Blockchain-Powered Carbon Credits Market: Decentralized Solutions for Climate Action

Duc Dang*[1], Viet Bui[2], Truc Do[3], Linh Nguyen[4]
[1]Department of Business Information Technology, University of Economics Ho Chi Minh City (UEH), Ho Chi Minh City, Vietnam
[2]Department of Business Information Technology, University of Economics Ho Chi Minh City (UEH), Ho Chi Minh City, Vietnam
[3]Department of Business Information Technology, University of Economics Ho Chi Minh City (UEH), Ho Chi Minh City, Vietnam
[4]Department of Business Information Technology, University of Economics Ho Chi Minh City (UEH), Ho Chi Minh City, Vietnam
ducdang.35221020127@st.ueh.edu.vn

Abstract. This paper explores the integration of blockchain technology to create a DAO to management subDAO, record proof of work and decentralized marketplace for carbon credits. As the world faces increasing environmental challenges, the need for efficient and transparent mechanisms to incentivize carbon reduction efforts is crucial. This research investigates the potential of blockchain to enhance the issuance, trading, and tracking of carbon credits, providing a decentralized solution to support global climate action.

Keywords: Blockchain, Carbon Credits, Climate Change.

1 Introduction

In recent years, rapid industrialization and modernization have had a detrimental impact on the environment.

Specifically, human activities have led to an increase in greenhouse gas (GHG) concentrations in the atmosphere, with global CO2 levels rising from approximately 280 parts per million (ppm) in the 18th century to a record high of about 415 ppm in 2022. Although CO2 data for 2023 has not yet been officially released by NOAA, preliminary comparisons from various sources suggest that global CO2 emissions may increase by 1.4% in 2023 compared to 2022 [1]. The emission of greenhouse gases into the atmosphere reduces the Earth's heat radiation capacity, contributing to global warming and significantly impacting human health, livelihoods, the economy, and ecosystems [2] [3] [4] [5].

Climate change, driven by human activities and industrial development, is negatively affecting weather patterns globally. It also poses a threat to human well-

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being and the health of the planet. Any further delays in coordinated global action to mitigate and address the consequences of climate change could forfeit the fleeting opportunity to curb climate change.

Consequently, climate change has become one of the most pressing challenges of the current era. This has led to the rapid development of the carbon credit market. This market serves as a mechanism allowing countries and organizations to offset their emissions by purchasing credits from projects that are either reducing or eliminating greenhouse gas (GHG) emissions.

1.1 A Motivation

The rationale for analyzing and applying Blockchain technology lies in its safety and transparency of data. Numerous studies have applied and provided analyses to elucidate the benefits, operational mechanisms, and performance of this technology.

The paper "Blockchain for the Metaverse: A Review [6]" presents an overview of blockchain and the metaverse, discussing methods of applying Blockchain to the Metaverse (such as Facebook) from technical perspectives including data collection, storage, sharing, data interaction, and data security. Additionally, it addresses the impact of blockchain on crucial supporting technologies in the metaverse, including the Internet of Things, artificial intelligence, and big data.

In "A Vademecum on Blockchain Technologies: When, Which, and How [7]," the authors aim to provide the community with a vademecum (implementation design guide), presenting an overview of blockchain that extends beyond its use in Bitcoin and surveying a selection of extensive literature from recent years. The authors outline key requirements and developments as blockchain evolves from permissionless to permissioned systems, distinguishing between proposed and tested consensus mechanisms and describing existing blockchain platforms.

The paper "Economics of Blockchain [8]" proposes two approaches to the economic field of blockchain: innovation-centered and governance-centered, based on case studies of Ethereum-based infrastructure protocols and the Backfeed platform.

In "Blockchain Technology Innovations [9]," the authors highlight various advantages of Blockchain, such as enabling more flexible value chains, faster product innovation, closer customer relationships, and quicker integration with cloud technology and IoT. Blockchain provides lower transaction costs with reliable, monitored contracts free from third-party intervention, facilitates smart contracts, commitments, and agreements with robust network security features. The paper also proposes a foundation for demonstrating the use of Blockchain technology in various industrial applications, including healthcare, with Healthchain being formalized and developed on IBM's Blockchain initiative. These concepts can be applied across

industries such as finance, government, and manufacturing, where security, scalability, and efficiency are critical.

The report "Blockchain in Education [10]" introduces the fundamental principles of Blockchain, focusing on its potential for the education sector, explaining how this technology can disrupt organizational norms and empower learners. It suggests scenarios for applying Blockchain in the educational field.

In "A Systematic Review of Blockchain [11]," the study reviews the current state of academic research on blockchain, particularly in business and economics. The paper also performs cluster analysis and identifies research themes such as "economic benefits," "blockchain technology," "initial coin offerings," "financial technology revolution," and "sharing economy."

The paper "Blockchain: Challenges and Applications [12]" surveys an application using Blockchain technology, presenting the applications and challenges faced.

In "Security and Privacy on Blockchain [13]," a survey is conducted, providing insights and analysis to help readers gain a deeper understanding of the security and privacy aspects of blockchain, including general concepts, attributes, techniques, and systems.

The paper "Blockchain in Developing Countries [14]" analyzes and argues based on a 2017 IT report stating that 42.9% of households in developing countries have internet access. It offers insights into core concerns related to organizations in developing countries and evaluates the potential of using blockchain to address these issues.

Finally, the paper "Blockchain Challenges and Opportunities: A Survey [15]" categorizes blockchain types, introduces typical blockchain consensus algorithms, evaluates blockchain applications, and discusses technical challenges and recent advancements in addressing these challenges. It also outlines future directions for blockchain technology.

Overall, the studies mentioned above, as well as the information collected by the authors, indicate that blockchain holds tremendous potential to revolutionize various industries. However, several challenges must be addressed before blockchain can be widely adopted, including:

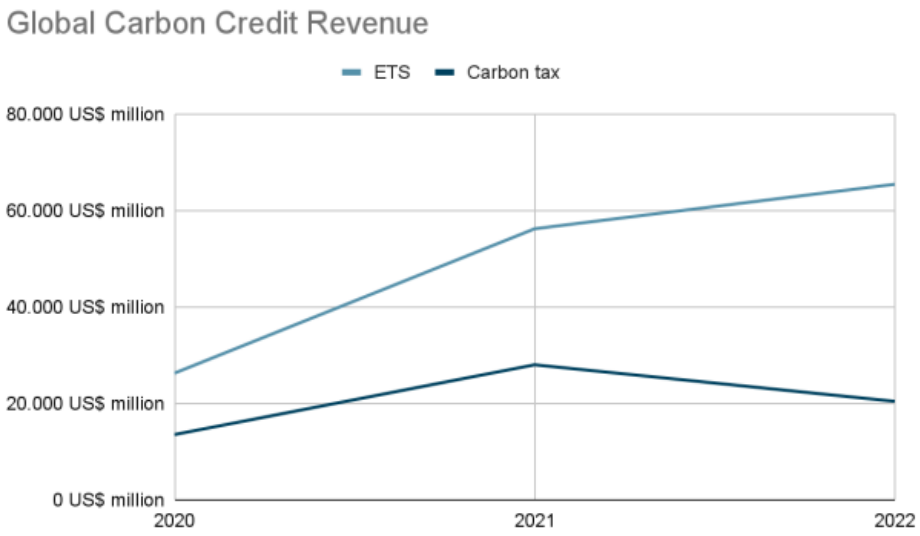
- Blockchain's relative complexity, which may make it difficult for users to understand and access.
- The processing of transactions on blockchain can be slow and resource-intensive.
- There is still no clear foundational basis for the widespread use of blockchain across many fields.

- Although blockchain is considered secure, there remains a risk of cyberattacks.

Despite these challenges, blockchain is a promising technology with the potential to offer significant societal benefits, particularly as blockchain continues to evolve and improve through current and future research.

Carbon credits (also known as greenhouse gas emission certificates) are an economic tool used to manage greenhouse gas (GHG) emissions, specifically CO2, into the atmosphere. Each carbon credit represents the right to emit one ton of CO2 or an equivalent amount of another greenhouse gas [16].

Fig 1. Global Carbon Credit Revenue



1.1.1 Benefits of Carbon Credits

Promoting Greenhouse Gas Emission Reduction: The trading of carbon credits creates a market for emissions, incentivizing individuals, organizations, and businesses to implement measures to reduce emissions in order to minimize the costs of purchasing carbon credits.

Financial Support for Emission Reduction Projects: Revenue from the sale of carbon credits can be allocated to fund projects aimed at reducing greenhouse gas emissions, such as afforestation and the development of renewable energy.

Contributing to Climate Change Goals: Carbon credits are a critical tool for countries to achieve their greenhouse gas reduction targets as outlined in international climate agreements.

1.1.2 Operation of the Carbon Credit Market

The carbon credit market operates based on the principles of supply and demand. Individuals, organizations, and businesses seeking to offset their emissions purchase carbon credits from those who have surplus credits. The price of carbon credits fluctuates depending on market demand and the amount of greenhouse gases reduced by the projects.

The carbon market is considered an effective solution for mitigating CO2 emissions in the atmosphere. It also provides a significant incentive for organizations and businesses to trade carbon credits to offset their emissions, helping them meet emission standards and enhance their brand image.

As emissions have increased each year, the carbon market has been rapidly expanding, with the value of each credit rising. According to emission trading systems (ETS) in countries with carbon regulations worldwide (see Appendix), the global average carbon price in 2022 reached USD 83 per ton, a 60% increase from 2021. The demand for carbon credits is expected to continue growing in the future. Additionally, the carbon market offers substantial economic benefits, fostering innovation and creativity in green technology and potentially creating more jobs to stimulate economic growth. Businesses participating in the market can profit from selling carbon credits or investing in emission reduction projects.

1.1.3 Application of Blockchain in Carbon Credit Management

Blockchain has the potential to offer numerous benefits for managing carbon credits [17] [18] [19], including:

- **Decentralized System:** Blockchain is a decentralized system, meaning all carbon credit transactions are recorded on a public ledger. This enhances transparency and traceability of carbon credits, minimizing the risk of fraud and market manipulation.
- **Automation:** Blockchain can automate many manual processes involved in managing carbon credits, saving time and reducing costs.
- **Security:** Blockchain provides a high level of security and protection against cyberattacks, safeguarding carbon credits from potential threats.
- **Global Market Creation:** Blockchain can facilitate the creation of a more liquid, global carbon credit market, enabling easier transactions between buyers and sellers.

However, there are also some limitations to consider when applying blockchain to carbon credit management:

- **Cost:** Implementing and maintaining a blockchain system can be costly.

- **Complexity:** Blockchain is a complex technology that may be difficult for some users to understand.
- **Regulatory Uncertainty:** The legal framework for using blockchain in carbon credit management is not yet clearly defined.

Overall, while the application of blockchain in carbon credit management offers significant potential benefits, there are also some limitations to consider. The decision to adopt blockchain will depend on specific cases, considering factors such as cost, complexity, and the needs of stakeholders.

1.1.3.1Some Technologies and Blockchain Platforms in Use:

IBM Hyperledger Fabric: This platform is used by the United Nations Environment Programme (UNEP) to monitor the issuance and trading of carbon credits.

Veridium Registry: This platform is used to register and track greenhouse gas emission reduction projects, generating carbon credits that can be traded on the market.

Energy Blockchain Consortium: This consortium is developing a blockchain platform for trading renewable energy and carbon credits.

1.1.4 Overview of Blockchain Technology

Blockchain is a decentralized digital ledger that stores transaction records linked and secured by cryptography. Blockchain can be likened to a public ledger that records all transactions occurring within a network, ensuring transparency and immutability [20].

1.1.4.1Key Characteristics of Blockchain:

Decentralization: No central authority controls blockchain. Instead, blockchain is stored across multiple computers (nodes) within the network.

Transparency: All transactions on the blockchain are publicly recorded and accessible to all members of the network.

Security: Blockchain is secured through cryptography, protecting it against fraud and tampering.

Immutability: Once recorded on the blockchain, a transaction cannot be altered or deleted

1.1.4.2How Blockchain Works

Transaction Creation: When a new transaction is created, it is broadcast to all nodes within the network.
Verification: Each node verifies the validity of the transaction based on rules defined in the blockchain protocol.

Block Addition: If the transaction is verified as valid, it is added to a new block.

Block Linking: The new block is linked to the previous block via a hash value, forming a chain of blocks.

1.1.4.3Applications of Blockchain in Various Fields

Cryptocurrencies: Blockchain serves as the foundation for cryptocurrencies such as Bitcoin, Ethereum, and others.

Smart Contracts: Blockchain can be used to execute smart contracts, which automatically enforce contract terms when specific conditions are met.

Supply Chain Management: Blockchain can track the origin and quality of products within the supply chain.

Healthcare: Blockchain can be used to store medical records and share health data securely.
Voting: Blockchain can be utilized to conduct secure and transparent elections.

1.2 Problem statement

In addition to its economic, environmental, and social benefits, the carbon market faces several challenges that hinder its long-term viability and effectiveness. One of the most significant challenges is the lack of market transparency. As a relatively new and specialized market for measuring and quantifying CO2 emissions reductions, the carbon market is susceptible to fraud, greenwashing, and other forms of market manipulation. This lack of transparency has led to several problems, including inflated carbon credit prices, discouraged investment in emission reduction projects, and difficulty for investors to assess risks and make informed investment decisions.To address these issues, solutions leverage the decentralized nature of blockchain technology to create carbon credits, enhancing market transparency. See Table 1 for further details.

Table 1. Blockchain-led Carbon Credit Project Initiatives.

Project	Status	Region
GROVE (FSL),2020	Development	Southeast Asia
Carbon Credit Token (CCT),	Development	Global

UniversalCarbon, 2019	Active	Global
Klima DAO	Active	Global

2 Literature Review

GROVE: Forestry Smart Ledger (FSL) is a project that aims to address the financial and transparency barriers that hinder the development of small-scale mangrove forestry projects. The project utilizes a peer-to-peer (P2P) network to connect mangrove forestry projects with funders and blockchain technology to record financial transactions and project environmental impacts. Local mangrove forestry projects can list their information on the GROVE platform, allowing individual and institutional funders to browse projects and pledge funding. Funding is then disbursed to local projects using tokens on the blockchain. Project progress is updated by funders through the GROVE dashboard.

Carbon Credit Token (CCT) is a project that applies RWAs (Real World Assets) of blockchain, using a real-world asset as collateral for a token on the blockchain to ensure the value of that token. This means that when a CCT is created, there must be a real-world credit issued and accepted. These CCTs will be traded on DEXs (Decentralize Exchange). This can ensure transparency in the creation of carbon credits as their origin can be easily traced on the blockchain, attract more investors to the market, increase the liquidity of carbon credits, and somewhat reduce the costs and procedures related to greenhouse gas regulations. Promote the development of the national carbon credit market and reach the international level.

Universal Carbon is a project to build a centralized carbon credit trading platform using blockchain technology. It issues UCC tokens, each representing one carbon credit, and these tokens are only circulated internally and not listed on any cryptocurrency exchanges. Universal Carbon acts as an observer and controller of carbon credit transfers to ensure compliance with transparency regulations. Additionally, blockchain technology ensures the security and integrity of transactions, as well as the transparency of data related to carbon credits. This project makes it easier for investors to access the market, increases liquidity, and reduces costs for businesses related to greenhouse gas emissions regulations. Ultimately, it contributes to the development of the carbon credit market.

Klima DAO is a pioneering project that applies blockchain technology and the DAO (Decentralized Autonomous Organization) mechanism to build a decentralized carbon treasury management model. The project issues the KLIMA token, which serves as a governance token, allowing holders to participate in the organization's decision-making process. Klima DAO operates by raising capital from the community through the sale of KLIMA tokens and using this capital to buy and sell carbon credits on the market. The project's goal is to generate profits for its members and sustain the DAO's

operations. All carbon credit purchases and sales are conducted transparently and fairly through a voting system of KLIMA token holders and recorded on the blockchain.

3 Methodology and Data

3.1 Proposal Method

To create a fair and transparent decentralized market for the issuance, buying, and selling of carbon credits, we propose the establishment of a Decentralized Autonomous Organization (DAO) consisting of greenhouse gas and climate change management agencies from participating countries.

The DAO will be responsible for managing the operation of the carbon market among member countries, including:

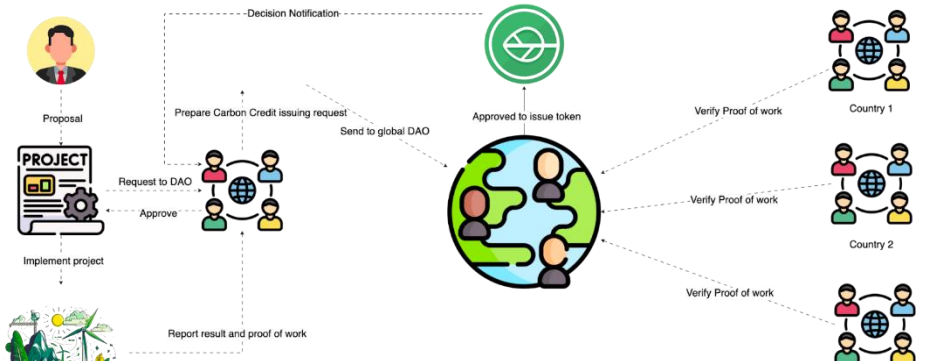
- Verifying carbon credit issuance: The DAO will establish a process for verifying and issuing carbon credits based on actual emissions data from member countries. This process will utilize reliable sensors and data sources to ensure accuracy and transparency.
- Establishing the market: The DAO will create a decentralized marketplace where member countries can buy and sell carbon credits. This market will be operated using smart contracts, ensuring security and efficiency.
- Each participating nation in the DAO can propose carbon credit issuance based on actual data of their emissions.

Proposals must include the following information:

- The amount of emissions reduced compared to the original target.
- The type of emission reduction project.
- The methodology for measuring and verifying emissions
- Supporting evidence (data from sensors, audit reports, etc.).

DAO members will evaluate and validate proposals based on agreed-upon criteria. The validation process will use blockchain's security and transparency techniques to ensure accuracy and fairness. Once validated, the proposal will be recorded on the blockchain ledger and carbon credits will be issued to the proposing nation.

Fig 2. A representation of the DAO communities with Other DAO.



3.2 Example Data

To conduct pilot testing, we collected data such as contributions, rankings, and member awards from blockchain communities, primarily Solana SuperteamVN with 4,818 members as of 2024, and two other communities for additional data.

Table 2. Blockchain Communities

Community	Members	Year
KlaytnVN	10,000	2022
SuperteamVN	4,818	2020
Viction	4,889	2023

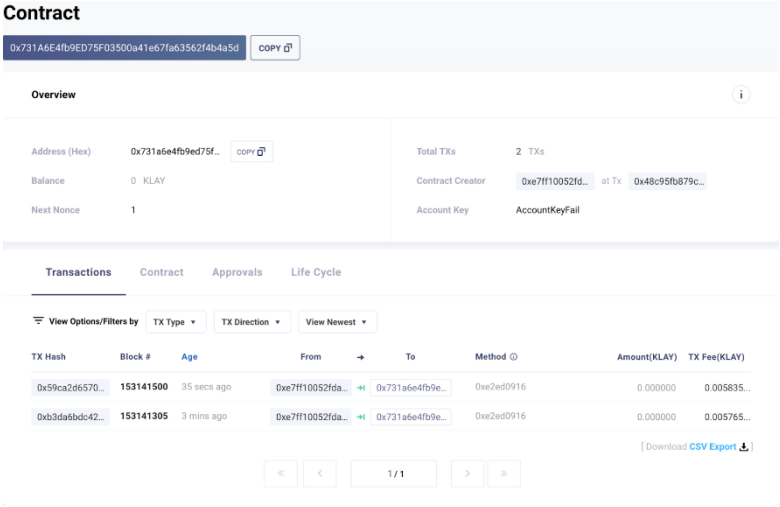
4 Results and Discussions

4.1 Results Overview

The implemented system successfully achieves the following:

Enhanced Transparency: All information and changes on the DAO can be tracked by the address of the smart contract on the block explorer, which is accessible to everyone. This prevents fraud and falsification of information, and also facilitates investors in tracking the progress of projects on the blockchain network.

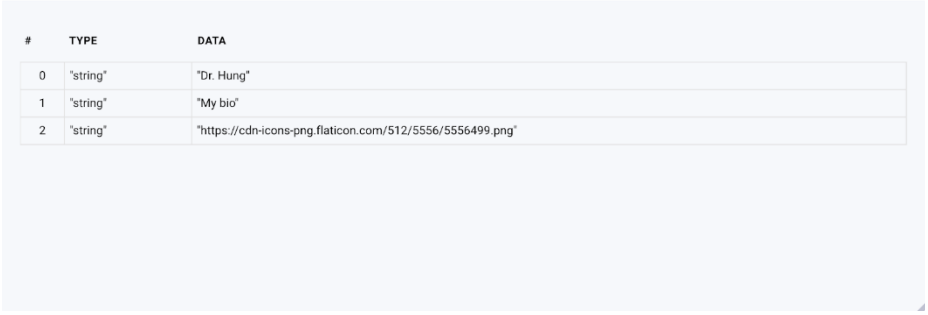
Fig 3. A contract address explored on Blockchain.



Sub DAO Management: Sub DAOs corresponding to countries or organizations can manage members, projects, and proposals.

Contribution Recording: Members of Sub DAOs can record their contributions and store their work results on the network after being approved by other members of the Sub DAO.

Fig 4. DAO member information is recorded on the blockchain



#	TYPE	DATA
0	"string"	"Dr. Hung"
1	"string"	"My bio"
2	"string"	"https://cdn-icons-png.flaticon.com/512/5556/5556499.png"

4.2 Results Discussions

The implemented system demonstrates the successful application of blockchain technology to enable a DAO consisting of multiple sub-DAOs to verify each other's proposals or use recorded proposals from the past as a basis for current proposals, such as creating carbon credits or addressing a specific issue.

Smart Contract Functionality: The developed smart contracts automate various processes within the DAO, including proposal management, contribution recording, and potentially even carbon credit issuance (Figure 3, details not shown). This automation reduces the risk of human error and streamlines DAO operations.

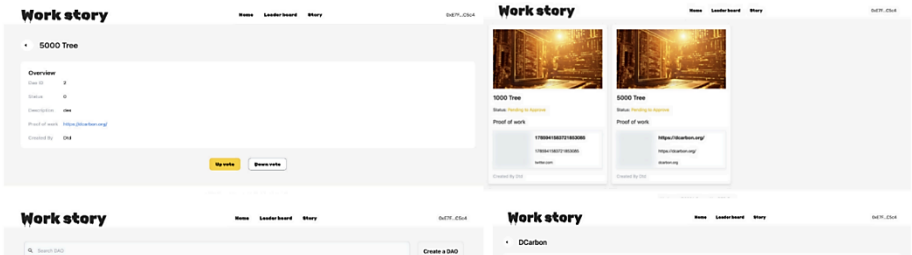
Future Enhancements: Further development could explore functionalities such as reputation systems for members, integration with oracle networks for real-world data verification to build a carbon credit marketplace.

4.3 Application Development

Development Environment: Nodejs, Reactjs, Solidity, Klaytn Blockchain and Remix.

Application of Smart Contract Technology to automate workflows, propose an application to manage Sub DAOs and record contributions and work of members, process and verify proposals for issuing carbon credits or related activities as shown in Figure 5.

Fig 5. Application workflow



5 Conclusion

This paper explores the potential of applying blockchain technology to create a decentralized market for carbon credits. As the world faces increasing environmental challenges, the need for effective and transparent mechanisms to incentivize carbon emission reduction efforts is crucial. This study investigates the potential of blockchain to enhance the issuance, trading, and tracking of carbon credits, providing a decentralized solution to support global climate action.

Establishment of a Decentralized Autonomous Organization (DAO) encompassing the greenhouse gas and climate change mitigation agencies of participating nations is proposed to create a fair and transparent decentralized market for controlling carbon credit issuance and trading.The DAO would be responsible for overseeing the operation of the carbon market among member nations, including verifying carbon credit issuance and establishing market rules.

Each participating nation in the DAO can propose the issuance of carbon credits based on actual data on their emissions levels. These proposals will be evaluated and verified by DAO members based on agreed-upon criteria. Once verified, the proposal will be recorded on the blockchain ledger and carbon credits will be issued to the proposing nation.

The application of blockchain to the carbon credit market has the potential to bring about many benefits, including:

Enhanced transparency: Blockchain provides a distributed, immutable ledger that allows for easy tracking of the origin and ownership of carbon credits. This can help reduce fraud and ensure the integrity of the market.

Improved efficiency: Blockchain can automate time-consuming manual processes involved in the issuance and trading of carbon credits, saving costs and improving market efficiency.

Increased accessibility: Blockchain can help expand access to the carbon credit market for smaller stakeholders, such as small businesses and local communities.

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