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Revolutionizing Carbon Credit Markets: Smart Contracts for a Sustainable Future

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The major issues of the next century are weather change and global warming. The Kyoto Protocol's globally motivated market mechanism is a workable method of reducing greenhouse gas emissions. According to this perspective, the emission of carbon dioxide (or other greenhouse gases) is treated as a commodity, creating a mechanism for trading carbon. Over the past ten years, initiatives have been made to develop this concept with varying degrees of success. The main issues with the current systems include scattered implementations, a lack of transparency that encourages double- and over-spending, and high transaction costs that benefit brokers and agents at the expense of consumers. With the help of blockchain technology and smart contracts, we hope to establish a carbon credit ecosystem that will increase the market's transparency, usability, liquidity, and uniformity to carbon markets. The system encompasses mechanisms to involve every participant, such as the energy sector, project verifiers, liquidity providers, NGOs, concerned citizens, and governments. It also includes a tokenization mechanism to securely digitize carbon credits with clear minting and burning protocols, a transparent mechanism for token distribution, a free automated market maker for trading the carbon tokens, and a mechanism to distribute tokens to all participants.This strategy could be used to a number of other credit/trading systems.
Keywords: Carbon Credit system, Credit/trading systems, Kyoto Protocol, Greenhouse gas emissions, Carbon trading, Smart contracts, Blockchain.

1. Introduction

Carbon emissions cause environmental change, which has detrimental effects on our health. More than 80% of the greenhouse gases released, according to the US Environmental Protection Agency, are carbon emissions in the form of carbon dioxide. By storing solar energy in the atmosphere, these carbon emissions cause an increase in global temperature. In turn, this affects weather patterns and water supplies. It also modifies the growing season for food crops and puts coastal populations in danger because of the increased risk of flooding brought on by the rising sea level. Additionally, certain freshwater systems may become contaminated by saltwater as a result of rising sea levels, necessitating additional desalination and aggressive drinking water treatment. For a better and healthier future, it is crucial to combat global warming and reduce these carbon emissions. As businesses show a greater interest in tracking their business operations, sustainability programs are gaining traction. Many businesses have even begun to acknowledge that sustainability is advantageous for everyone. Since customers and investors are becoming more aware of and supportive of sustainability initiatives, they are not only beneficial to the environment but also a great method to improve the brand's reputation. According to research, supply chains frequently account for a significant portion of a company's overall greenhouse gas emissions, with shipping or transit being the main offender.

1.1 Carbon footprint

The amount of carbon dioxide, greenhouse gases, or other carbon compounds released into the atmosphere as a result of an organization's or business's operations is measured as its "carbon footprint." Transportation, fuel use, water use, power use, and garbage generation are some of the causes of this emission.Carbon footprints are primarily used to evaluate and compare how an organization's presence affects the environment.Organizations can find areas where they could cut their carbon emissions and further develop sustainable practices by monitoring and understanding the components that make up their carbon footprint.

Figure1 represents the various sources of Greenhouse gases emissions in industries To calculate the carbon footprint from CO2 emissions, you need to consider the amount of CO2 emitted and convert it into equivalent units of carbon dioxide (CO2e) to account for other greenhouse gases' global warming potential. To do this, multiply the quantity of CO2 emissions (typically measured in metric tons) by the appropriate global warming potential factor for each gas (e.g., methane or nitrous oxide). Sum the CO2e emissions from all gases to get the total carbon footprint. Additionally, consider emissions from various sources like energy consumption, transportation, and industrial processes, ensuring you include direct and indirect emissions.

1.2 Carbon credits

Carbon credits, also known as carbon offsets, are a key component of strategies to mitigate climate change by reducing greenhouse gas (GHG) emissions. These credits represent a measurable reduction in GHG emissions, typically one metric ton of carbon dioxide equivalent (CO2e), and can be bought, sold, or traded in various carbon markets. The concept of carbon credits is based on the idea that emissions reductions can be achieved in a cost-effective manner by financing projects or activities that reduce or remove emissions elsewhere. These projects can include renewable energy installations, reforestation efforts, methane capture from landfills, and energy efficiency improvements. By purchasing carbon credits, organizations or individuals can offset their own emissions, contributing to global efforts to combat climate change and achieve emissions reduction targets. The use of carbon credits is often part of corporate sustainability initiatives and regulatory compliance measures, such as those outlined in international agreements like the Kyoto Protocol and the Paris Agreement.A carbon credit represents a tradable authorization or certificate that grants the holder the privilege to release one metric ton of carbon dioxide or the equivalent of another greenhouse gas into the atmosphere. Currently, there exist two primary categories of carbon credits:

Voluntary Emissions Reduction (VER): This type of carbon offset is traded in the voluntary or over-the-counter market for credits.

Certified Emissions Reduction (CER): These emission units or credits are generated within a regulatory framework designed to offset emissions from a particular project. Notably, CERs are subject to oversight by a third-party certifying body, distinguishing them from VERs.

1.3 Carbon trading

Indeed, the utilization of blockchain technology has initiated a carbon trading approach aimed at curbing pollution levels by incentivizing companies that achieve emission reductions. In this context, companies will receive carbon credits permitting a specific level of carbon emissions. All these carbon credits will be securely stored on a blockchain, facilitating their transfer between two companies. Within this system, every transaction involving carbon credits between companies will be meticulously recorded on the digital ledger in a transparent and unalterable manner. Moreover, when carbon credits are transferred from one company's account to another, smart contracts will automatically execute payments to the transferring company as compensation for these carbon credits.

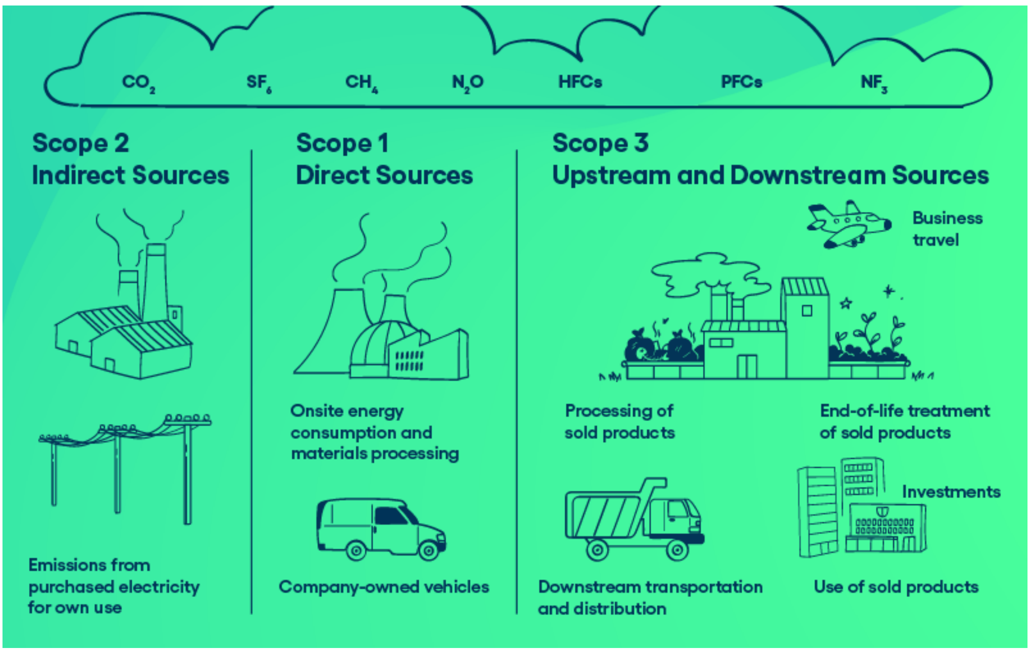

Figure 1. Various sources of Greenhouse gases emissions in industries

1.4 Blockchain

Blockchain technology is a revolutionary decentralized digital ledger system that securely records and verifies transactions across a network of computers. Each block in the chain contains a set of transactions, and once a block is added to the chain, it becomes immutable and tamper-resistant. This transparency and immutability make blockchain highly reliable and resistant to fraud. Blockchain has far-reaching applications beyond cryptocurrencies like Bitcoin; it can be used for secure data sharing, supply chain management, smart contracts, and even in environmental science to track carbon credits and emissions. Its potential lies in creating trust in a trustless environment, eliminating intermediaries, and enhancing the efficiency and transparency of various processes across industries.Blockchain technology has revolutionized the way data is stored and retrieved. It provides a decentralized and tamper-proof ledger that can be accessed by anyone in the network. One of the key features of blockchain technology is distributed consensus. This consensus mechanism ensures that all parties in the network agree on the validity of the transactions, making the blockchain a reliable and trustworthy source of information

1.5 Benefits of using blockchain

Blockchain technology offers a secure, efficient, and user-friendly platform ideally suited for the implementation of Carbon Credit Markets. The blockchain's unchangeable, cryptographically protected distributed ledger ensures the trustworthy issuance and monitoring of carbon credits. Public blockchains are readily accessible to small and medium-sized enterprises, lowering the barriers to entry into the carbon trading market. Moreover, the information shared by companies becomes transparent and available to all participants. Recently, free automated market makers (AMMs) have emerged on blockchain networks, enabling the direct trading of digitized assets without intermediaries and with minimal algorithmic fees. These AMMs provide the necessary foundation to establish a digital carbon credit ecosystem that involves all stakeholders.

1.6 Related work

By measuring carbon emission rights using blockchain technology, it seeks to increase the trustworthiness of transactions. One of the 17 goals of the UN-SDGs (United Nations Sustainable Development Goals) uses blockchain to verify carbon emission rights. It also introduces the required dApp[4]. In fact, by utilizing big data and artificial intelligence in mobile cloud environments, we can safeguard against anomalous carbon emissions. In order to address these issues, this study suggests a blockchain-based carbon emission rights verification system that makes use of the governance system analysis and blockchain mainnet engine.

Carbon emission credits represent the permission to release greenhouse gases, substances that contribute to environmental stress on Earth. When humans emit carbon dioxide (CO_2), nature absorbs it, maintaining a certain level of CO_2 in the atmosphere. However, when emissions exceed the Earth's capacity to naturally regulate the environment, CO_2 concentration gradually rises, leading to global warming and climate change. In 2017[5], global CO_2 emissions increased by 1.4%, reaching 32.5 billion tons. This exceeded the limits set by the Kyoto Protocol 2, implemented in 2005, which restricted companies' greenhouse gas emissions to a manageable level, aiming for a 5.2% reduction in emissions from developed countries compared to 41.8 billion tons. To address this issue, the Emission Trading Scheme utilizes market principles to efficiently reduce greenhouse gases, and this trading system is expanding worldwide, including in Korea, allowing companies to freely buy or sell their remaining or insufficient emission allowances[3,6].

By leveraging decentralized blockchain technology, it becomes possible to use the information and transmission records of carbon emission allowances, resulting in safer transactions. In the coming years, it is anticipated that carbon credits will be exchanged through peer-to-peer (P2P) communication methods. In the European Union (EU), individuals are already involved in the buying and selling of carbon credits. To guarantee the secure trading of these carbon credits, we propose the implementation of a methodology that incorporates blockchain technology[1,2].

2. Materials and methods

Our objective is to establish a Blockchain-based Carbon Credit Ecosystem that enhances liquidity, transparency, accessibility, and standardization within carbon markets. This ecosystem encompasses all involved parties, a tokenization system with well-defined protocols for creating and removing tokens, a transparent method for distributing tokens, and an Automated Market Maker (AMM) for trading these carbon tokens.In this project, there are various stakeholders involved, including those who generate carbon credits (e.g., wind farms, tree-planting initiatives, CO2 sequestration projects), as well as those who consume these credits (such as carbon-emitting entities like the energy industry). Additionally, there are other participants like regulators, concerned citizens, and validators. Validators are a critical component of this ecosystem; they are accredited experts dispersed globally with the technical expertise needed to assess and onboard projects onto an open architecture marketplace. This marketplace facilitates connections between parties interested in generating and retiring carbon credits.By transforming carbon credits into digital tokens that are distributed to carbon credit generators when their projects have been properly validated, we will transfer carbon credits to the Blockchain. Trading carbon credits will take place on a decentralized Blockchain trading platform between buyers and sellers. Supply and demand-driven market dynamics will decide the price. By delivering the given Carbon Tokens to a smart contract or specified blockchain address whose private key is unknown to any party and may be seen by the group of validators as well as regulators or other stakeholders, the Carbon Tokens would be retired using a "buy and burn" strategy. Non-fungible tokens will be distributed to the businesses and people who successfully burn their carbon tokens as a carbon reduction measure.

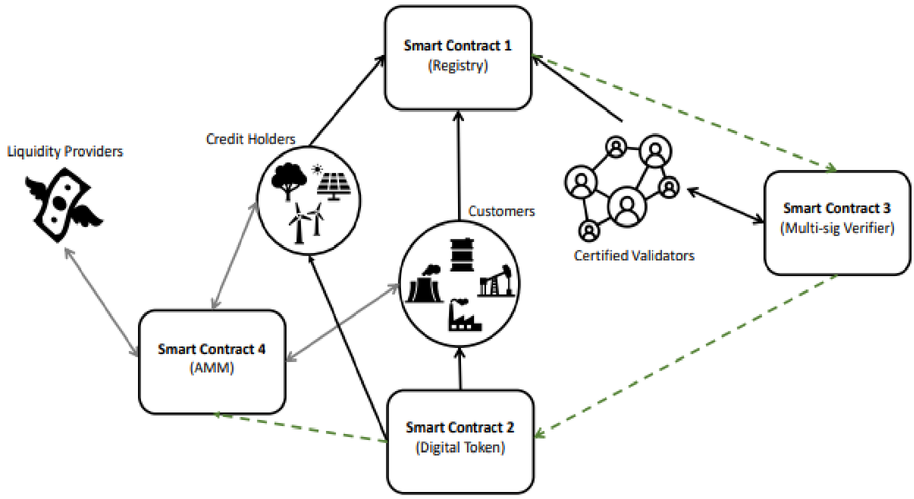

Figure 2. Flow diagram showing the proposed Carbon credit ecosystem on a blockchain

2.1. Stakeholders involved in Carbon Credit system

1. Verifiers: Their role involves the validation of carbon credits held by credit holders. They also ensure that the burning of carbon tokens corresponds to an appropriate reduction in emissions.

2. Carbon Credit Holders: These are organizations that possess carbon credits within the emissions trading ecosystem.

3. Clients: This category encompasses individuals and businesses with an interest in mitigating their carbon footprint by purchasing carbon credits and redeeming carbon tokens.

2.2 Smart Contract for CarbonCredit

The smart contract is designed to manage a Carbon Credit ecosystem, aiming to enhance transparency and accessibility within carbon markets. It includes various components such as registering carbon credit holders, verifiers, and customers.

The CarbonCreditHolder struct stores information about individuals or entities holding carbon credits, including their name, ID, the number of credits held, price per credit, validity period, and Ethereum address. Users can register themselves as carbon credit holders using the registerCreditHolder function.

- The verifier struct contains details about entities responsible for verifying carbon credit-related information, such as their name, home country, registration and license numbers, and Ethereum address.

- Verifiers can be registered through the registerVerifiers function.

- The customer struct stores information about customers, including their first name, last name, email, contact details, and an ID.

- Customers can be registered using the registerCustomer function.

The code also includes functions for retrieving lists of verifiers and carbon credit holders, as well as customer profiles. The onlyOwner modifier restricts access to certain functions to the contract owner.This smart contract aims to create a decentralized blockchain-based ecosystem for managing carbon credits, improving transparency and accessibility in carbon markets. It allows various stakeholders to interact and participate in the carbon credit ecosystem securely.

2.3 Smart Contract for Credit Token

The contract uses several mappings and variables to keep track of token balances, approved credits, and tokens approved for burning. These include "BalanceOf," "approvedCredits," and "tokensApprovedForBurn" mappings.

1. Verifiers can approve credits held by a particular address. The approved credits are added to the "approvedCredits" mapping for the specified address.

2. Credit holders can create carbon tokens based on the credits they have been approved for. The credits are transferred from the approved credits to the token contract, and the equivalent number of tokens is minted to the credit holder's address.Credit holders can also transfer carbon tokens to other addresses. The function updates token balances accordingly.

3. Verifiers can approve a certain number of carbon tokens for burning by a specific holder. This can be used to ensure that the burning of tokens corresponds to the correct reduction in emissions.

4. The contract owner (presumably an entity responsible for managing token burning) can initiate the burning of approved carbon tokens. The function burns the approved tokens, updates the total supply, and subtracts the burned tokens from the holder's balance.

5. Users can purchase carbon credits by sending Ether to this contract. The function transfers the specified number of carbon tokens from the contract to the sender, equivalent to the Ether value.

2.4 Smart Contract for Certification

Verifiers are able to confirm the creation and burning of the carbon tokens using a multi-signature smart contract. For this contract to be automatically performed, at least 70% of the verifiers must approve it.

This smart contract, named "Certification," appears to extend functionality from a previous contract called "CreditToken" and introduces additional features related to non-fungible tokens (NFTs) and certifications.

The contract uses several mappings to manage NFT ownership, approvals, and other related data:

- idToOwner: Maps a unique token ID to its current owner's Ethereum address.

- idToApproval: Maps a unique token ID to an Ethereum address that has approval to transfer the token on behalf of the owner.

- ownerToNFTokenCount: Maps an Ethereum address to the count of NFTs owned by that address.

● burnedTokens: Maps an Ethereum address to the number of tokens that have been burned by that address.

1. addBurnedTokens function allows for the addition of burned tokens to an address's record. It checks if the burnTokens function from the parent contract (CreditToken) returns true before adding the burned tokens to the address's record in the burnedTokens mapping.

2. Mint an internal function is used to mint (create) a new NFT or certification and assign it to a specific address (_to) with a given token ID (_tokenId). Several checks are performed:

a. Ensures that the recipient address (_to) is not the zero address (address(0)).

b. Verifies that the token with the given ID does not already exist (i.e., it's not owned by anyone).

c. Requires that the recipient (_to) has burned at least 20 tokens, presumably as a condition for receiving this certification or NFT.

3. addNFToken an internal function is responsible for adding a newly minted NFT to an owner's record. It checks if the NFT with the given token ID does not already exist and then updates the mappings accordingly, assigning ownership of the NFT to the recipient address (_to) and incrementing their NFT count.

3. Results and Discussion

This smart contract, named "Certification," appears to extend functionality from a previous contract called "CreditToken" and introduces additional features related to non-fungible tokens (NFTs) and certifications.

The implementation of a blockchain-based carbon credit ecosystem has shown significant potential in addressing critical issues related to climate change and carbon emissions. The system introduces several key features and benefits:

● Transparency: Blockchain technology ensures transparency in the carbon credit market. All transactions and credits are recorded on an immutable ledger, providing verifiable proof of emissions reduction and credit ownership.

● Accessibility: The ecosystem is designed to be inclusive, involving various stakeholders such as credit generators, verifiers, consumers, and more. This inclusivity widens the market and encourages broader participation in carbon credit trading.

● Standardization: The use of smart contracts and standardized protocols ensures consistency in carbon credit management. This reduces ambiguity and increases trust among participants.

● Tokenization: The tokenization of carbon credits allows for the efficient and secure representation of these credits on the blockchain. It simplifies trading, reduces paperwork, and increases the ease of ownership transfer.

- Liquidity: The presence of an automated market maker (AMM) facilitates the trading of carbon tokens, increasing market liquidity. This enables participants to buy and sell credits more easily.

- Accountability: With blockchain, every step in the carbon credit lifecycle can be traced. This promotes accountability among credit generators, verifiers, and consumers, reducing the risk of fraud or double-counting.

3.1 Transactions Throughput

Transaction throughput refers to the number of transactions that a blockchain network can process within a given time period, typically measured in transactions per second (TPS). It is a measure of the processing capacity of a blockchain system. It represents the number of transactions that can be processed and confirmed by the system in a second.The number of transactions per second ranges from fewer transactions to 100 transactions. For Ethereum Blockchain , 15 transactions can be processed per second.

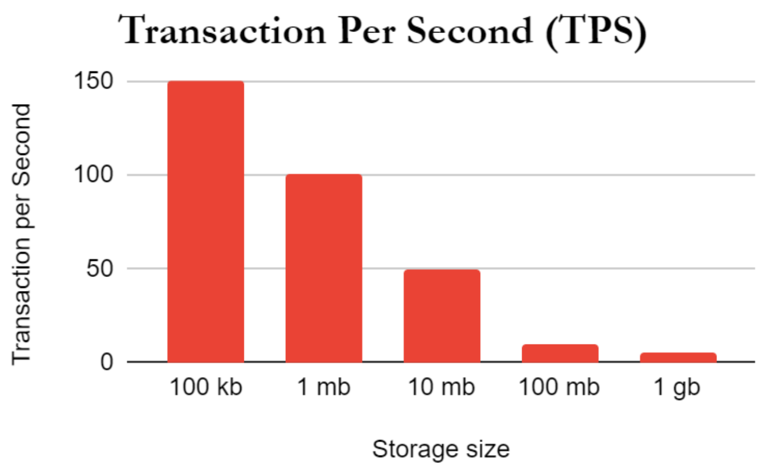

Figure 3. Transaction per second vs Storage Size

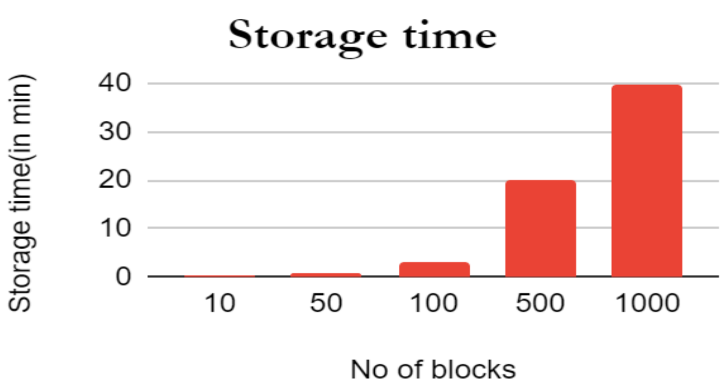

Figure 4. Storage time

The figure 4 depicts the relationships between the number of blocks and the time to store the product details. The storage time will increase when the number of block increases

3.2 Retrieval time

The retrieval time for getting carbon credit details stored in smart contracts can depend on various factors such as the size of the smart contract, the number of transactions stored in the contract, the complexity of the mapping function, and the network conditions. However, once the mapping function and smart contract are designed and deployed, the retrieval time can be very fast as it only involves searching for the specific ID and returning the corresponding details stored in the contract.The retrieval time will be calculated by multiplying block time with no of blocks.

Retrieval Time = Block Time * Number of Blocks

In general, the retrieval time for getting carbon credit details stored in smart contracts can be measured in seconds. This makes smart contracts a very efficient and reliable method for storing and retrieving details in a blockchain-based system.

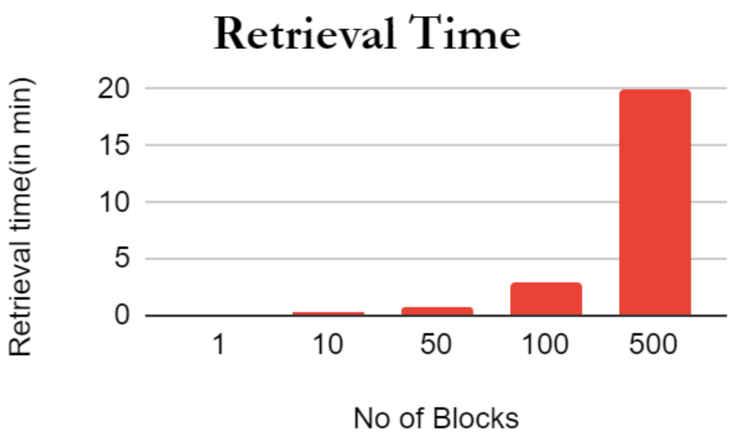

Figure 5. Retrieval time

The figure 5 depicts the relationships between the number of blocks and the time to retrieve the product details. The retrieval time will increase when the number of block increases

3.3 Number of transactions in each block

The number of transactions in each block of Ethereum can vary depending on the size and complexity of the transactions being processed and the available network resources.`On average, the current number of transactions in a block is around 100-200, but this can vary depending on the network conditions and the complexity of the transactions being processed. During times of high network congestion, the number of transactions in a block may be lower, while during periods of low activity, the number of transactions in a block may be higher.

The blockchain-based carbon credit ecosystem offers a robust framework for addressing the challenges associated with carbon emissions and climate change. It builds upon the principles of the Kyoto Protocol and other carbon credit mechanisms by leveraging the advantages of blockchain technology. One of the notable benefits of this ecosystem is its potential to attract a wider range of participants. By involving not only large corporations but also concerned citizens and smaller businesses, it can create a more decentralized and democratized carbon credit market. This can result in a more equitable distribution of the benefits of carbon credit trading. Additionally, the use of smart contracts for the issuance and management of carbon credits can significantly reduce administrative overhead. This not only lowers transaction costs but also streamlines the verification and retirement processes. However, challenges still remain. Integration with existing carbon credit systems and regulations may require careful consideration and cooperation with governments and regulatory bodies. Moreover, ensuring the accuracy of emissions data and the effectiveness of verification processes is crucial to maintain trust in the ecosystem.

4. Conclusion

The blockchain-based carbon credit ecosystem represents a promising solution to the pressing global challenges of climate change and carbon emissions. By leveraging blockchain technology and smart contracts, this ecosystem enhances transparency, accessibility, and standardization in carbon markets. It involves various stakeholders, including credit generators, verifiers, and consumers, fostering a more inclusive and efficient marketplace. Through tokenization, secure digitization, and transparent distribution of carbon credits, the ecosystem promotes liquidity and accountability. Furthermore, the use of blockchain technology provides a solid foundation for addressing environmental concerns and advancing sustainable practices, offering a promising path toward a more eco-conscious future.

References

[1]Ahmad, S.; Tahar, R.M. Selection of renewable energy sources for sustainable development of electricity generation system using analytic hierarchy process: A case of Malaysia. Renew. Energy 2014, 63, 458–466.

[2]Chowdhury, G.; Koya, K. Information practices for sustainability: Role of iSchools in achieving the UN sustainable development goals (SDGs). J. Assoc. Inform. Sci. Technol. 2017, 68, 2128–2138.

[3]Gai, K.; Wu, Y.; Zhu, L.; Qiu, M.; Shen, M. Privacy-preserving Energy Trading Using Consortium Blockchain in Smart Grid. IEEE Trans. Ind. Inform. 2019, 3548, 3515–3558.

[4]Kim, S.-K., and Huh, J.-H., (2020), Blockchain of Carbon Trading for UN Sustainable Development Goals, Sustainability, 12, 4021; doi:10.3390/su12104021

[5]Lee, D.; Han, S.; Kim, J. Economic and Environmental Assessment of a Renewable Stand.-Alone Energy Supply System Using Multi-objective Optimization. Korean Chem. Eng. Res. 2017, 55, 332–340.

[6]Luo, F.; Dong, Z.Y.; Liang, G.; Murata, J.; Xu, Z. A Distributed Electricity Trading System in Active Distribution Networks Based on Multi-Agent Coalition and Blockchain. IEEE Trans. Power Syst. 2018, 34, 4097–4108.