Project 2329 | March 2024

SJSU SAN JOSÉ STATE UNIVERSITY

MTI MINETA TRANSPORTATION INSTITUTE

The Transportation Sector, Cap-and-Trade and Blockchain: A Carbon Credit Trading Platform

Aditya Mankar
Forouzan Golshani, PhD, FNAI, FIEEE, FAAIA

CSUTC California State University Transportation Consortium

CALIFORNIA STATE UNIVERSITY LONG BEACH

MINETA TRANSPORTATION INSTITUTE

Founded in 1991, the Mineta Transportation Institute (MTI), an organized research and training unit in partnership with the Lucas College and Graduate School of Business at San José State University (SJSU), increases mobility for all by improving the safety, efficiency, accessibility, and convenience of our nation's transportation system. Through research, education, workforce development, and technology transfer, we help create a connected world. MTI leads the Mineta Consortium for Transportation Mobility (MCTM) and the Mineta Consortium for Equitable, Efficient, and Sustainable Transportation (MCEEST) funded by the U.S. Department of Transportation, the California State University Transportation Consortium (CSUTC) funded by the State of California through Senate Bill 1 and the Climate Change and Extreme Events Training and Research (CCEETR) Program funded by the Federal Railroad Administration. MTI focuses on three primary responsibilities:

Research

MTI conducts multi-disciplinary research focused on surface transportation that contributes to effective decision making. Research areas include: active transportation; planning and policy; security and counterterrorism; sustainable transportation and land use; transit and passenger rail; transportation engineering; transportation finance; transportation technology; and workforce and labor. MTI research publications undergo expert peer review to ensure the quality of the research.

Education and Workforce Development

To ensure the efficient movement of people and products, we must prepare a new cohort of transportation professionals who are ready to lead a more diverse, inclusive, and equitable transportation industry. To help achieve this, MTI sponsors a suite of workforce development and education opportunities. The Institute supports educational programs offered by the Lucas Graduate School of Business: a Master of Science in Transportation Management, plus graduate certificates that include High-Speed and Intercity Rail Management and Transportation Security Management. These flexible programs offer live online classes so that working transportation professionals can pursue an advanced degree regardless of their location.

Information and Technology Transfer

MTI utilizes a diverse array of dissemination methods and media to ensure research results reach those responsible for managing change. These methods include publication, seminars, workshops, websites, social media, webinars, and other technology transfer mechanisms. Additionally, MTI promotes the availability of completed research to professional organizations and works to integrate the research findings into the graduate education program. MTI's extensive collection of transportation-related publications is integrated into San José State University's world-class Martin Luther King, Jr. Library.

Report 24-02

The Transportation Sector, Cap-and-Trade and Blockchain: A Carbon Credit Trading Platform

Aditya Mankar

Forouzan Golshani, PhD, FNAI, FIEEE, FAAIA

March 2024

A publication of the
Mineta Transportation Institute
Created by Congress in 1991

College of Business
San José State University
San José, CA 95192-0219

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. 24-02	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle The Transportation Sector, Cap-and-Trade and Blockchain: A Carbon Credit Trading Platform		**5. Report Date** March 2024 **6. Performing Organization Code**
7. Authors Aditya Mankar Forouzan Golshani, PhD, FNAI, FIEEE, FAAIA		**8. Performing Organization Report** CA-MTI-2329
9. Performing Organization Name and Address Mineta Transportation Institute College of Business San José State University San José, CA 95192-0219		**10. Work Unit No.** **11. Contract or Grant No.** ZSB12017-SJAUX
12. Sponsoring Agency Name and Address State of California SB1 2017/2018 Trustees of the California State University Sponsored Programs Administration 401 Golden Shore, 5th Floor Long Beach, CA 90802		**13. Type of Report and Period Covered** **14. Sponsoring Agency Code**
15. Supplemental Notes 10.31979/mti.2024.2329		

16. Abstract

This study offers a solution that facilitates direct trading of carbon credits with no intermediaries by using blockchain technology aligned with the cap-and-trade system. With this solution, along with other major transformations in the industry, the transportation sector can take more ownership of emissions and mitigate the impact of its role as the largest contributor of greenhouse gasses. The solution sits at the confluence of the Cap-and-Trade initiative, carbon credit trading, and blockchain technology. Although the concept of blockchains has been the subject of significant curiosity, scrutiny, boosterism, investment, criticism, it most importantly is at the core of useful, rapidly growing innovations. The technology is critical because it removes the need for costly intermediaries for the successful functioning of complex systems. More specifically, the technology has demonstrated that value and asset trading can take place securely and meticulously in the absence of middlemen such as financial intermediaries and other brokers. This study shows how a democratized trading system for carbon credit trade can be constructed in which the parties conduct trades directly, with no third-party involvement, speeding up the process and potentially making it more secure and efficient. This intersection of cap-and-trade and blockchain may increase global participation in peer-to-peer exchange, which will help increase universal participation in carbon offset credits trading and allow the transportation sector to contribute actively to both short- and long-term climate change solutions.

17. Key Words Cap-and-trade, Carbon offset credit, Blockchains Environmental quality, Policy, Legislation and regulation	**18. Distribution Statement** No restrictions. This document is available to the public through The National Technical Information Service, Springfield, VA 22161.		
19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 34	**22. Price**

Form DOT F 1700.7 (8-72)

DOI: 10.31979/mti.2024.2329

Mineta Transportation Institute
College of Business
San José State University
San José, CA 95192-0219

Tel: (408) 924-7560
Fax: (408) 924-7565
Email: mineta-institute@sjsu.edu

transweb.sjsu.edu/research/2329

CONTENTS

LIST OF FIGURES

List of Abbreviations

BTC	Bitcoin
CAT	Cap-And-Trade
CBDC	Center-Backed Digital Currency
CCS	Carbon Capture and Storage
dApp	Decentralized Application
DLT	Distributed Ledger Technology
DOCE	Decentralized Offset Credit Exchange
ESG	Environmental, Social, Governance
ETH	Ether
ETS-EU	Emission Trading System – European Union
GHG	GreenHouse Gas
NFT	Non-Fungible Token
P2P	Peer-to-Peer
PBFT	Practical Byzantine Fault Tolerance
PoA	Proof-of-Authority
PoS	Proof-of-Stake
PoW	Proof-of-Work

Executive Summary

A 2022 congressional report is unequivocal on the environmental impacts of the transportation sector, which is the largest source of carbon dioxide emissions in the United States. Specifically, the report notes that trucks have the second highest average CO2 emissions per Ton-Mile of freight of all modes of transportation, behind only air transport. The method presented herein offers a solution that facilitates this industry sector's move toward being a contributor to global solutions for climate control, rather than being one of the biggest culprits for climate change.

The cap-and-trade system, which aims to limit the maximum amount of emissions across all industries and reduce the capped amount by some margin each year, is currently the most widely accepted international program in support of the environment. This initiative empowers various entities to compensate for their excess carbon emissions by acquiring another entity's carbon offset credits. Once verified by independent third-party organizations, carbon offset credits representing one metric ton of emission reduction can be traded to any interested party. Such trades offer industries the time needed to develop the methods and technologies necessary to achieve their emission reduction targets.

Currently, the cap-and-trade system, encompassing the offset credit exchange, exhibits inherent limitations, of which the lack of standardized global adaptation is the most problematic. However, many of the limitations can be mitigated by using blockchain technology, which, as a Peer-to-Peer system, incorporates decentralization, increased privacy, consensus mechanisms that do not rely on mutual trust, and the ability to incorporate smart contracts.

With no centralized authority, which inevitably may cater to a specific region or country, a global Peer-to-Peer exchange system will help increase universal participation in carbon offset credits trading. This solution is significant because the earth is battling a historical rate of adverse climate conditions and the transportation sector bears its fair share of responsibility for one of the key contributors to our current climate crisis, greenhouse gas emissions.

1. Introduction

Climate change is a reality that most scientists are aware of, but the rate and severity of climate change have long been debated. However, in recent years, there has been unequivocal evidence that climate change affects weather patterns worldwide; the effects of climate change are no longer concentrated in a select few countries, but are evident across the entire world. Dramatic changes in biodiversity, drought, floods, wildfires, sea levels, and extreme weather are occurring globally. A great majority of scientists consider the root cause of the change to be the emission of Greenhouse Gases (GHG). Out of all the components of GHG, carbon dioxide has the most significant impact. As such, in the context of human-caused climate variations, many scientists use GHG and carbon dioxide interchangeably. During the peak of the spread of the COVID-19 virus in 2020, when human activities were significantly restricted, a major improvement in climate conditions was observed worldwide and linked to reduced GHG emissions. Different human activities, such as burning fossil fuels, manufacturing goods and services, transportation, farming, and deforestation contribute to emissions in one way or another.

To date, one of the most promising approaches to addressing the climate crisis is the cap-and-trade program. The first cap-and-trade program was proposed in the Kyoto Protocol of 1997 and provided an option to reduce greenhouse gas emissions [1]. While countries that wish to be proactive in curbing emissions have implemented a variety of regulations, the cap-and-trade (CAT) program has been the most widely accepted one.

With the maturation of carbon credit markets [2], different countries such as the United States, Canada, and Australia, and even some regions such as California and Greater Chicago, have developed their own trading model and platform. This has inhibited the creation of a universal model and a unified set of rules that allows everyone to participate equally. In addition, there are some regions with more stringent laws and regulations that exploit the resources of countries with more lenient laws. This further adds to the instability and uncertainty of the global carbon credit marketplace. Thus, in addition to continuous improvement in the international cap-and-trade policies, a stable technical infrastructure is needed. Similar to the integration of technology into stock market trading, in this paper we explore the possibility of integrating modern technology, namely blockchains, in the carbon credit trading systems.

1.1 Transportation Sector and Carbon Emissions

A recent congressional report, dated December 2022, unequivocally states that the transportation sector is the largest source of carbon dioxide emissions in the United States. Specifically, they warn that "Emissions from transportation surpassed emissions from the electric power sector five years ago and now constitute two-fifths of domestic emissions from burning fossil fuels." The 2021 shares of energy-related carbon emissions by the economic sector show Transportation at 38%, Electric Power at 33%, Industrial at 17%, Residential at 7%, and Commercial at 5% [22]. The silver lining, the article states, is that despite the increase in motor vehicle travel since 2005, CO_2 emissions have declined, due to the auto industry's advances with respect to emission control. For example, in the case of new light-duty vehicles (cars and light-duty trucks), the average fuel economy has improved from 20 miles per gallon to 25 miles per gallon between 2005 and 2021. However, the reality is that cars and trucks continue to account for a large percentage of the CO_2 emissions from transportation.

Focusing on the freight transportation segment, trucks have the second highest average CO_2 emissions per Ton-Mile of freight of all modes of transportation, after air transport (rail has the lowest). Considering that trucks carry more Ton-Miles of freight than the other modes of transportation (Trucks 43%, Rail 29%, and Pipeline, Water and Air 28%), the trucking industry has a significantly larger share of the environmental burden than all others.

The Congressional Budget Office report [22] states that "historically, only 15 percent of total CO_2 emissions in the US were offset by the net absorption of CO_2 by the nation's forests and soil." An unrestricted trading system in favor of promoting carbon-absorbing enterprises will empower the transportation sector to become a proactive participant in global solutions for climate control. The time is right for such cross-sector collaborative exchanges because of the available technologies and recent regulatory mandates. More specifically, the solution presented in this article aims to posture this industry sector as a contributor to global solutions for climate control, instead of having the negative reputation as the largest culprit of climate change.

1.2 The Cap-and-Trade Program

The cap-and-trade (CAT) program is a regulatory compliance system developed to curb carbon emissions by capping the permitted levels of overall emissions and lowering the cap over the years. The governing body sets an overall carbon emission limit for the organizations participating in CAT. Each organization is given a fixed number of permits (also called carbon credits) which dictate its carbon emission allowance. One ton of carbon emissions is permitted for each carbon credit. Credits can be distributed through free allocation, past emission data, production capacity, or auction [3]. There are two main aspects of CAT, outlined below.

Carbon Credit Trading: The amount of permissible emission for a company is determined by the initial offering of carbon credits. If the emission from the company exceeds the allowable limit, a penalty is issued correlating to the amount of excess emission. To avoid paying the fine, organizations can purchase extra carbon credits from an organization with a surplus. Some companies need more carbon credits than are allocated to them, for reasons such as the nature of their business and production, the high cost of switching to a new technology, or the high setup cost. Other industries need much less than their competitors due to efficient processes and/or use of innovative technologies. Trading permits are allowed under CAT to maintain the balance in emissions without going over the capped limit. An organization can sell its excess credits at a defined price to those in need and increase its revenue. This incentivizes investment in green and optimized technologies [4] and creates an ecosystem that collectively curbs emissions without affecting any single entity. The cap amount is then reduced each year, proportionally reducing each organization's permit value to promote the shift to a more optimized or cleaner process. This gradual reduction gives organizations enough time to adapt to new requirements without adversely affecting their production costs [5–6].

Carbon Credit Offsetting: Changing a company's production methodology to reduce carbon emissions can be a high-risk or long-term process. It is sometimes impractical to keep emissions below the set limit. Apart from credit trading, "carbon offsetting" provides another way for organizations to compensate for their extra emission. Carbon offsetting is the process through which an organization may receive credit for making an honest effort to reduce the atmosphere's carbon through actions that it would not normally take. This is also treated as a tradeable commodity [2]. One such way is to invest in projects that conserve nature and natural resources which would otherwise be destroyed. For example, forestation is widely considered an efficient way to reduce carbon in the atmosphere. Organizations can promote forestation or prevent deforestation to receive extra carbon credits. They can also set up renewable energy plants for credits. The idea behind this feature is that, even if the exploitation of nature and natural resources is local, it has adverse effects worldwide. This program provides an opportunity to set up a global carbon offset program which allows organizations to gain carbon credits.

Recently, technology has been developed which allows companies to capture carbon directly from the atmosphere and store it underground. Many companies capture the carbon dioxide that they generate and then securely transport it for safe disposal. This process is called Carbon Capture and Storage (CCS). Though this process is efficient in recording the exact amount of carbon captured, secure disposal of such a large amount of carbon is a substantial task. There are a few cases where the captured carbon has been reused to produce something else, conflicting with the primary purpose of reducing carbon emissions. This is a relatively new development and, thus, it is still under scrutiny.

1.3 Peer-to-Peer Technology

Without global participation, cap-and-trade policies will not be able to keep up with the rate at which climate change is happening. However, to achieve global participation in these programs, a common platform is needed, along with a stable infrastructure and fair rules. Peer-to-Peer (P2P) technology offers a suitable transaction infrastructure without the need for a centralized authority. A P2P system is a decentralized network of independent but interconnected devices that communicate directly with one another using a traditional network infrastructure. These devices are known as nodes or peers.

A traditional network consists of multiple clients and one or more servers, known as the client-server model. The client requests data and services from the server, and the server responds. In a P2P network, each connected node can take on the client and server roles. As each node acts as a separate entity, irrespective of the processing capacity, it can be anonymous. These networks can be dynamic, which means nodes may join or leave the network as needed. In the simplest case, each node maintains a list of its neighbors. When a new node joins the system, it connects to several other independent nodes, and this causes the corresponding node list to be updated. Since various nodes may or may not contain the entire data of the available nodes, when a node acting as a client requests data, the request is propagated from node to node until one or multiple nodes that can fulfil the request receive it. These nodes will then act as a server and respond to the request. The client then receives a random part of the request data from each server, thus reducing the single point of failure. As no single network path is used for all the responses, there are significant possibilities for decreasing the overall bandwidth usage and increasing the speed of the network. This is also an effective way for achieving parallelism and avoiding network congestion.

1.4 Blockchains

A Peer-to-Peer network enables transactions without prior mutual trust but is also susceptible to malware. The P2P network connection can bypass firewalls, and the malicious node can attack the system. Furthermore, nodes can be anonymous in P2P systems, making them a regulatory nightmare. Some of the possible challenges include denial-of-service, a dispute among the nodes, and impersonation. These may quickly turn the system into an unreliable platform with numerous privacy concerns. Due to the absence of a centralized authority, the responsibility of making and enforcing rules and regulations is delegated to the entire network.

Blockchain technology is inherently a Peer-to-Peer network in which nodes maintain a distributed ledger. By virtue of being a P2P system, it is managed by the nodes involved. Each transaction executed on the network is logged in the ledger, a copy of which is maintained by every node, and each node has the responsibility of verifying each transaction.

As autonomous members of a distributed system, all participating nodes must come to a consensus for accepting a transaction, and once there is a consensus, all nodes execute the transaction at exactly the same time. To facilitate the process of consensus building, certain nodes which have distinguished themselves by solving a very difficult problem or by proving that they have a genuine interest in maintaining the correctness of the blockchain can provide assurance to other nodes about the validity of the pending transactions. The nodes that solve a very costly puzzle before vouching for the validity of a transaction are called "miners". Similarly, nodes that can prove their genuine interest in the accuracy of the blockchain, for example by owning a significant amount of assets that would diminish in value if the blockchain becomes inaccurate, are called "stakers". Current implementations of blockchains rely on either miners or stakers to vouch for the correctness of the proposed next block.

Once validated by either miners or stakers, each new block and transactions therein are re-validated by the nodes, and as soon as at least 50% of the nodes come to the consensus that the proposed block is indeed valid, the block is then ready to be added to the blockchain. The addition of new blocks happens at very specific intervals. Once the predetermined time interval has elapsed, the new block is then locked onto the block of verified transactions in the ledger. Blockchain offers many features that are integral to its optimal functioning as well as those that are added to overcome the shortcomings of a traditional P2P network, which are listed below.

The Double Spending Problem: In the blockchain, each coin or token is backed by the underlying asset. These tokens can then be traded as a commodity. Each token can be used for a transaction. As there is no central authority, these transactions are signed with digital signatures to prove ownership of that token. Each transaction takes some time to process, and a single token can be used multiple times, as only recipients can verify the associated transaction. In addition, some transactions might even be invalidated. Blockchains make use of features, such as Hash functions and consensus, that prevent double spending [8].

Hash Functions: Blockchain can process a large number of transactions per second, each consisting of some amount of information. All the details of the transaction need to be stored in the ledger. Blockchain creates a hash of each transaction instead of the complete transaction, and only the hash is stored in each block. The hash function is a one-way function that converts an input of any size to a fixed-length output. This output is called a hash value. Each block consists of many valid transactions. The block's hash is then fed to the next block, creating a chain of valid transactions. This makes it easy to verify the validity of any transaction.

Consensus among Peers: Since there is no central authority to create trust and determine the validity of any transaction, the responsibility of maintaining the reliability of the network falls onto the nodes. The transaction is deemed valid if most nodes can validate it. As nodes may be added and removed from the system, the network can be attacked by malicious nodes. Different consensus mechanisms can make the system resilient against such attacks. Some consensus algorithms are Proof-of-Work (PoW), Proof-of-Stake (PoS), Proof-of-Authority (PoA), Practical Byzantine Fault Tolerance, and Proof-of-Reputation. This is a core part of any blockchain and helps reach a standard agreement among peers [9–11].

Transparency: The main idea of a P2P decentralized system is that the transactions are transparent to everyone. All the transactions are available publicly and can be easily traced in the system. Some blockchains might use anonymous addresses for confidentiality, but the level of identity exposure is utterly dependent on the implementation of the blockchain.

1.5 Coins and Tokens

Blockchain technology is often intertwined with coins and tokens. The most common misunderstanding people have is about Bitcoin. Bitcoin (BTC) is presumed to be a coin, which is true, but more importantly it is a blockchain network. The Bitcoin blockchain offers a variety of functionalities such as transaction validation and smart contracts, apart from the coin being used as a store of value. Similarly, Ethereum is a blockchain network and Ether (ETH) is a coin that facilitates the transactions and operations on the Ethereum blockchain. Tokens are just like coins and the distinction is based on how they are used.

Coins: A coin does not represent any underlying utility but rather operates on its own independent blockchain. It is used to store value and acts as a medium of exchange, just like any traditional currency. Bitcoin is a blockchain as well as a coin (symbolized by BTC). Ether (or ETH) is a coin that facilitates transactions on the Ethereum blockchain. Coins can be mined or earned by performing the validation work (e.g., Proof-of-Work) or by offering stakes while doing the transaction validation (e.g., Proof-of-Stake). Both BTC and ETH are often also referred to as tokens, which is not entirely incorrect; using the term 'coin' symbolizes their exact utility.

Tokens: Contrary to coins, tokens do not have their own blockchain. Tokens are built on other existing blockchains, for different purposes. These tokens are not mined but are rather created by application developers and distributed to users. The protocol for the creation and distribution of tokens is embedded in a smart contract that is deployed on a blockchain. Tokens are often used as a utility in exchange for various other utilities such as service payment, get discounts, represent ownership, and access to a service, to name a few. Tokens are not meant to be used as a medium of exchange. Depending on the case, tokens can be termed Utility tokens, Governance tokens, or Security tokens, among other designations. A Security token represents the ownership of assets. These are transferrable and can be designed to represent fractionalized ownership as well. Essentially, tokens are designed by the product designer to serve a purpose specific to its product. Governance tokens give the right to vote or have a say in rules, regulations, and protocols as specified by the application. This allows people to develop a democratized product that is not controlled by a central authority. Utility tokens can be used for a specific purpose or for a broad spectrum of activities. SushiSwap is one such token that allows users to exchange one coin or token for another. MANA, a utility token native to the game Decentraland, allows players of the game to trade items.

Ethereum is the most widely used blockchain that offers the infrastructure and application layer to develop tokens on top of it. It has developed multiple standards for the development of different utilities of tokens. The ERC-20 token standard is commonly used to develop tokens that are not unique and are transferrable. ERC-20 tokens offer other functionalities like determining the total supply of tokens, event broadcasting, and state management, to name a few. There are other standards under development on top of ERC-20 to mitigate some of its restrictions.

Non-Fungible Tokens: Non-Fungible Tokens (NFTs) are critical to many applications, including ours. NFTS are a unique kind of utility token as no two NFTs represent the same asset or value. ERC-721 is the most commonly used token standard for the development of NFTs. The need for non-fungible tokens arises with the goal of assigning a special characteristic to a specific token. Users can determine the value of an NFT based on its age, rarity, history, reputation, acceptance, or some other factor. Each NFT can bear a different value for each individual or application. Thus, it is perfect for representing such objects as collectible items, lottery tickets, certifications, etc.

The ERC-1155 token standard is a recent development related to the development of NFTs. It offers a standard interface extending the ERC-721 functionality to improve security, efficiency, and flexibility [12].

NFTs are unique and are not directly exchangeable, unlike a common token or coin. Each holds a different value and may not be traded directly, necessitating a trading platform. These trading platforms are often called marketplaces. In our proposed solution to the problems facing the carbon credit system, each carbon credit is mapped to an NFT that includes its details. Even though each carbon credit provides the same utility of fixed carbon emission, we use the NFT to track information such as how it was created, who approved it, the history of transactions, when it was used, and any other important information. We can then design a trading platform that facilitates NFT transactions.

1.6 Smart Contracts

A smart contract is a contract that is programmed and deployed onto the blockchain. These can be automatically invoked upon the triggering of any event. Smart contracts can be programmed to perform any specific operation. The major characteristic of a smart contract is that it is immutable by virtue of being recorded permanently. They can be triggered on the initiation of a transaction, capturing the initiators' information, verifying it, and generating value. Smart contracts can then be made to perform automated tasks, including identifying and triggering other contracts. They can also act as the embodiment of an algorithm or a protocol that will perform auto-validation and update the blockchain ledger [13–15]. Many characteristics of smart contracts closely resemble the characteristics of blockchains. A few of them are discussed below.

a. **Immutability**: Once the smart contract is deployed on the blockchain, it cannot be altered or changed. Thus, it must go through various checks before it is deployed.

b. **Security**: Cryptographical techniques support the security of intelligent contracts as an integral part of its operation. The immutable nature of the overall system makes its security much more robust. If a hacker can find and exploit any vulnerability in the code of the smart contract, it may result in significant loss of assets.

c. **Self-enforcing**: The intelligent contract invocation does not need human intervention and is triggered by specific events.

2. Combining Blockchains and the Transportation Sector

Automation—powered by the Internet of Things (IoT)—has provided new opportunities to grow the efficiency, economy, and resilience of the transportation sector. Specifically, the three areas of interest in this study—goods, vehicles, and services—have seen significant changes in recent years. However, many of the improvements have been achieved in a silo. Our goal is to simplify business and trade by enabling information sharing across the silos. The two main hurdles that the proposed system addresses are (a) trade between anonymous and identified parties, and (b) trade with or without the need for a central authority or third party.

The proposed Blockchain platform simplifies the transportation sector's transactions, specifically those related to energy and the environment. It allows transactions to be programmable, secure, unforgeable, time-stamped, immutable, unanimous, and transparent. The cost associated with blockchain is often compared to the costs and advantages of having a centralized system. In [16], authors have identified how the transmission cost can be reduced significantly if the central authority is removed and Peer-to-Peer transaction is promoted. In [17], authors have concluded that a smart contract to enable transactions on the blockchain can be automated, thus reducing dependency on humans for verification and completion. This saves humans many hours and guarantees the process is executed.

2.1 Leveraging Blockchain for Energy Trade

Integration of technology such as the Internet of Things (IoT) into the transport industry has enabled real-time tracking, enhanced efficiency, reduced cost, improved safety, and increased transparency. Despite notable advances within different transport sectors, the implementation and advantages are limited to separate silos. New challenges have emerged due to the isolation of data and information within each transport sector. Data and information are often stored and managed within the department. This poses two challenges: fragmented knowledge and limited collaboration. We strongly believe the advances within each silo have immense potential to unlock greater applications if the information is shared securely among them. By harnessing secure data sharing and the P2P transaction capabilities of the blockchain, we can unlock the untapped potential of cross-sector integration.

Blockchain-based systems will enable improved operational efficiency and resource utilization and an integrated transport system. They can provide a standardized framework for cross-sector data sharing and transactions without exposing sensitive information. We believe the integration of different silos in the transport sector and secure cross-silo information sharing is the pathway to achieving a truly efficient ecosystem.

2.2 Energy Trade

To gain a comprehensive understanding of energy trading, it is essential to understand the inherited issues associated with a different form of energy trading. For this study, we identified the intricacies of the lifecycle of carbon credits and explored the existing carbon trading systems across the world. Through the study, we unearthed the complexities of the trading system and a common set of challenges associated with it. The proposed proof-of-concept for carbon trading will serve as a foundation for integrating multiple forms of energy trading. It provides a systematic framework for trading energy commodities without the need for a centralized authority.

Challenges with Carbon Trading and Energy Trading: The carbon offset program is an integral part of carbon trading. Traditional carbon credits are issued by the government and are traded on the established system. Meanwhile, offset credits are verified by an authorized third party and can be traded over the counter. After careful observation of carbon credit trading systems, a recurring pattern in the core functionality of the trading systems emerged. This pattern can be abstracted into a comprehensive framework that can facilitate the trading of diverse commodities, not just carbon credits. A carbon credit is essentially a commodity that is traded based on price on certain platforms. Similarly, there are other commodities like water rights, biodiversity offsets, and renewable energy certificates. All these are traded on specialized commodity exchanges. Having a single, dependable, transparent platform will promote public faith in its legitimacy. Trading of all these commodities is based on a similar framework. This framework addresses the two most important aspects of a common energy trading system, explained below:

Credibility of the credits: A blockchain-based trading system requires the unit of energy commodity to be converted into a digital form (token). The process of converting a unit of physical commodity to a digital commodity is known as **Tokenization**. This process is essential to maintaining the integrity and authenticity of the system.

Transaction transparency: To maintain the transparency and verifiability of the system, transactions need to be open. Blockchain inherently maintains an immutable record of each transaction in the form of hash code. Any transaction done on the blockchain is verified and validated by the participating nodes, and the transaction history of each token can be viewed on the specific Blockchain Scanner. Considering the transparency requirement and the properties of Blockchain, we propose the **Commodity Trading Framework** and discuss it in detail in the subsequent chapter.

3. Energy Trade System Architecture

In traditional trading platforms, user access is controlled through account sign-in and session management. Blockchain, in its simplest form, is a distributed database that maintains transaction records.

Ethereum is the choice of blockchain for this project since it is widely accepted as the most established and mature public blockchain. It is the underlying platform that allows the development and execution of smart contracts. Rules and regulations can be incorporated into a smart contract so that the structure is not tampered with and transparency is maintained. As the system is blockchain-based, users need a Web3 wallet to interact with it and the medium of exchange must be cryptocurrency.

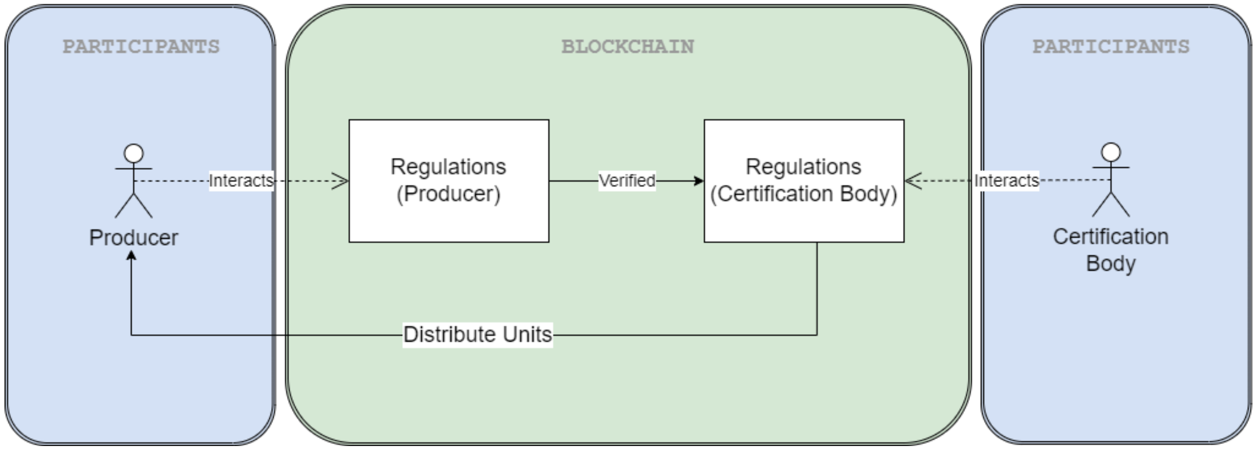
Each energy credit can be mapped to an NFT. By representing energy credits as NFTs, we can maintain their uniqueness. This allows us to incorporate metadata such as the user that created it, the certification body that approved it, the date it was transferred, the price it was transferred at, and so on. Converting the physical unit of a commodity to a digital token is a highly specialized task and is delegated to the registered third-party certification body. It allows the public to determine the legitimacy and maintain the transparency of NFT and certification authority. Any user with a Web3 wallet can interact with the system and act as a buyer, seller, or credit producer.

As discussed in the previous chapter, the development of a commodity trading platform goes through two important phases. In the first phase, a unit of a commodity is defined, and a certain number of units are generated. We call this process "commodity tokenization." If we consider the stock market, this is the phase when the ownership percentage is converted into a fixed number of shares. In the second phase, a structure for the trading of commodities between participants is defined. It determines the rules and regulations for the transfer of NFT ownership. We call this the process of developing a 'trading framework'. Let us look at each phase in more detail.

3.1 Commodity Tokenization

The goal of Commodity Tokenization is to convert each unit of the commodity into equivalent tokens, i.e., to mint new tokens. The definition of a unit is different for each commodity and thus each module needs to be specific to the commodity, but the framework remains the same. Refer to Figure 2, which is a high-level perspective on how different modules, identified in the section above, interact with each other.

Figure 1. The High-level View of Commodity Tokenization Workflow

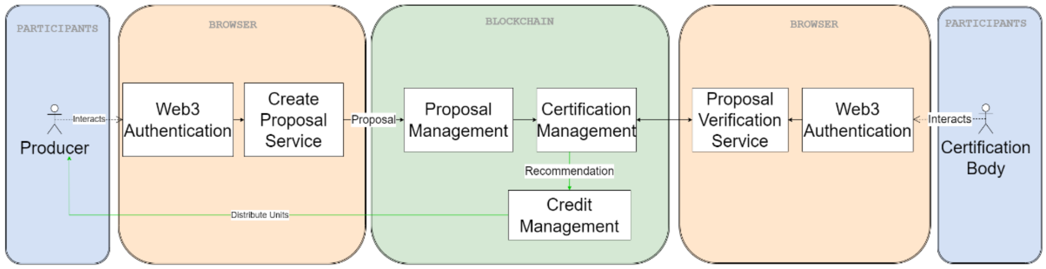


First, a producer interacts with the blockchain to submit a request to mint tokens. All the modules of the blockchain are deployed using smart contracts. The smart contract, which is specifically designed to handle the request from the producer, will verify it. Upon verification, this request is then transferred to a separate smart contract module that interacts with a third-party certification body. The certification body is responsible for determining the credibility of the request, and either approves or rejects the proposal. Upon approval, a set of tokens will be minted and transferred back to the producer.

This seemingly simple flow of logic is adapted to the system framework as shown in Figure 2, which describes in detail how modules perform specific tasks and communicate with each other. The browser is an interface that allows users to interact with the blockchain. It is used to provide and receive information from the blockchain. Each user must be authenticated through a Web3 wallet before they can communicate with blockchain modules.

For any commodity to be converted into units, a producer first needs to create a proposal that includes the necessary background work, due diligence, financial history, ownership record, necessary approvals, proof of intent, proof of value, and other relevant information. Of course, this depends on the type of commodity being converted. The Create Proposal service module is a web service that the producer can access over the internet. The data from the producer is then bundled into a single proposal and sent to the Proposal Management module, which is deployed on a blockchain. This is a smart contract that defines the rules, regulations, and guidelines for a proposal to be accepted. It is imperative to know that the Proposal Management module does not determine the outcome of the proposal but rather specifies the structure of the proposal. The structure framework is encoded in a specific smart contract. Each newly created proposal is basically a new object of the same smart contract that enforces a common structure to the new proposal. The advantage of having a smart contract is that all the proposals derived from it are public and its entire history can be viewed by anyone.

Figure 2. Commodity Tokenization Framework

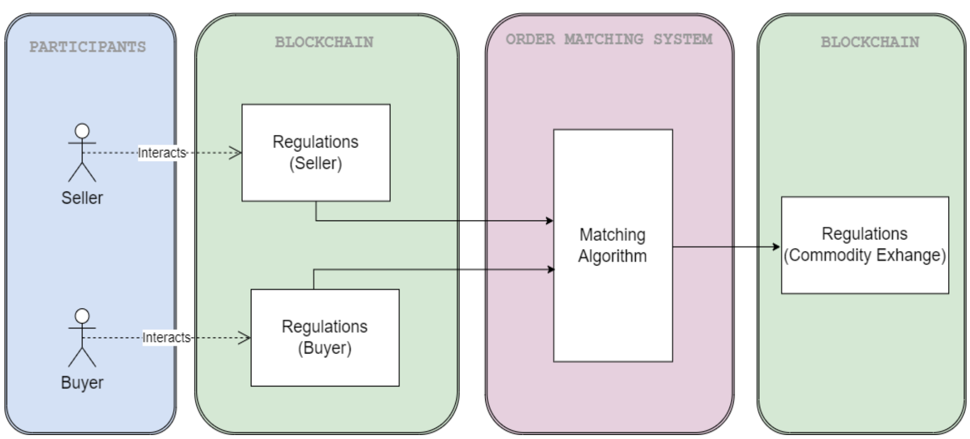


Proposal acceptance or rejection is a highly specialized task. It is somewhat subjective and requires dealing with continuous changes in the industry, common standards accepted by the market, interpretations of the proposal content, and changes in regulations. Thus, a specific *Certification Management* system is required to determine if the proposal can be accepted or not. To use an analogy, laws are written in the Constitution but we still need judges to enforce them and determine the appropriate outcome for each specific case. Different independent third parties (e.g., the certification body) interact with the *Certification Management* module. The interacting certification body determines if the proposal is accepted or rejected, and the subsequent decisions and actions are updated on smart contracts and transferred to the *Credit Management* module. *Credit Management* is just a set of instructions written on smart contracts. It automates how units of the commodity credit will be distributed upon approval.

3.2 Commodity Trading Framework

Once a commodity is tokenized, the created tokens can be traded among the participants. A trading framework has only two interacting entities: a seller and a buyer. We first discuss the generic protocol for trading, illustrated in Figure 3.

Figure 3. The High-Level Commodity Trading Workflow



As shown in Figure 3, the buyer and seller interact with the blockchain modules that create buy orders and sell orders, respectively. These orders are fed to the order book of the *Order Matching Algorithm* module. *Order Matching Algorithm* then identifies the matching orders and updates the blockchain module to handle commodity exchange. Once matching orders are found, logic embedded in the smart contract executes the transaction.

The identified workflow is grafted onto the architectural framework, as shown in Figure 4. All the verifications, processing, and transactions are executed completely on the blockchain. A browser is an intermediary that provides an interface to interact with the blockchain. The *Order Matching System* is kept outside the blockchain for the following reasons:

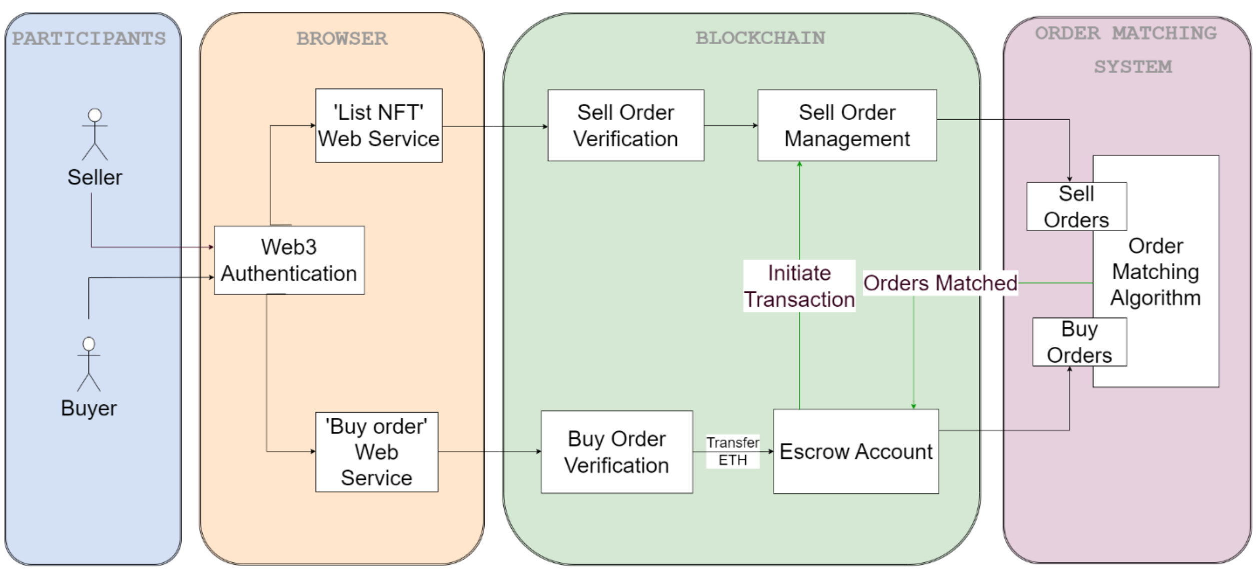
1. Even though most trading is based on price matching, each commodity trade can be based on a unique matching system such as quantity, quality, reputation, etc.

2. The *Order Matching Algorithm* scans the order book continuously for new and previous orders to find a match. This process could be expensive to execute on the blockchain.

3. An unconfirmed and unexecuted buy/sell order creates overhead and can fill the blockchain with irrelevant data.

4. The *Order Matching System* is designed to be a read-only application that listens to smart contract events and has no permission to modify orders. A detailed explanation is provided in the subsequent section.

Figure 4. Commodity Trading Model Framework



In the commodity trading model framework, as presented in Figure 4, the regulations that are specific to buyers are embedded in the *Buy Order Verification* module. On the other hand, the regulations specific to sellers are divided into two separate modules, namely *Sell Order Verification* and *Sell Order Management*. The functionality of the module handling the commodity exchange is integrated into the *Sell Order Management* and *Escrow Account* modules. We assume that Ether (ETH) is the medium of exchange. We discuss the specifics of each module below.

1. **Web Services**: Different web services are used to interact with the blockchain. All of them are accessed through a browser. First, Web3 authentication is required through a decentralized wallet. Another web service is the 'Buy Order' web service, which allows user to enter the preferences of the commodity it is willing to buy. The common preferences may include the bidding price and quantity of tokens. The last web service is the 'List NFT' web service. It is an interface that allows the user (the owner of an NFT) to list an NFT for sale.

2. **Sell Order Verification**: When a user lists the NFT for sale, it is imperative to verify that the specified NFT actually belongs to the user. As there is no central database that holds all the information about the user, ownership verification is essential. This module is responsible for all the due diligence involved in ownership verification.

3. **Sell Order Management**: A sell order must be created once the required information is verified. It is a smart contract that performs the following three main operations:

    a. The *Sell Order Management* creates a smart contract that will act as a sell order. The sell order contains information about the NFT, the NFT owner's address, transaction history, ownership history, the owner's transaction preferences, and attributes of metadata that are essential for the *Order Matching System*.

    b. On creation of a sell order, it broadcasts a notification, also known as an emitting event, to the applications outside the blockchain. This alerts external applications to the state of the smart contract.

    c. It provides a '*payable*' interface to the sell order smart contract which allows automatic transfer of the NFT to the ETH-paying wallet.

4. **Buy Order Verification**: Similar to *Sell Order Verification*, this module verifies the user and its preferences such as bid price, token quantity, and the user's access privileges

5. **Order Matching System**: The order matching algorithm depends on the type of commodity that is being traded and the transaction rules that need to be implemented. The most common algorithm used is Price-Time priority, where the first buyer with a matching price is matched with the seller. There are other established algorithms as well. The *Order*

Matching System subscribes to the events emitted by the *Sell Order Management* module and keeps track of the state of all the sell orders. It also subscribes to the *Escrow Account* module to track the state of the buy orders. When a matching order is found, it communicates with the escrow account.

6. **Escrow Account**: The escrow account is a smart contract-based account that is responsible for the following operations:

    a. It locks the ETH that the buyer is willing to pay for an NFT.

    b. It will create a smart contract that acts as a buy order. The buy order will contain information about the buyer's preference and the buyer's address.

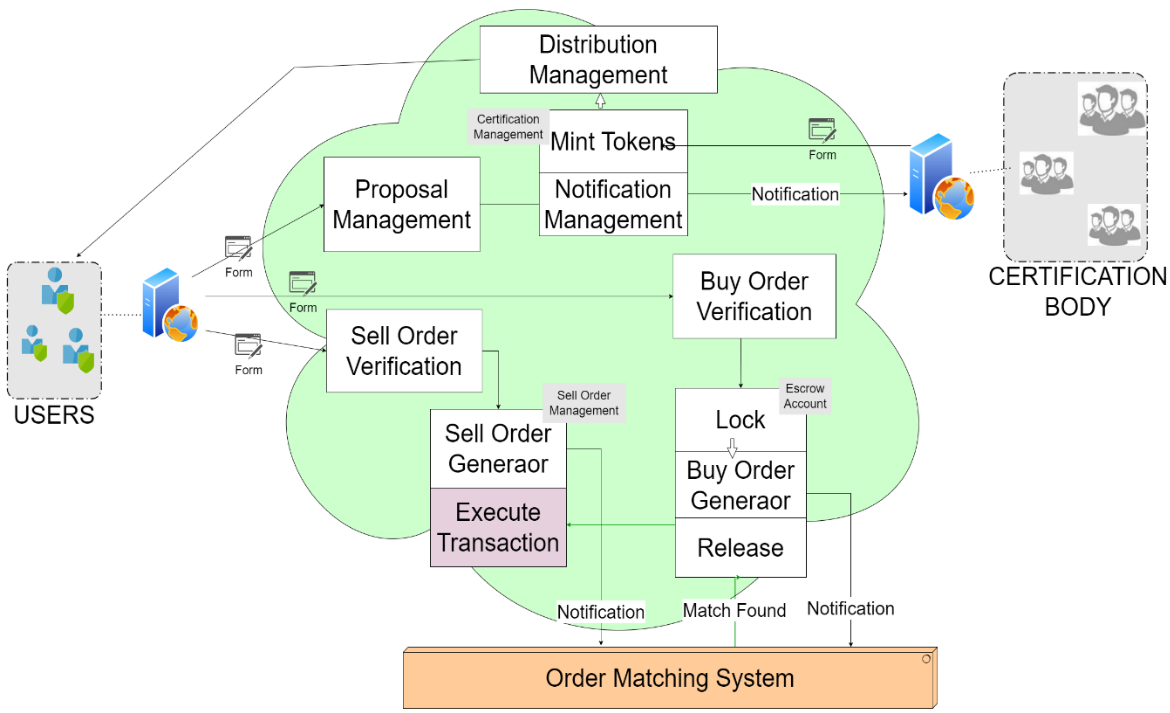
    c. It broadcasts the notification about the state of the buy order to the applications outside the blockchain.

    d. It communicates with the *Order Matching System* to identify the matching orders. On receiving the matching order confirmation, the locked ETH is transferred to the *Sell Order Management* module and triggers the '*payable*' interface to complete the transaction.

4. System Overview and Application

The Decentralized Offset Credit Exchange (DOCE) is developed as the proof-of-concept for the specialized implementation of the Commodity Trading System. Its architecture is completely based on the *Commodity Tokenization* framework and *Commodity Trading Model* framework that we discussed in previous chapters. Figure 5 shows the bird's-eye view of the DOCE architecture.

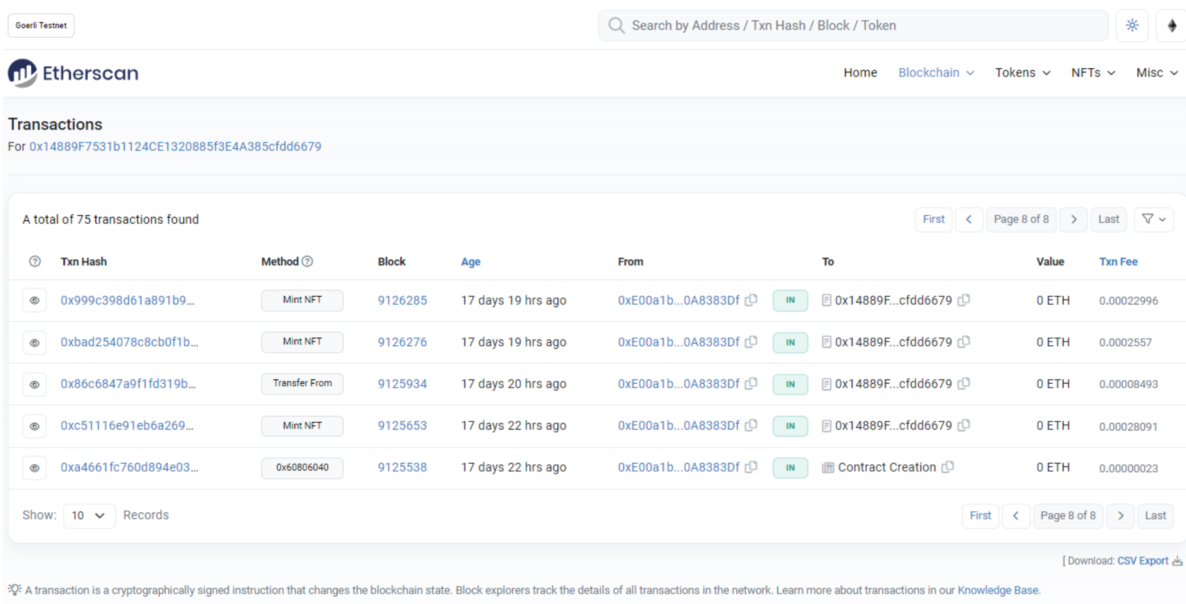
Figure 5. A High-Level View of Decentralized Energy Exchange



For this system to run smoothly, it needs to be developed on a permissionless blockchain. We used the Ethereum blockchain. A smart contract, developed in Solidity, contains the rules for the NFT creation, distribution, transfer, exchange, and decommission and defines the core structure of the NFT metadata. It is the core of the system as integrating the security and rules is paramount. The Ethereum blockchain offers multiple alternative networks that mimic its functionality. These are designed specifically for development and testing purposes and are called the Ethereum Testnets. Using Testnets, the developer does not need to spend ETH to test smart contracts and applications. Any smart contract that can be deployed on the Ethereum Mainnet can be deployed on the Testnet. We deployed our proposed system on one such Testnet, known as the Goerli Testnet.

Each transaction on the blockchain generates a unique hash value. A transaction is directly searchable through the hash generated for a specific blockchain. All transactions done on the Ethereum network are visible to the public on the blockchain explorer. The blockchain explorer is an interface through which any user can search for a transaction or operation made on the blockchain. The Etherscan is the blockchain explorer for Ethereum, and the Goerli Testnet Explorer (https://goerli.etherscan.io/) records all transactions done on the Goerli blockchain. The hash generated for the deployed smart contract is "0x14889F7531b1124CE1320885f3E4A385cfdd6679" and the same can be verified on Goerli Testnet, as shown in Figure 6. The first transaction recorded for this contract hash would be "Contract Creation", which indicates that our smart contract is successfully deployed and we can interact with it. Once the smart contract that creates and manages the NFT is deployed, the proposed system is developed around the interaction with this smart contract.

Figure 6. Smart Contract Deployment on Blockchain



We are keen to preserve the transparency inherent in a decentralized trading system. Figure 7 is a snippet of one of the services in the developed application that allows users to see all the carbon credits that are in circulation and available on the blockchain. The user can view all the details of a credit—such as the approved proposal, the proposal producer, the approving Certification Authority, and the entire transaction history of the credit—by clicking the "Info" button. The proposed system provides an interface for credit transactions, but all the transactions are executed on the blockchain. These can be verified through Blockchain Scanner by searching the smart contract hash as shown in Figure 8.

Figure 7. Total Credits in Circulation on Blockchain

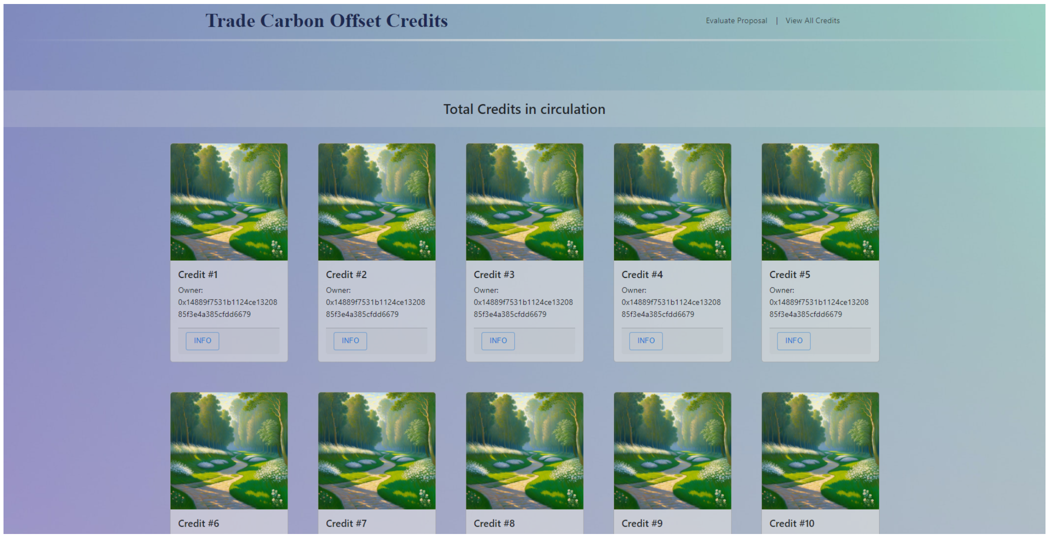
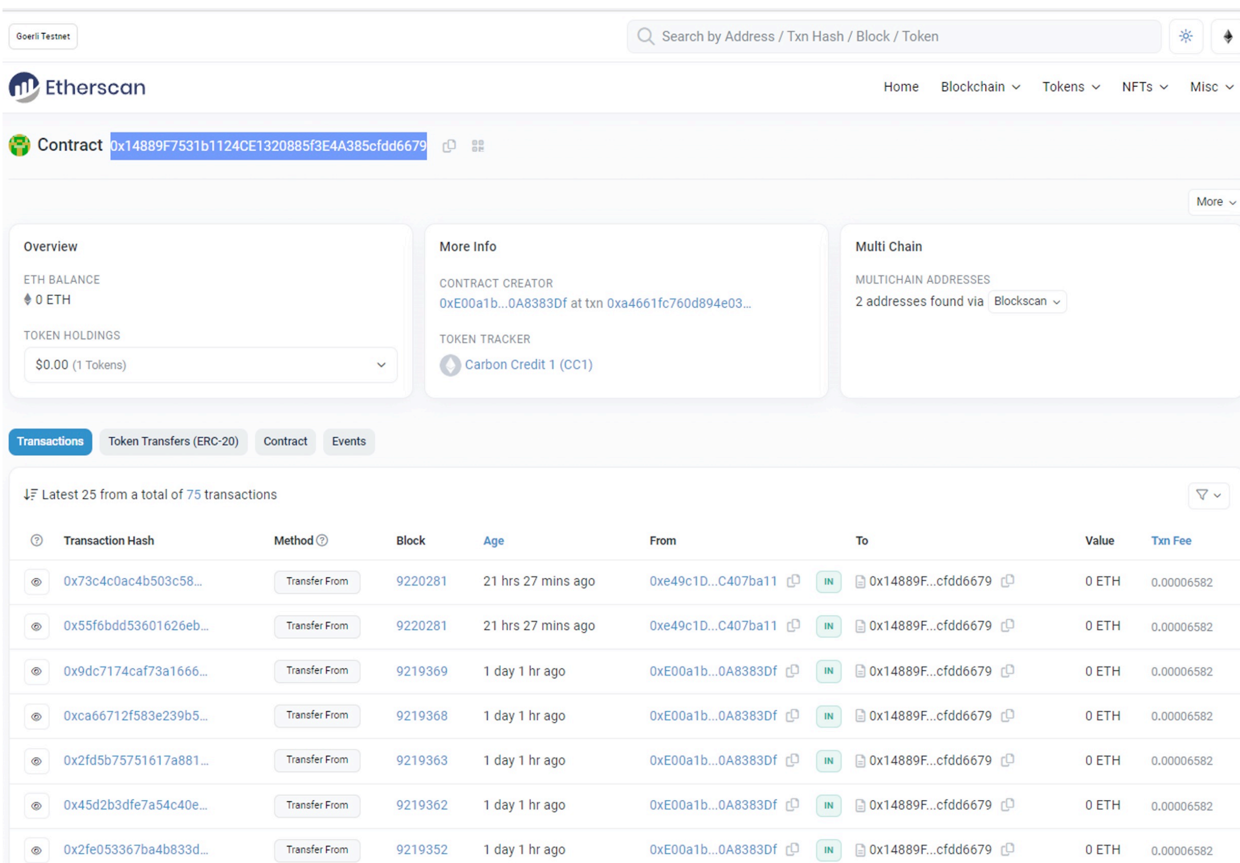


Figure 8. Credit Circulation on Blockchain Scanner



To summarize, we identified how we can leverage blockchain technology through the Commodity Tokenization Framework and Commodity Trading Model Framework to create a decentralized application. This application is both strategically controlled and transparent. This system does not store any data locally or at any centralized location. All the transactions done on the DOCE can be viewed and verified on the blockchain explorer. Thus, we can achieve decentralized P2P transactions, transparency, verifiability, and a trustless system.

We can implement the developed system and integrate credits from the transport sector with little to no changes. As credits of the transport sector are generated and distributed at its discretion, the transport authority will act as the Certification Body. Onboarding of the transport authority as a Certification Body is a one-time process. For every unit of resource that we want to tokenize, an official proposal will be created, just like we discussed with carbon offset credits. This proposal will be directed to the appropriate certification body. This certification body will have strategic control over the creation and distribution of these tokens through smart contracts, yet transparency will be maintained. This allows smooth and sequential onboarding of independent sectors without affecting other systems. It will enable secure strategic information sharing across different silos of the transportation sector and unlock new potential applications, increasing the overall efficiency of the ecosystem.

One key area that our proposed framework enables is the facilitation of exchange within different transportation sectors. The developed system will provide a platform to track and increase ownership of the overall emissions of each sector, motivating businesses to act on carbon emissions through offset credits.

4. Conclusions

With the ports of Los Angeles and Long Beach in the vicinity of their university campus, the authors of this report did not have to go far for data on transportation sector carbon emissions. The two ports collectively handle nearly 20 million TEUs—10.7 million by the Port of Los Angeles and 9 million by the Port of Long Beach (A TEU or Twenty-Foot Equivalent Unit is a measure of volume in twenty-foot-long containers. Two TEUs equal one FEU, which is a Forty-Foot Equivalent Unit). For simplicity, let us assume that only one-quarter of these containers leave the ports on trailer trucks that carry forty-foot containers. The daily number of trucks carrying cargo to and from the ports is just over 10,000 per day. Added to this are trains that carry a significant majority of the containers and a smaller volume that are transported by other means. Even with the great strides that have been taken toward minimizing emissions, simple calculations show that the transportation industry continues to be one of the largest producers of carbon emissions. The developed system will encourage the sector to take more ownership of the emission and provide easy facilitation for offsetting.

Carbon offset credits are traded on normal markets as well as over the counter; multiple platforms facilitate trading. The credit information is disclosed at the discretion of the seller and the platform. The European Union has developed a single database for tracking the emission trading system, but questions often arise concerning data transparency and integrity. Yuan et al. [18] showcased that consumers are becoming more aware of climate change and prefer products that are less harmful to the environment, even if the purchasing cost is higher. This incentivizes companies to invest more even if the initial adaptation cost is higher. However, as stated earlier, there is no common validation process through which an offset credit buyer can verify the legitimacy of the credits.

The proposed system allows anyone to verify the history of a credit. Overall, it improves the transparency and trustworthiness of the system. The proposed system makes carbon credits accessible worldwide, irrespective of location and regulations, thus increasing the possibility of large-scale adaptation. The proposed framework is devoid of regional politics and regulations, which encourages transportation operators, companies, and people to join voluntarily.

Bibliography

[1] J. Han and Y. Wei, "The Simulation System of China's Carbon Trading Based on Grey Prediction," *2011 International Conference of Information Technology, Computer Engineering, and Management Sciences*, 2011, pp. 273–276, doi: 10.1109/ICM.2011.154.

[2] Y. Bai, T. Song, Y. Yang, O. Bocheng, and S. Liang, "Construction of Carbon Trading Platform using Sovereignty Blockchain," *2020 International Conference on Computer Engineering and Intelligent Control (ICCEIC)*, 2020, pp. 149–152, doi: 10.1109/ICCEIC51584.2020.00037.

[3] Y. Zhang, "Pricing Decision Theory and the Empirical Research on International Carbon Emissions Trading," *2012 International Conference on Computer Science and Electronics Engineering*, 2012, pp. 6–10, doi: 10.1109/ICCSEE.2012.461.

[4] Y. Cheng and Z. Xiong, "Strategic investment in low-carbon technology and optimal production under carbon cap-and-trade regulation," *2017 29th Chinese Control and Decision Conference (CCDC)*, 2017, pp. 6567–6573, doi: 10.1109/CCDC.2017.7978356.

[4] D. Huang, J. Chen and J. Zhang, "Optimal production planning under cap-and-trade with fixed setup costs," *2014 11th International Conference on Service Systems and Service Management (ICSSSM)*, 2014, pp. 1–4, doi: 10.1109/ICSSSM.2014.6943389.

[6] H. He, Z. Luo, C. Ma, and H. Yu, "Production strategy with substitution under cap-and-trade regulation," *2016 International Conference on Logistics, Informatics and Service Sciences (LISS)*, 2016, pp. 1–5, doi: 10.1109/LISS.2016.7854502.

[7] Imran Azim, Wayes Tushar, Tapan K. Saha, Chau Yuen, and David Smith, "Peer-to-peer kilowatt and negawatt trading: A review of challenges and recent advances in distribution networks," *Renewable and Sustainable Energy Reviews*, vol. 169, 2022, 112908, ISSN 1364–0321, https://doi.org/10.1016/j.rser.2022.112908.

[8] Lee, M. Shin, K. S. Kim, Y. Kang and J. Kim, "Recipient-Oriented Transaction for Preventing Double Spending Attacks in Private Blockchain," *2018 15th Annual IEEE International Conference on Sensing, Communication, and Networking (SECON)*, 2018, pp. 1–2, doi: 10.1109/SAHCN.2018.8397151.

[9] S. Nakamoto, "Bitcoin: A peer-to-peer electronic cash system[J]", *Decentralized Business Review*, pp. 21260, 2008.

[10] D. Larimer, Delegated proof-of-stake consensus [EB/OL], 11 2020, [online] Available: https://bitshares.org/technology/delegated-proof-of-stake-consensus.

[11] M Castro and B. Liskov, "Practical byzantine fault tolerance[C]", *OSDI*, vol. 99, no. 1999, pp. 173–186, 1999.

[12] ERC-1155 Multi-Token standard. ethereum.org. (n.d.). https://ethereum.org/en/developers/docs/standards/tokens/erc-1155/

[13] Z. Zhu, J. Su, Z. Jiang, M. Ye, and Z. Zheng, "Making Smart Contract Classification Easier and More Effective," 2022 IEEE International Conferences on Internet of Things (iThings) and IEEE Green Computing & Communications (GreenCom) and IEEE Cyber, Physical & Social Computing (CPSCom) and IEEE Smart Data (SmartData) and IEEE Congress on Cybermatics (Cybermatics), 2022, pp. 228–230, doi: 10.1109/iThings-GreenCom-CPSCom-SmartData-Cybermatics55523.2022.00067.

[14] R. Sujeetha and C. A. S. Deiva Preetha, "A Literature Survey on Smart Contract Testing and Analysis for Smart Contract Based Blockchain Application Development," *2021 2nd International Conference on Smart Electronics and Communication (ICOSEC)*, 2021, pp. 378–385, doi: 10.1109/ICOSEC51865.2021.9591750.

[15] A. Pinna, S. Ibba, G. Baralla, R. Tonelli, and M. Marchesi, "A Massive Analysis of Ethereum Smart Contracts Empirical Study and Code Metrics," *IEEE Access*, vol. 7, pp. 78194–78213, 2019, doi: 10.1109/ACCESS.2019.2921936.

[16] B. Zhang, C. Jiang, J. -L. Yu, and Z. Han, "A Contract Game for Direct Energy Trading in Smart Grid," *IEEE Transactions on Smart Grid*, vol. 9, no. 4, pp. 2873–2884, July 2018, doi: 10.1109/TSG.2016.2622743.

[17] Y. Hanada, L. Hsiao and P. Levis, "Smart Contracts for Machine-to-Machine Communication: Possibilities and Limitations," *2018 IEEE International Conference on Internet of Things and Intelligence System (IOTAIS)*, 2018, pp. 130–136, doi: 10.1109/IOTAIS.2018.8600854.

[18] J. Yuan, J. Ma and W. Yang, "Revenue-sharing contract for supply chain under a Cap and Trade system," *2016 International Conference on Logistics, Informatics and Service Sciences (LISS)*, 2016, pp. 1–6, doi: 10.1109/LISS.2016.7854442.

[19] E. Al Kawasmi, E. Arnautovic and D. Svetinovic, "Bitcoin-based decentralized carbon emissions trading infrastructure model," *Syst. Eng.*, vol. 18, no. 2, pp. 115–130, 2015.

[20] Congressional Budget Office, "Emissions of Carbon Dioxide in the Transportation Sector," December 2022, https://www.cbo.gov/publication/58861.

About the Authors

Aditya Mankar

Aditya Mankar is a software engineer with expertise in enterprise software development and system design and a specialization in Blockchain technology and distributed systems. The author's career commenced with a five-year tenure at Scientific Games, where he made valuable contributions to the game development industry. Subsequently, the author embarked on an academic journey, culminating in the attainment of a Master's degree in Computer Science from California State University, Long Beach.

Forouzan Golshani, PhD, FNAI, FIEEE, FAAIA

Dr. Golshani is a Fellow of the National Academy of Inventors, a Lifetime Fellow of IEEE, and a Fellow of AAIA. He served as Dean of the California State University – Long Beach (CSULB) College of Engineering from 2007 to 2020. Currently, he is a Commissioner on the Los Angeles County Aviation Commission and a Professor of Computer Science and Engineering at CSULB. Previously, he was NCR Distinguished Professor and Chairman of the Computer Science and Engineering Department at Wright University in Ohio, a Center Director and Professor at Arizona State University, and a Research Fellow at Imperial College in London. The author of more than 200 articles, Golshani served as the editor-in-chief of IEEE MultiMedia and on its editorial board, IEEE Transactions on Multimedia, and other scholarly publications. He has registered 10 U.S. and two international patents and has founded several successful startups.

MTI FOUNDER

Hon. Norman Y. Mineta

MTI BOARD OF TRUSTEES

Directors

Karen Philbrick, PhD
Executive Director

Hilary Nixon, PhD
Deputy Executive Director

Asha Weinstein Agrawal, PhD
Education Director
National Transportation Finance
Center Director

Brian Michael Jenkins
National Transportation Security
Center Director

MTI MINETA TRANSPORTATION INSTITUTE