking ahead, it can only be hoped that advancements in blockchain infrastructure as well as more sophisticated carbon credit validation methods will lead to increased efficiencies, as well as greater accessibility and quality, of

decentralized carbon markets. Further study regarding regulations as well as global standards is also expected to be necessary. This is because sound regulations will play an important part in facilitating trust, adoption, as well as sustained success related to blockchain-based carbon markets.

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