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A FINAL PROJECT REPORT ON

" Blockchain-Based Carbon Credit Ecosystem "

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Certificate

This is to certify that the Project Entitled

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ABSTRACT

Climate change caused by industrial carbon emissions poses a significant threat to global sustainability. To combat this, carbon credit systems are used to regulate and reduce greenhouse gas emissions. However, conventional systems often face challenges such as lack of transparency, delayed verification, fraud, and centralization. To address these issues, our project introduces a "Blockchain-Based Carbon Credit Ecosystem" that leverages decentralized technology to ensure secure, transparent, and tamper-proof management of carbon credits.

In this ecosystem, the government allocates carbon credits to industries based on their production volume. If an industry exceeds its emission limits, it must purchase additional credits from farmers who earn them by planting trees. Farmers upload proof in the form of images, which are then verified by the admin before credits are issued. Smart contracts handle credit issuance and transfers, ensuring automation and eliminating the risk of manipulation or double-spending.

The system consists of three key modules—Farmer, Industry, and Admin—each interacting through a secure blockchain network integrated with a Django backend, MySQL database, and a React.js frontend. Web3.js is used for blockchain interactions, and all credit transactions are immutably stored.

By utilizing blockchain technology, our system increases trust, reduces administrative overhead, and supports environmental sustainability by incentivizing carbon offsetting. It serves as a scalable model for real-world carbon credit management with potential global applicability.

Keywords: Blockchain, Carbon Credit Ecosystem, Smart Contracts, Sustainability, Transparency, Tokenization, Web3.js, Decentralized Application.

Contents

CERTIFICATE **ii**

ACKNOWLEDGEMENT **iii**

ABSTRACT **iv**

List of Figures **vii**

List of Tables **vii**

1 INTRODUCTION **1**

1.1 Introduction 1

1.2 Aim 3

1.3 Motivation 3

1.4 Objectives 4

2 LITERATURE REVIEW **5**

3 PROBLEM STATEMENT AND OBJECTIVES OF THE PROJECT **7**

4 SOFTWARE REQUIREMENT SPECIFICATION **9**

4.1 Introduction 9

4.1.1 Purpose 9

4.1.2 Scope 10

4.1.3 Definition, Acronyms, Abbreviation 10

4.2 Overall Description 10

4.2.1 Project perspective 10

4.2.2 Assumptions and Dependencies 11

4.3 System features and requirements 11

4.3.1 Functional Requirements 11
4.3.2 External Interface Requirements 11
4.3.3 System Features 11
4.3.4 Nonfunctional Requirements 12

5 PROJECT REQUIREMENT 13
5.1 Software and Hardware Requirement Specifications 14
5.1.1 Software Requirement 14
5.2 Flow Chart 16

6 PROJECT REQUIREMENT SPECIFICATION 17
6.1 Blockchain Technology 17
6.2 Django 19
6.3 Proposed System Architecture 21
6.3.1 Algorithm Used: Hash-Based NFT Generation 22
6.4 High Level Design Of Project 23
6.4.1 DFD Diagram 23
6.4.2 DFD Description 25
6.5 UML Diagram 26
6.5.1 UML Description 27
6.6 Sequence Diagram 28
6.6.1 Sequence Diagram Description 29
6.7 Activity Diagram 30
6.7.1 Activity Diagram Description 31
6.8 Test Cases 33

7 WORKING MODULE 39
7.1 Experimental Results 39

PROJECT PLAN 39

8 FUTURE SCOPE 47

9 Conclusion 50

List of Figures

5.1 Flow chart 16

6.1 DFD-0 23
6.2 DFD-1 24
6.3 UML Diagram 26
6.4 Sequence Diagram 28
6.5 Activity Diagram 30

7.1 Login and registration Page 40
7.2 Home page 41
7.3 Farmer Dashboard 42
7.4 Government Validation Page 43
7.5 Farmers Information Page 44
7.6 Proof Submission Page 45
7.7 City industries overview 46

9.1 Gantt chart of Carbon Credit System 51
9.2 IEEE Project Competition Certificate 53
9.3 IEEE Project Competition Certificate 53
9.4 IEEE Project Competition Certificate 54
9.5 IEEE Project Competition Certificate 54
9.6 Certificate of Publication 55
9.7 Certificate of Publication 55
9.8 Certificate of Publication 56
9.9 Certificate of Publication 56

List of Tables

2.1 Research Papers and Summaries 6

Chapter 1

INTRODUCTION

1.1 Introduction

Climate change is one of the most pressing challenges of our time, requiring innovative solutions to reduce greenhouse gas emissions. One such approach is carbon credit trading, where companies are given credits representing the right to emit a certain amount of carbon dioxide (1 credit = 1 ton of CO). Companies that emit less than their limit can trade or sell excess credits, encouraging others to reduce emissions.

However, traditional carbon credit systems face major issues such as lack of transparency, double counting, and high administrative costs. These systems are often fragmented across regions with inconsistent rules, leading to inefficiencies. Additionally, the difficulty in tracking credit lifecycles leads to risks like over-crediting and double-spending. High fees and reliance on brokers discourage small players, limiting participation to large corporations.

To overcome these limitations, there is an urgent need for a modern, trustworthy system. Blockchain technology offers a powerful solution through its decentralized, secure, and immutable ledger. A blockchain-based carbon credit platform removes intermediaries, cuts costs, and provides a transparent record of every transaction—from issuance to final use. This approach not only enhances trust and efficiency but also invites broader participation across sectors and regions.

Blockchain technology provides a powerful solution to these problems. Its decentralized and immutable ledger ensures that all transactions—whether issuance, sale, or usage of carbon credits—are recorded transparently and securely. Our project proposes a blockchain-based carbon credit ecosystem using smart contracts, which automate the issuance and transfer of credits based on predefined rules. This eliminates the need for brokers or centralized verification agencies, drastically reducing transaction costs and delays. Farmers upload photographic proof of their tree plantations, and these are reviewed by the government (admin) for approval. Once validated, smart contracts are triggered to issue credits directly to the farmer's account

The use of tokenization ensures that each carbon credit is converted into a unique digital asset on the blockchain, enabling accurate tracking and eliminating the risk of duplication or double-spending. Our system integrates React.js for the user interface, Django for backend services, and MySQL for managing metadata. Blockchain operations, including credit issuance and transactions, are handled via Web3.js smart contracts. The proof submitted by farmers can also be stored on IPFS to preserve integrity and reduce storage overhead. This makes the credit generation and validation process more accessible, verifiable, and trustable for all stakeholders.

To improve market liquidity, industries can directly purchase credits from farmers through a peer-to-peer trading interface. Smart contracts ensure the credit is transferred only if conditions are met and both parties agree. Each transaction is publicly visible and traceable on the blockchain. Additionally, once a credit is consumed by an industry, it is marked as 'retired' and cannot be reused. This ensures credibility and accountability. By minimizing third-party involvement and reducing overhead, our blockchain-based approach enhances participation from grassroots farmers and industries alike. It aligns with national and global sustainability goals and presents a scalable model for carbon market ecosystems.

1.2 Aim

The primary aim of the "Blockchain-Based Carbon Credit Ecosystem" project is to create a decentralized platform where the government issues carbon credits to industries based on their emission thresholds, and excess emitters can purchase credits directly from farmers. The system leverages blockchain and smart contracts to ensure that all transactions are secure, traceable, and tamper-proof. The goal is to digitize the carbon credit lifecycle by automating the issuance of credits to farmers upon verification of tree-planting evidence and enabling direct peer-to-peer trading with industries. The platform ensures transparent auditing, prevents fraud through immutable records, and promotes environmental sustainability by incentivizing green practices across stakeholders.

1.3 Motivation

The motivation behind the Blockchain-Based Carbon Credit Ecosystem project arises from the urgent need to address climate change through innovative technological solutions. As industries continue to grow, managing carbon emissions effectively has become a global priority. Traditional systems for managing carbon credits often lack transparency and are prone to fraud, leading to inefficient tracking and trading. Farmers who contribute to sustainability by planting trees often go unrewarded, while industries find it difficult to purchase reliable offsets. Our project aims to bridge this gap by using blockchain technology to ensure that every transaction from credit issuance to trading is secure, verified, and traceable through smart contracts and decentralized storage.

In today's interconnected world, there is a pressing demand for systems that provide real-time tracking and verification of environmental contributions. By allowing farmers to upload tree plantation proof, which is then verified by government authorities, the platform ensures fair and accurate carbon credit distribution. The motivation to create this platform also stems from the need to eliminate intermediaries and manual verification processes. A user-friendly, blockchain-backed solution will encourage industries and farmers to participate actively in reducing carbon emissions. This not only supports local sustainability efforts but also contributes to broader global climate goals.

1.4 Objectives

The Objectives of our project are as follows:

- Develop a blockchain-powered platform to ensure transparent transactions in carbon credit transfers between industries and farmers.
- Define clear procedures for issuing credits to farmers based on verified tree plantation data submitted via image proof.
- Reduce administrative overhead and middlemen by using a decentralized architecture and automated smart contracts.
- Use smart contracts to handle credit buying, selling, and compliance enforcement without manual intervention.
- Enable proof verification through a secure admin dashboard built on Django, backed by real-time image and metadata analysis.
- Design a React-based user-friendly frontend for farmers, industries, and admins to interact with the system seamlessly.
- Employ strict verification layers to ensure only valid and audited credits are granted to eligible farmers.
- Implement a permanent retirement process for carbon credits once used, ensuring no double-counting or reuse.
- Align the ecosystem's operation with environmental compliance goals set by national bodies and global agreements.
- Maintain all transactional and verification data in a secure and scalable MySQL database for audit and reporting.

Chapter 2

LITERATURE REVIEW

Sr. No.	Research Paper	Author	Summary
1	Blockchain for Carbon Credits	Padmavati, G. Charan Reddy	G. Charan Reddy explores how blockchain can improve transparency and security in carbon credit markets by automating verification and preventing double-counting. Tokenizing credits on a decentralized ledger could also increase market accessibility, supporting global climate goals.
2	Blockchain of Carbon Trading for UN Sustainable Development	Seong-Kyu Kim, Jun-Ho Huh	Seong-Kyu Kim and Jun-Ho Huh explore how blockchain can support sustainable development by enabling transparent and efficient carbon trading, aligning with the United Nations' sustainability goals. Blockchain could enhance accountability and reduce fraud in carbon markets.
3	Blockchain in Carbon Credit Markets	Abhishek Anand, Divya Kalash	Abhishek Anand and Divya Kalash examine the application of blockchain technology in carbon credit markets, emphasizing how it can streamline the validation process and improve the reliability of carbon credits.

Sr. No.	Research Paper	Author	Summary
4	A Blockchain-based Carbon Credit Ecosystem	Soheil Saraji, Mike Borowczak	Soheil Saraji and Mike Borowczak propose a blockchain-based ecosystem for managing carbon credits, focusing on the benefits of decentralized ledgers to prevent double-counting and enhance market accessibility.
5	Blocks and Credits: A Sustainability Lens on Blockchain Technology	Carly Nemanic, Michael Enejison, Obinna Ejide	Carly Nemanic, Michael Enejison, and Obinna Ejide analyze the potential of blockchain technology in supporting sustainable practices, particularly in managing and trading carbon credits with a focus on environmental impact.
6	A Digital Carbon Credits Ecosystem, Powered by Blockchain	Infosys	Infosys introduces a digital ecosystem powered by blockchain to support carbon credit markets, enhancing the trustworthiness of credit issuance and simplifying the verification process for emissions reductions.
7	Blockchain Technology for Carbon Credit Management	Yashwanth Kolli	Yashwanth Kolli examines the application of blockchain in carbon credit management, highlighting its potential to reduce fraud, increase transparency, and make carbon credits more accessible to a wider range of stakeholders.
8	Blockchain and the Carbon Credit Ecosystem: Sustainable Management of the Supply Chain	Preetam Basu, Akhilesh Singh	Preetam Basu and Akhilesh Singh discuss how blockchain can be integrated into the carbon credit ecosystem to support sustainable supply chain management, focusing on traceability and accountability in carbon markets.

Table 2.1: Research Papers and Summaries

Chapter 3

PROBLEM STATEMENT AND OBJECTIVES OF THE PROJECT

As industries are required to comply with carbon emission limits, there is a rising need for a transparent and secure system to manage carbon credits. Existing manual or centralized systems suffer from inefficiencies, fraud, and lack of trust among stakeholders. Current practices make it difficult to trace the issuance and usage of credits, especially when involving diverse entities like farmers and industries. A system is needed where farmers can submit tree plantation proof to earn credits, industries can purchase excess credits fairly, and government authorities can verify all actions securely and transparently. Blockchain technology, integrated with smart contracts and decentralized verification, offers a viable solution by ensuring transparency, traceability, and elimination of tampering or fraud in credit transactions.

Based on the analysis of existing limitations and the unique requirements of involving farmers, industries, and government bodies, the goal of this project is formulated as follows: "To design and develop a blockchain-based carbon credit ecosystem that facilitates secure and transparent carbon credit issuance, trading between industries and farmers, and ensures traceable, verified transactions using smart contracts and decentralized verification processes."

So the various objectives of the research which are in accordance with the goal of the these are listed below:

- To identify existing loopholes and inefficiencies in current carbon credit tracking systems and determine how blockchain can improve verification, trust, and transparency among farmers, industries, and government auditors.
- To develop a blockchain-based application where farmers can earn carbon credits by submitting verified proof of tree plantation through image uploads, with credits issued after admin approval using Web3.js smart contracts.
- To implement a decentralized trading platform using blockchain that allows industries exceeding emission limits to securely purchase additional credits from farmers without intermediaries, ensuring fair access and pricing.
- To incorporate a permanent credit retirement process through smart contract execution, ensuring that once a credit is used to offset emissions, it cannot be reused or misrepresented in the system.
- To evaluate and ensure performance, scalability, and reliability of the system, using Proof of Stake (PoS)-like logic for smart contract execution while maintaining energy efficiency and low infrastructure costs.
- To design an intuitive web interface using React.js and Django that enables all users—farmers, industries, and administrators—to manage credit issuance, trading, and verification seamlessly and effectively.
- To build a secure verification and audit system that allows the admin to validate farmer submissions and store verified data using a MySQL database for transparent recordkeeping and regulatory compliance.

Chapter 4

SOFTWARE REQUIREMENT SPECIFICATION

4.1 Introduction

The Blockchain-based Carbon Credit Ecosystem is a decentralized web application aimed at managing carbon credits between farmers, industries, and government authorities. Using blockchain technology, it ensures secure and transparent issuance, tracking, and trading of carbon credits. Farmers can upload image-based proof of tree plantations, which is verified by the admin before credits are issued. Industries that exceed emission limits can purchase extra credits directly from farmers. The system promotes environmental sustainability through traceable, fraud-resistant transactions using smart contracts and digital records.

4.1.1 Purpose

The purpose of this Software Requirement Specification (SRS) is to define the key requirements for the Blockchain-based Carbon Credit Ecosystem. This platform aims to automate the lifecycle of carbon credits—from generation by farmers to usage by industries—using blockchain for verification and transparency. The SRS outlines functional and non-functional specifications while emphasizing the system's goals: accurate credit tracking, reduced fraud, and secure, real-time verification by the admin using blockchain-powered smart contracts.

4.1.2 Scope

The scope of this Software Requirement Specification (SRS) includes the design and implementation of a decentralized system for managing carbon credits. It will allow farmers to earn credits for verified tree plantations, enable industries to purchase extra credits, and provide admins with tools for validation. The platform uses Web3.js smart contracts, a Django backend, MySQL database, and React.js frontend. Features include credit issuance, image proof upload, trading, admin verification, and audit trails. Support for third-party services like MetaMask and image storage is also covered under the project's scope.

4.1.3 Definition, Acronyms, Abbreviation

- CCES: Carbon Credit Ecosystem System - IPFS: InterPlanetary File System - PoS: Proof of Stake - DLT: Distributed Ledger Technology

References

- Web3.js and Ethereum Smart Contract documentation - Guidelines for sustainable carbon credit practices - Django and React.js framework documentation - IPFS and decentralized storage standards

4.2 Overall Description

4.2.1 Project perspective

The Blockchain-Based Carbon Credit Ecosystem is developed to provide a transparent and trustworthy platform for managing carbon credits issued to farmers and traded with industries. Farmers submit photographic proof of tree plantations, which is verified by the admin before credits are issued. Blockchain technology using Web3.js records all transactions immutably, preventing double spending and enhancing credibility across the system. This decentralized approach ensures all stakeholders have real-time access to accurate and tamper-proof carbon credit data.

Project Functions

- Uploading and verification of farmer-submitted proof images. - Issuance and tracking of carbon credits on blockchain. - Trading of carbon credits between farmers and industries. - Admin audit and transparent transaction history for all participants.

General Constraints

- Continuous internet connection required for blockchain operations. - Compatibility with modern web browsers on desktop and mobile devices. - Dependence on reliable image storage and blockchain node availability.

4.2.2 Assumptions and Dependencies

- Users understand basic carbon credit procedures. - System depends on blockchain network and third-party wallet integrations. - Admin timely verifies farmer proof submissions for credit issuance.

4.3 System features and requirements

4.3.1 Functional Requirements

- Enable farmers to upload proof images for credit issuance. - Admin verifies proofs and issues carbon credits accordingly. - Allow industries to buy, use, and track carbon credits via smart contracts. - Maintain secure, immutable transaction records on blockchain.

4.3.2 External Interface Requirements

- User-friendly React.js frontend supporting all user roles. - Integration with Web3.js for blockchain transactions and wallet support. - Secure Django backend APIs interacting with MySQL database.

4.3.3 System Features

- Blockchain ensures immutability of all credit transactions. - Automated workflows for credit issuance, trading, and retirement. - Admin dashboard for verification, audit, and system monitoring.

4.3.4 Nonfunctional Requirements

- Usability: Accessible interfaces for farmers, industries, and admins. - Performance: Smooth handling of concurrent users and uploads. - Security: Encryption and secure authentication for all data exchanges.

Chapter 5

PROJECT REQUIREMENT

With growing concerns about climate change, carbon credit systems provide a mechanism for industries to manage their emissions by trading credits with farmers who plant trees. Farmers earn carbon credits by submitting photographic proof of their plantations, which are then verified by an admin. However, traditional systems often face problems like lack of transparency, fraud, and inefficient credit tracking, limiting their effectiveness and trustworthiness.

Moreover, current platforms usually lack real-time verification and immutable transaction records, making it difficult to ensure the authenticity of issued credits and to prevent double spending. This creates a pressing need for a transparent, secure, and efficient system that guarantees each carbon credit is unique, verifiable, and accurately reflects emission offsets.

To solve these challenges, we propose a Blockchain-Based Carbon Credit Ecosystem that leverages blockchain technology with Web3.js to create an immutable and decentralized ledger of all carbon credit transactions. By integrating smart contracts for automated verification and using admin oversight to validate farmer submissions, this system ensures transparency, reliability, and security throughout the carbon credit lifecycle, empowering stakeholders to engage confidently in sustainable environmental practices.

5.1 Software and Hardware Requirement Specifications

5.1.1 Software Requirement

Functional Requirements

- **Credit Issuance:** The system will issue carbon credits to farmers after admin verification of tree plantation proofs.
- **Emissions Tracking:** IoT devices and third-party APIs will provide real-time environmental data linked to the blockchain.
- **Smart Contracts:** Automated contracts will govern carbon credit transactions between farmers and industries, ensuring trust and compliance.
- **Credit Retirement:** Carbon credits used by industries for emission offsetting will be permanently retired (burned) to prevent reuse.

Non-Functional Requirements

- **Performance:** The platform must process transactions swiftly and support multiple simultaneous users and IoT data inputs.
- **Security:** All blockchain transactions, user data, and IoT inputs should be securely encrypted and protected from unauthorized access.
- **Scalability:** The system should efficiently scale to accommodate growing numbers of farmers, industries, and connected IoT devices.
- **Availability:** High availability with minimal downtime to ensure stakeholders can access the platform anytime.

Design Constraints

- The system will use a blockchain framework with Proof of Stake (PoS) consensus to ensure energy-efficient, secure transactions.

Assumptions

Assumptions

- Users, including farmers and industries, will have stable internet access and devices capable of running the web-based application and interacting with blockchain components.

5.2 Flow Chart

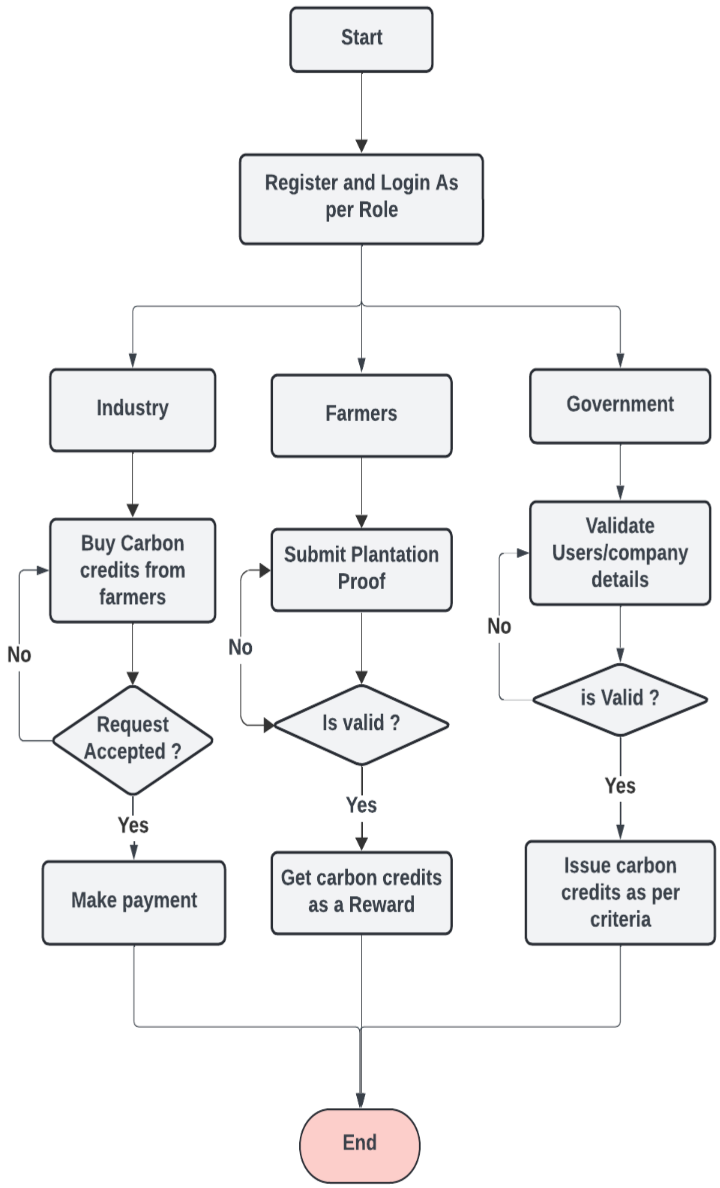


Figure 5.1: Flow chart

Chapter 6

PROJECT REQUIREMENT SPECIFICATION

6.1 Blockchain Technology

Blockchain technology is a decentralized, distributed ledger system that ensures secure, transparent, and immutable transactions. In the context of carbon credit management, blockchain provides a solution for tracking carbon credits in a tamper-proof manner, ensuring that once a carbon credit is purchased or retired, it cannot be reused or duplicated. Blockchain leverages cryptographic techniques and consensus mechanisms like Proof of Stake (PoS) to guarantee data integrity and authenticity without relying on a central authority. This technology is particularly useful for applications in sectors like carbon credits, where transparency and accountability are crucial.

One of the core features of blockchain is its ability to store transaction data in blocks, which are linked in a chain. Each block contains a cryptographic hash of the previous block, ensuring that any alteration in one block would require changing all subsequent blocks, making tampering virtually impossible. Blockchain's decentralized nature means that no single entity controls the data, which provides a higher level of security and trust among participants. The system operates on a peer-to-peer network where each participant maintains a copy of the entire blockchain, ensuring redundancy and fault tolerance.

The consensus algorithms used in blockchain, like Proof of Work (PoW) or Proof of Stake (PoS), help to validate transactions and add blocks to the chain. For carbon credit markets, the use of PoS is preferred as it is more energy-efficient than PoW, which is vital for sustainability-focused projects. Blockchain also enables the creation of smart contracts, which are self-executing contracts with the terms of the agreement directly written into code. These contracts can automate transactions and ensure that carbon credits are only traded or retired under the right conditions, providing both security and efficiency.

Blockchain's ability to track and authenticate carbon credits makes it an ideal technology for improving the transparency and trustworthiness of carbon markets, especially in a decentralized ecosystem where participants may not know or trust each other. Furthermore, blockchain can facilitate the creation of a digital identity for each carbon credit, making it easier to track the life cycle of each credit, from issuance to retirement, ensuring that no credit is fraudulently reused. With blockchain, the carbon credit market can become more accessible, transparent, and efficient, driving further adoption and fostering a cleaner, more sustainable future.

Blockchain's Key Components:

- Consensus Mechanisms: Blockchain uses consensus algorithms like Proof of Stake (PoS) or Proof of Work (PoW) to validate transactions and ensure that all nodes in the network agree on the state of the blockchain.

- Smart Contracts: These are self-executing contracts that automatically carry out terms of agreements, reducing the need for intermediaries and minimizing human error.

- Cryptographic Hashing: Blockchain employs hashing algorithms such as SHA-256 to secure data and ensure integrity by linking each block to the previous one.

- Distributed Ledger: Blockchain operates on a distributed ledger system, where each participant in the network holds a copy of the entire blockchain, ensuring redundancy and reliability.

- Decentralized Network: Blockchain operates without a central authority, relying on a network of nodes (participants) to validate transactions and maintain the ledger.

6.2 Django

Django is a high-level, open-source Python web framework that encourages rapid development and clean, pragmatic design. It provides a robust backend foundation for building secure, scalable web applications. In the context of the Carbon Credit Management System (CCMS), Django serves as the primary backend framework responsible for handling business logic, database interactions, user authentication, and API development, ensuring efficient management of carbon credit data and transactions.

Django follows the Model-View-Template (MVT) architectural pattern, which separates data models, user interface templates, and business logic. This separation allows developers to maintain clean, organized code and makes the application easier to test and extend. Within the CCMS, Django models represent entities such as users, carbon credits, and transaction records, while views handle the processing of requests and responses, facilitating communication between the frontend and the database.

One of Django's core strengths is its built-in Object-Relational Mapping (ORM) system, which simplifies database operations by allowing developers to interact with the database using Python code instead of SQL queries. This feature helps the CCMS efficiently manage complex data operations, such as credit issuance, verification, trading, and retirement, while ensuring data integrity and consistency.

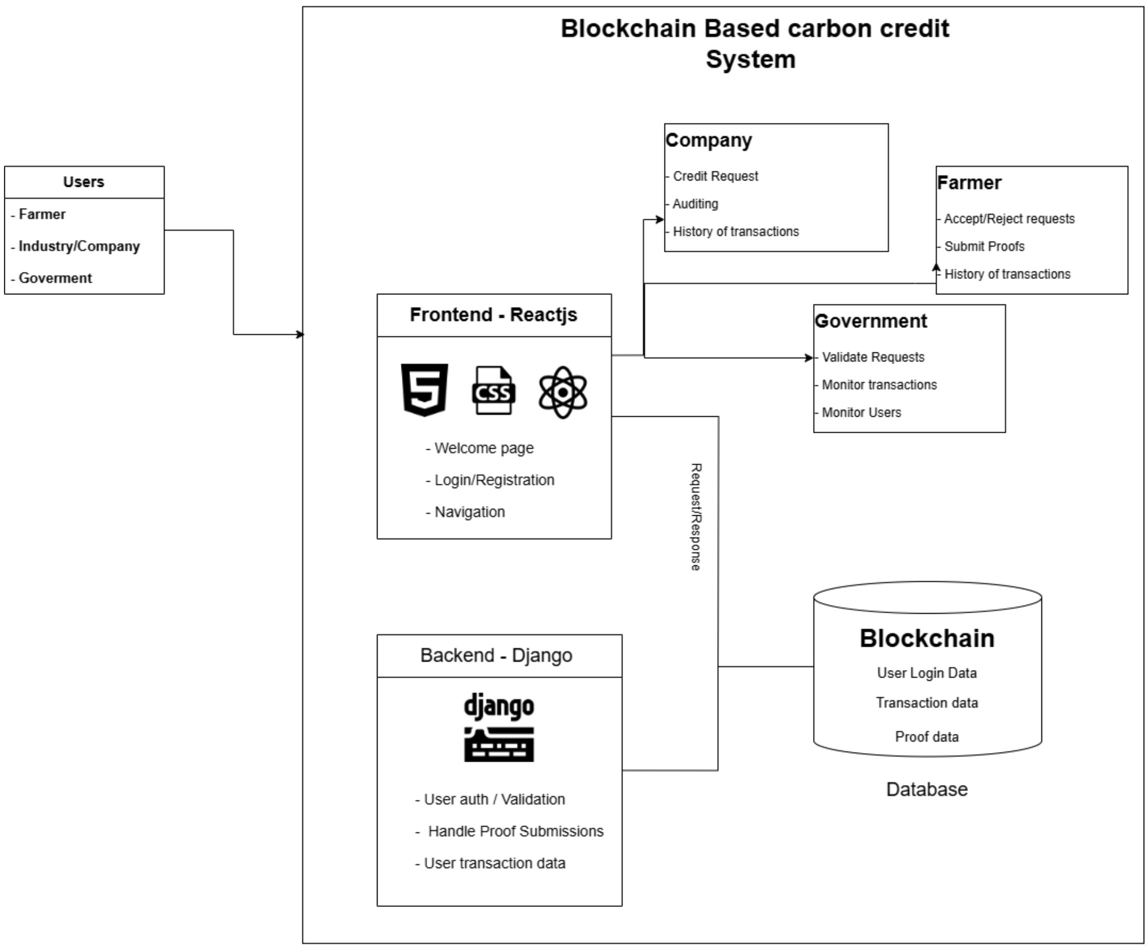
Additionally, Django comes with a powerful authentication system, which the CCMS utilizes to secure user accounts and enforce access control based on user roles, such as farmers, industries, and administrators. The framework's robust security features, including protection against common vulnerabilities like SQL injection and cross-site scripting (XSS), make it a reliable choice for handling sensitive environmental and transaction data.

Django also supports the creation of RESTful APIs through frameworks like Django REST Framework (DRF), enabling seamless integration with the React frontend and blockchain components. This allows real-time communication between the frontend and backend, ensuring that users receive instant updates on carbon credit status, transactions, and verification results.

- **Model-View-Template Architecture:** Promotes organized and maintainable code by separating data, business logic, and presentation layers.
- **Object-Relational Mapping (ORM):** Simplifies database operations, allowing efficient management of carbon credit data and transactions.
- **Robust Authentication and Security:** Provides built-in user authentication and safeguards against common web vulnerabilities, ensuring data protection.
- **REST API Support:** Enables development of APIs that facilitate communication between the frontend, backend, and blockchain modules for real-time data exchange.
- **Scalable and Rapid Development:** Supports quick feature implementation and scalability to accommodate growing data and user demands within the CCMS.

6.3 Proposed System Architecture

The proposed architecture outlines the complete flow of the Blockchain-Based Carbon Credit Ecosystem. It demonstrates how different roles—users, admin, and the blockchain—interact for transparent, secure, and tamper-proof eco-certification.



figureSystem Architecture of the Proposed Carbon Credit Ecosystem

6.3.1 Algorithm Used: Hash-Based NFT Generation

Unlike traditional blockchain systems that rely on computationally heavy consensus algorithms like Proof of Work (PoW), our system uses a lightweight, hash-based NFT mechanism. This enables sustainability and transparency with minimal energy consumption.

Here's how the process works:

- Users submit digital proof of eco-friendly activities (e.g., planting trees).
- Admin manually verifies and approves the submission.
- Upon approval, the system generates a unique hash value representing the activity.
- This hash is minted into an NFT and stored on the blockchain.
- Each NFT serves as verifiable, tamper-proof digital proof of the environmental action.

This algorithm ensures:

6.4 High Level Design Of Project

6.4.1 DFD Diagram

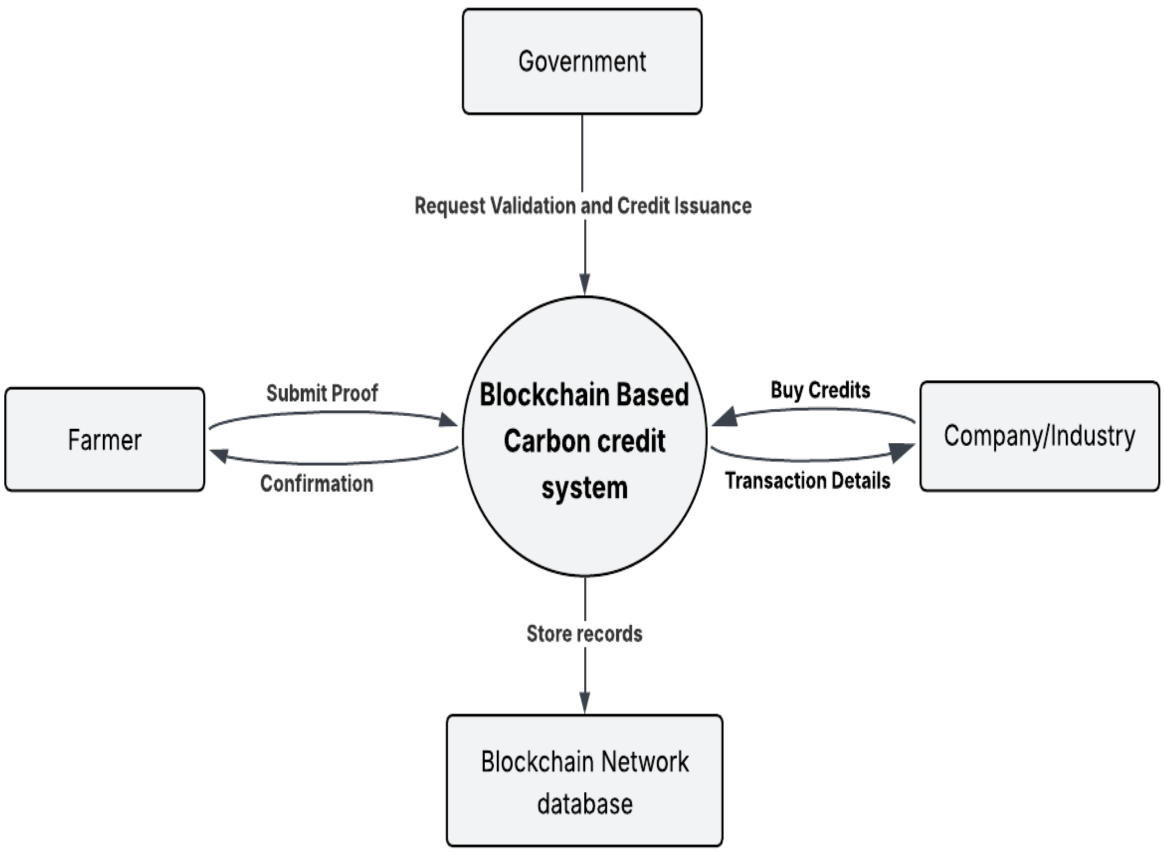


Figure 6.1: DFD-0

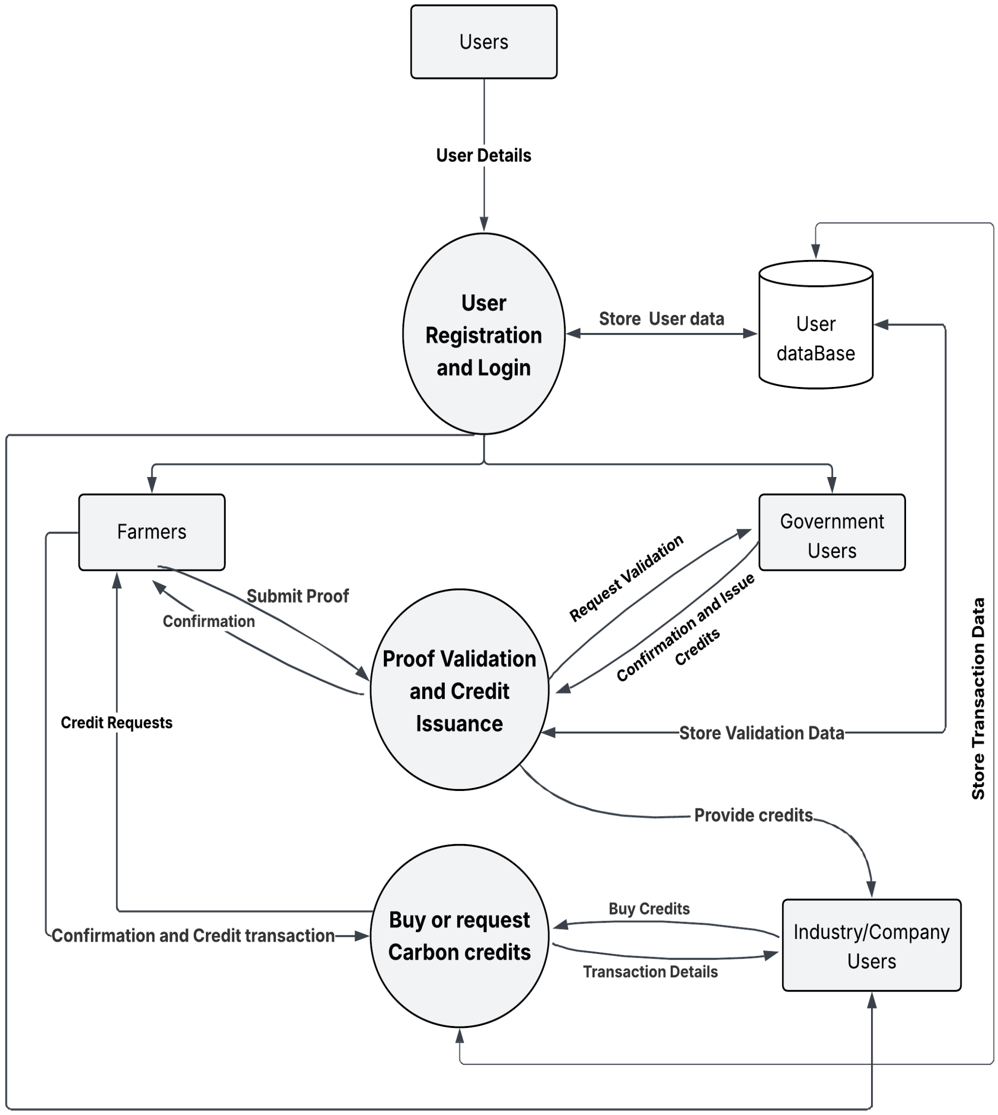


Figure 6.2: DFD-1

6.4.2 DFD Description

In a blockchain-based carbon credit system, Data Flow Diagrams (DFDs) are essential tools for visually depicting the system's processes and data movements at various levels of detail. DFDs provide a clear, structured view of how information flows within the system, making them useful in understanding and designing the interactions between different components and external entities.

The DFD Level 0 or Context Diagram provides a high-level overview of the system. It shows the entire blockchain-based carbon credit system as a single process, interacting with external entities like Users and Verification Agencies. This level simplifies complex processes by summarizing all interactions as straightforward data flows, helping stakeholders understand the primary functions without delving into specific details.

Moving to DFD Level 1, the system is broken down into major processes, such as User Management, Credit Management, and Verification. These processes represent core functions in the carbon credit system, such as managing user data, handling credit requests, and verifying transactions. At this level, data flows become more specific, detailing how information is exchanged between processes and external entities. This top-level decomposition aids in refining the high-level system requirements.

Finally, DFD Level 2 dives deeper into the individual processes within the system, further expanding components such as Credit Management into sub-processes like Request Credit and Approve Credit. These detailed processes show the inner workings of each core function, providing a closer look at how data is processed and transferred within each activity. This level of detail is useful for developers and analysts who need to understand the intricacies of each process for implementation.

DFDs serve as a bridge between business requirements and system design, gradually transforming abstract ideas into concrete workflows. In the context of blockchain applications for carbon credits, DFDs help identify essential information flows and dependencies, ensuring that all stakeholders—from business analysts to developers—share a unified vision of the system's functionality and data movement.

6.5 UML Diagram

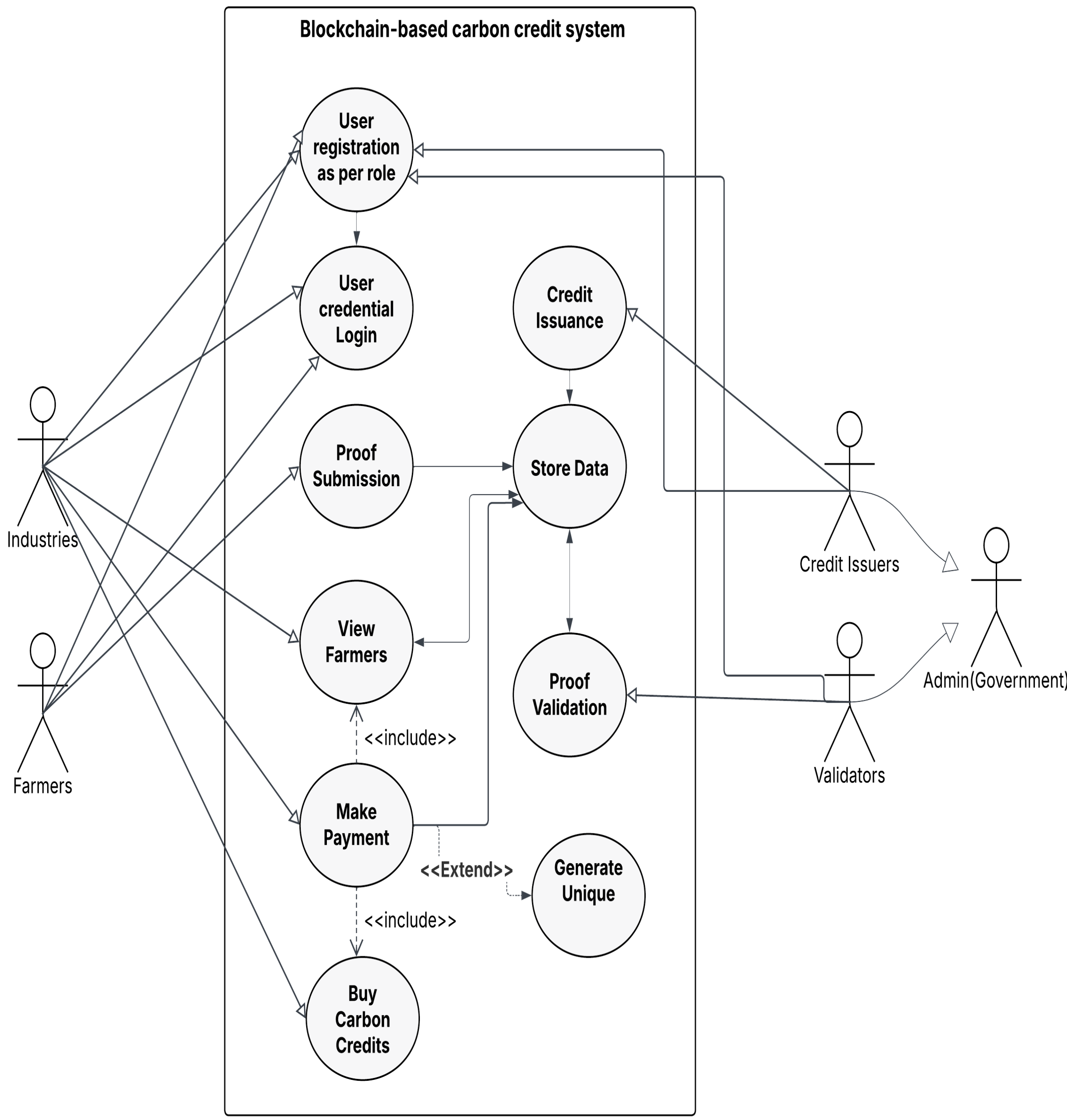


Figure 6.3: UML Diagram

6.5.1 UML Description

In our blockchain-based carbon credit ecosystem project, use-case diagrams model the high-level functions and interactions between the system and its users. These diagrams capture key processes such as user registration, proof submission, credit issuance, validation, and trading within a comprehensive container system.

The primary actors include Industries, Farmers, Credit Issuers, Validators, and Admin (Government) authorities. Industries purchase carbon credits to offset emissions, while Farmers generate credits through sustainable practices. Credit Issuers evaluate and issue verified credits, Validators ensure legitimacy, and Admin authorities oversee regulatory compliance.

The system encompasses interconnected use cases: user registration as per role, credential login, proof submission, data storage, credit issuance, proof validation, viewing farmers, payment processing, carbon credit purchasing, and generating unique transaction hash codes for blockchain traceability. Important relationships exist between processes: "View Farmers" includes "Make Payment" functionality, while "Make Payment" extends to "Generate Unique Transaction Hash Code."

The container architecture ensures all processes operate within a unified blockchain environment, maintaining data integrity and transparency. External actors interact through well-defined interfaces while internal operations handle secure transaction processing. The system design facilitates seamless communication between different stakeholders, enabling efficient carbon credit marketplace operations.

The UML use-case diagram visually represents these interactions, helping clarify the system's scope and behavior. By identifying key use cases such as "Proof Submission," "Credit Issuance," and "Buy Carbon Credits," the diagram provides a clear overview of system operations. This comprehensive modeling approach ensures all stakeholder requirements are captured and serves as a foundational tool for guiding the development process of the blockchain-based carbon credit ecosystem.

Furthermore, the diagram establishes clear boundaries between system functionalities and external interactions, providing developers with a structured framework for implementation. The visual representation helps stakeholders understand their roles and responsibilities within the ecosystem, ensuring effective collaboration and system adoption.

6.6 Sequence Diagram

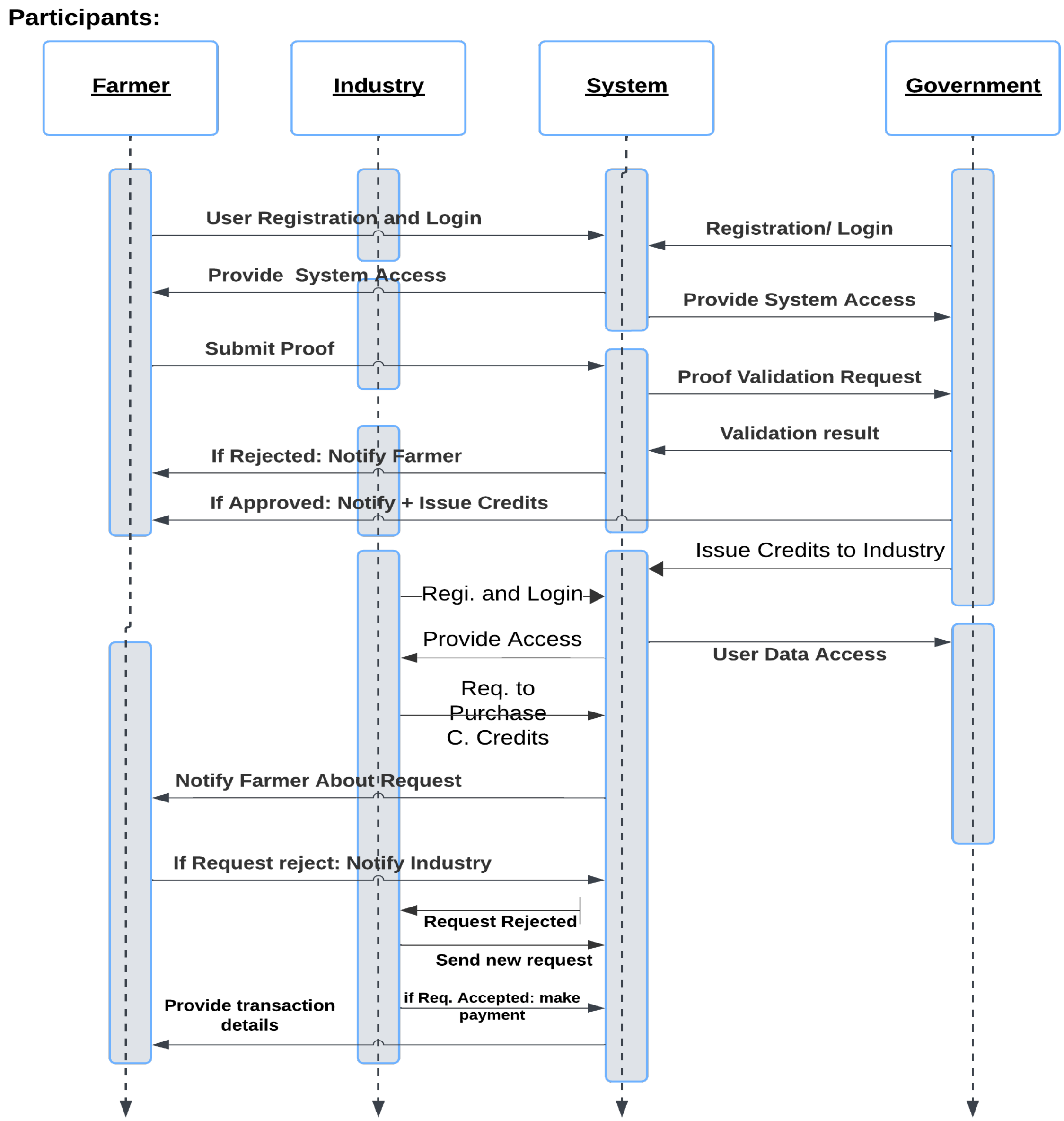


Figure 6.4: Sequence Diagram

6.6.1 Sequence Diagram Description

The sequence diagram for our blockchain-based carbon credit ecosystem illustrates the chronological interactions and message exchanges between four key participants: Farmer, Industry, System, and Government. This diagram captures the complete workflow from initial user registration to final transaction completion, demonstrating how different stakeholders communicate within the carbon credit marketplace.

The process begins with user registration and authentication, where both farmers and industries must register with the system and complete login procedures. The system facilitates this registration process and provides appropriate access levels based on user roles. Once authenticated, the system grants access to participants, enabling them to utilize platform functionalities according to their specific requirements.

The core carbon credit generation process starts when farmers submit proof of their sustainable practices to the system. This proof submission triggers a validation workflow where the system forwards the proof validation request to government authorities. The government entity reviews the submitted documentation and returns a validation result to the system. Based on this validation outcome, the system follows two paths: if the proof is rejected, the farmer receives notification of rejection; if approved, the system issues carbon credits and notifies the farmer of successful credit generation.

Following successful credit issuance, industries can access the system to request carbon credits. When an industry submits a request to purchase carbon credits, the system notifies the farmer about the incoming request. The farmer can either accept or reject the purchase request based on their availability and terms.

If the request is rejected, the system notifies the industry and allows them to submit a new request. When a request is accepted, the system initiates the payment process where the industry makes payment for the requested credits. Upon successful payment confirmation, the system provides transaction details to the farmer, completing the process. This sequence diagram helps clearly show how each step flows from one participant to another, making it easier to understand the full process from registration to final credit transfer. It ensures that all roles and actions are well-organized and easy to follow within the system.

6.7 Activity Diagram

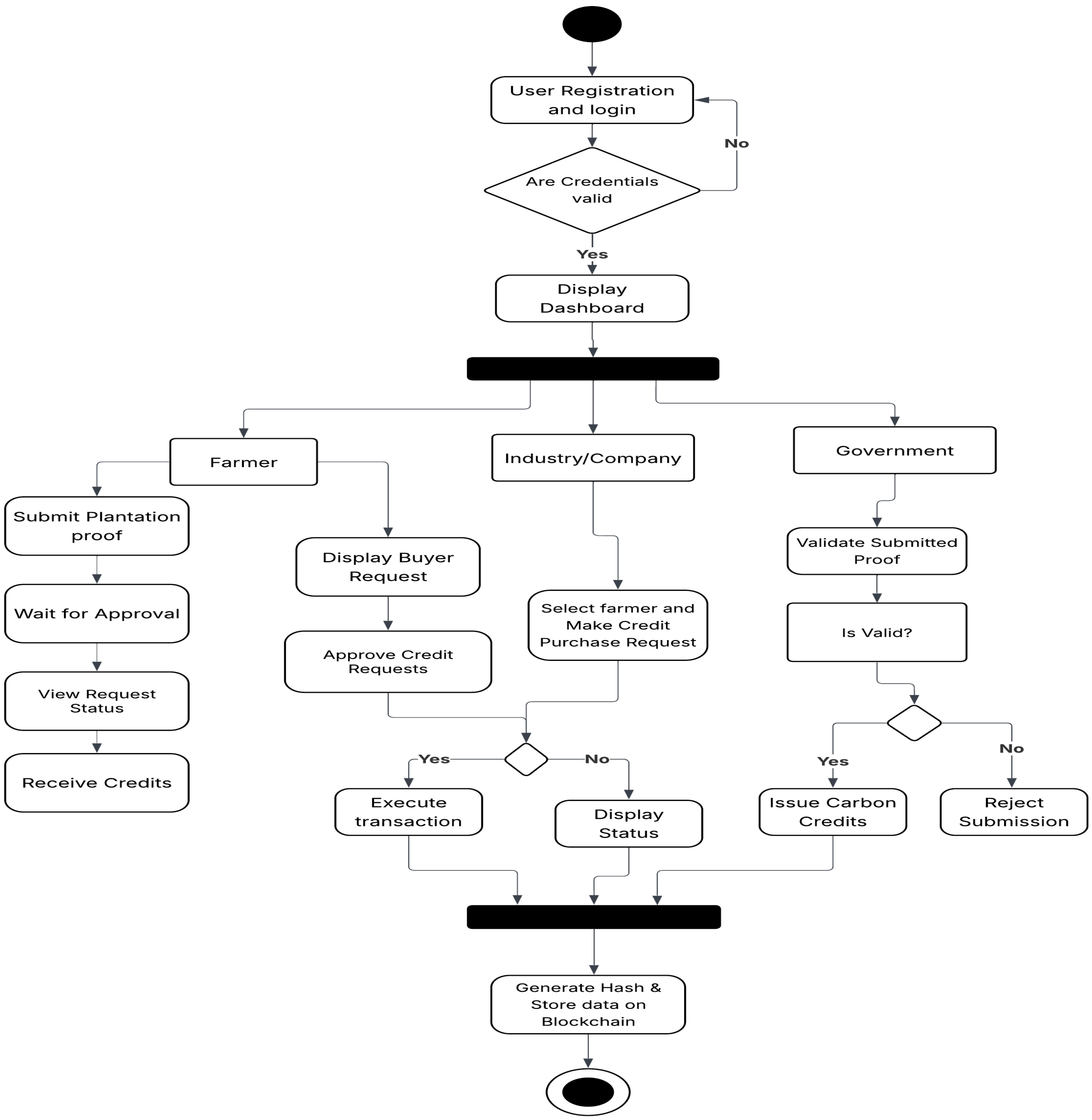


Figure 6.5: Activity Diagram

6.7.1 Activity Diagram Description

he activity diagram represents the operational flow of the Blockchain-Based Carbon Credit Ecosystem. It visualizes how various roles—Farmers, Industries/Companies, and the Government/Admin—interact with the system to perform actions related to carbon credit management, verification, and exchange. The diagram outlines the transition of processes from initial login to final blockchain recording, ensuring each action is securely traced.

Initially, users must register and log into the system. Upon submission of valid credentials, they are directed to a role-specific dashboard. The system classifies users into three categories: Farmers, who engage in sustainable activities; Industries/Companies, who buy carbon credits; and Government/Admin, who validate and issue credits. In case of incorrect login details, the user is prompted to reattempt authentication.

Farmers contribute to the ecosystem by submitting proof of plantation, usually images containing metadata that verifies time and location. The proof enters a pending state, awaiting approval from the Government. During this period, the farmer can monitor their request's status. Upon approval, the system issues carbon credits to the farmer, which are visible and tradable on their dashboard.

The Government/Admin plays a critical role by reviewing and validating all proof submissions. If a submission meets validation criteria, carbon credits are issued to the farmer. If the proof is invalid, it is rejected, and the user is notified. This ensures only genuine contributions are rewarded, maintaining the system's integrity.

Industries or companies, on the other hand, explore available carbon credits from farmers. After selecting a suitable offer, they place a purchase request. The system verifies the request, and if approved, processes the transaction. This exchange of credits supports industries in meeting their sustainability goals while incentivizing green practices among farmers.

One of the most significant aspects of the ecosystem is the use of blockchain technology. Once a transaction or credit issuance is completed, the system generates a unique hash for the event. This information is then stored on the blockchain ledger, ensuring immutability, transparency, and permanent traceability. The integration of blockchain not only prevents tampering and fraud but also strengthens the accountability of each participant in the ecosystem. In conclusion, the activity diagram serves as a backbone for understanding system behavior. It provides a comprehensive view of user roles, conditional decisions, action flows, and secure data handling.

6.8 Test Cases

Test Case 1: User Registration and Login

1. **Test Case Name:** User Registration and Login
2. **Test Description:** Verify that users (farmer, industry, admin) can register and securely log in to the system.
3. **Test Steps:**
   - Open the Carbon Credit Ecosystem web application.
   - Click on “Register”.
   - Fill in required details: role, username, email, password, organization (if applicable).
   - Submit the registration form.
   - Log out and navigate to the login page.
   - Enter valid credentials.
   - Click on “Log In”.
   - Verify redirection to the user dashboard based on role.

Test Case 2: Proof Submission by Farmer

1. **Test Case Name:** Farmer Tree Plantation Proof Submission
2. **Test Description:** Verify that farmers can submit image proof for tree plantations for carbon credit issuance.
3. **Test Steps:**
   - Log in as a Farmer.
   - Navigate to “Submit Proof” section.
   - Upload valid image(s) and input tree count/location data.
   - Submit the form.
   - Verify successful submission and ”Pending Verification” status.

Test Case 3: Admin Verification and Credit Issuance

1. **Test Case Name:** Admin Verification and Smart Contract-Based Credit Issuance
2. **Test Description:** Verify that the admin can review farmer submissions and issue credits using smart contracts.
3. **Test Steps:**
   - Log in as Admin.
   - Navigate to "Verification Dashboard".
   - Review submitted image and metadata.
   - Click on "Approve".
   - Verify smart contract triggers and credits are issued to the farmer.
   - Confirm credit issuance entry on the blockchain ledger.

Test Case 4: Carbon Credit Trading (P2P)

1. **Test Case Name:** Peer-to-Peer Credit Trading
2. **Test Description:** Verify that industries can request and purchase carbon credits directly from farmers.
3. **Test Steps:**
   - Log in as Industry.
   - Browse available carbon credits for sale.
   - Select desired credit and submit trade request.
   - Farmer logs in and reviews trade request.
   - Farmer approves request.
   - System processes payment and transfers credit using smart contract.
   - Verify transaction record is stored on blockchain.

Test Case 5: Credit Balance Update

1. **Test Case Name:** Credit Balance Update Post-Transaction

2. **Test Description:** Ensure that the buyer's and seller's credit balances are updated accurately after a transaction.
3. **Test Steps:**
   - Complete a credit purchase transaction.
   - View buyer and seller dashboards.
   - Confirm credit debit and credit amounts.

Test Case 6: Unauthorized Access Prevention

1. **Test Case Name:** Role-Based Access Control Validation
2. **Test Description:** Ensure users cannot access unauthorized modules or features.
3. **Test Steps:**
   - Log in as a Farmer.
   - Attempt to access Admin or Industry modules via URL or menu.
   - Verify access is denied and redirection occurs.
   - Repeat for Industry and Admin roles attempting restricted access.

Test Case 7: IPFS Proof Storage

1. **Test Case Name:** Verification of IPFS Proof Storage
2. **Test Description:** Confirm that submitted images are securely stored on IPFS.
3. **Test Steps:**
   - Submit proof as a Farmer.
   - Retrieve IPFS hash.
   - Open IPFS link and verify image accessibility.

Test Case 8: Smart Contract Event Logging

1. **Test Case Name:** Event-Based Smart Contract Logging

2. **Test Description:** Check whether all major events are logged using the `emit` function.
3. **Test Steps:**
   - Trigger an action (e.g., credit approval, purchase).
   - Check blockchain explorer or smart contract logs.
   - Verify presence of corresponding event.

Test Case 9: Credit Limit Enforcement

1. **Test Case Name:** Emission Limit Check for Industry
2. **Test Description:** Ensure that industries cannot buy credits unless their emissions exceed the allowed limit.
3. **Test Steps:**
   - Log in as Industry.
   - Check emission data.
   - Try purchasing credits with emissions within the limit.
   - Confirm that the system blocks the transaction.

Test Case 10: Geo-Restriction Enforcement

1. **Test Case Name:** Geolocation-Based Trade Restriction
2. **Test Description:** Ensure industries can only buy from farmers in the same city.
3. **Test Steps:**
   - Log in as Industry.
   - Try to request credits from a farmer in a different city.
   - Confirm transaction is blocked.

Test Case 11: Real-Time Dashboard Updates

1. **Test Case Name:** Dynamic Dashboard Refresh

2. **Test Description:** Validate that dashboards reflect real-time data changes after transactions.
3. **Test Steps:**
   - Log in and stay on dashboard.
   - Perform transaction in another window.
   - Confirm UI updates automatically or on refresh.

Test Case 12: In-App Notification after Credit Approval

1. **Test Case Name:** Notification System Validation
2. **Test Description:** Ensure that in-app notifications are shown after credit approval to farmers.
3. **Test Steps:**
   - Submit proof as Farmer.
   - Admin approves the proof.
   - Log in as Farmer and check notification bell or dashboard alert.

Test Case 13: Proof Rejection Flow

1. **Test Case Name:** Admin Rejects Invalid Proof
2. **Test Description:** Ensure admins can reject invalid or fake proofs and notify farmers.
3. **Test Steps:**
   - Submit an unclear or invalid image.
   - Admin logs in and rejects the submission.
   - Verify status changes to "Rejected" and in-app alert appears.

Test Case 14: Blockchain Ledger Verification

1. **Test Case Name:** Blockchain Entry Verification

2. **Test Description:** Verify that all transactions (issuance and trading) are recorded immutably on the blockchain.
3. **Test Steps:**
   - Perform a credit issuance or trade.
   - Access the blockchain explorer or internal log.
   - Validate entry data (timestamp, addresses, amount).

Test Case 15: Secure Logout

1. **Test Case Name:** Session Termination and Security
2. **Test Description:** Confirm that user sessions are securely terminated upon logout.
3. **Test Steps:**
   - Log in as any role.
   - Click "Logout".
   - Try accessing any internal URL directly.
   - Confirm redirection to login and session expiration.

Chapter 7

WORKING MODULE

7.1 Experimental Results

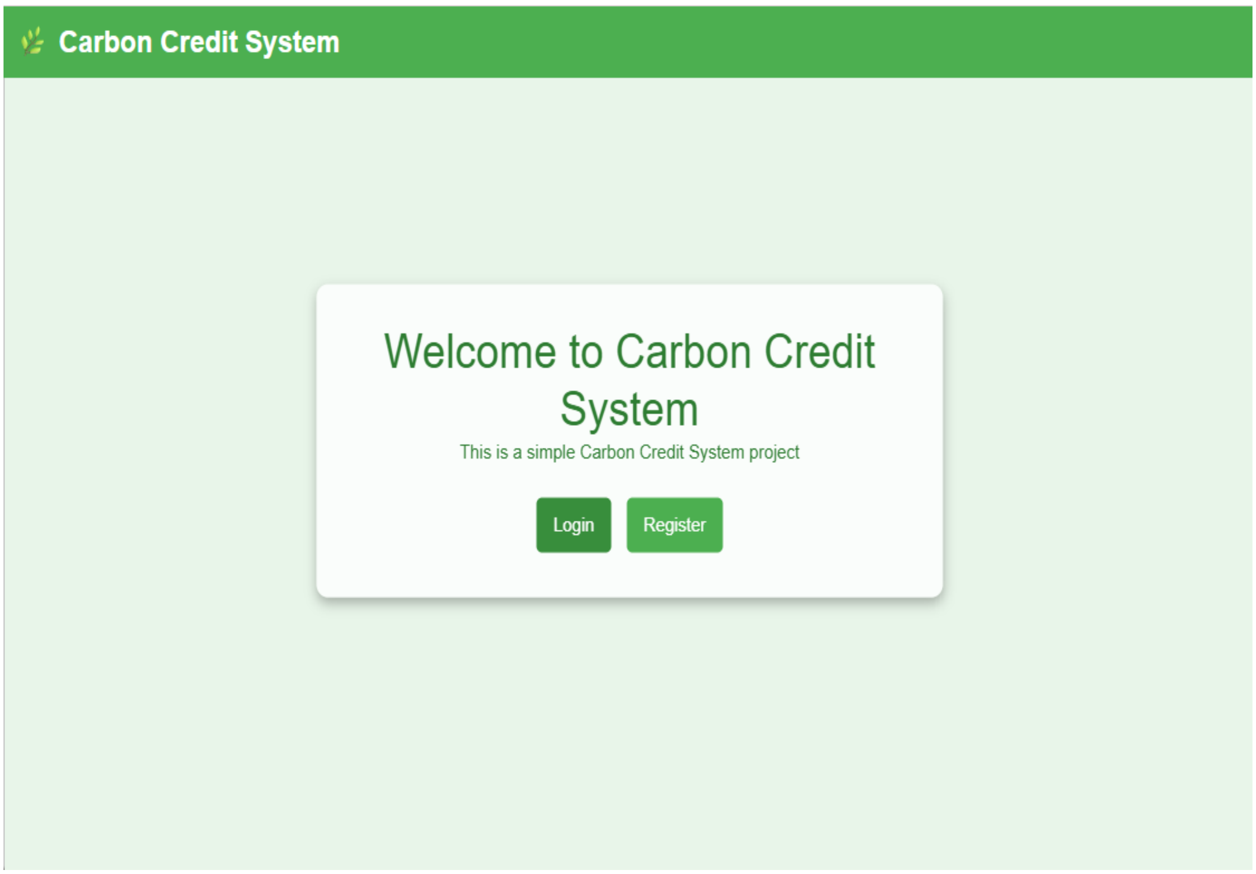


Figure 7.1: Login and registration Page

Description: This page allows users to either create a new account or log in to their existing account. Users can select their role as a farmer, industry, or admin to access the features related to their role.

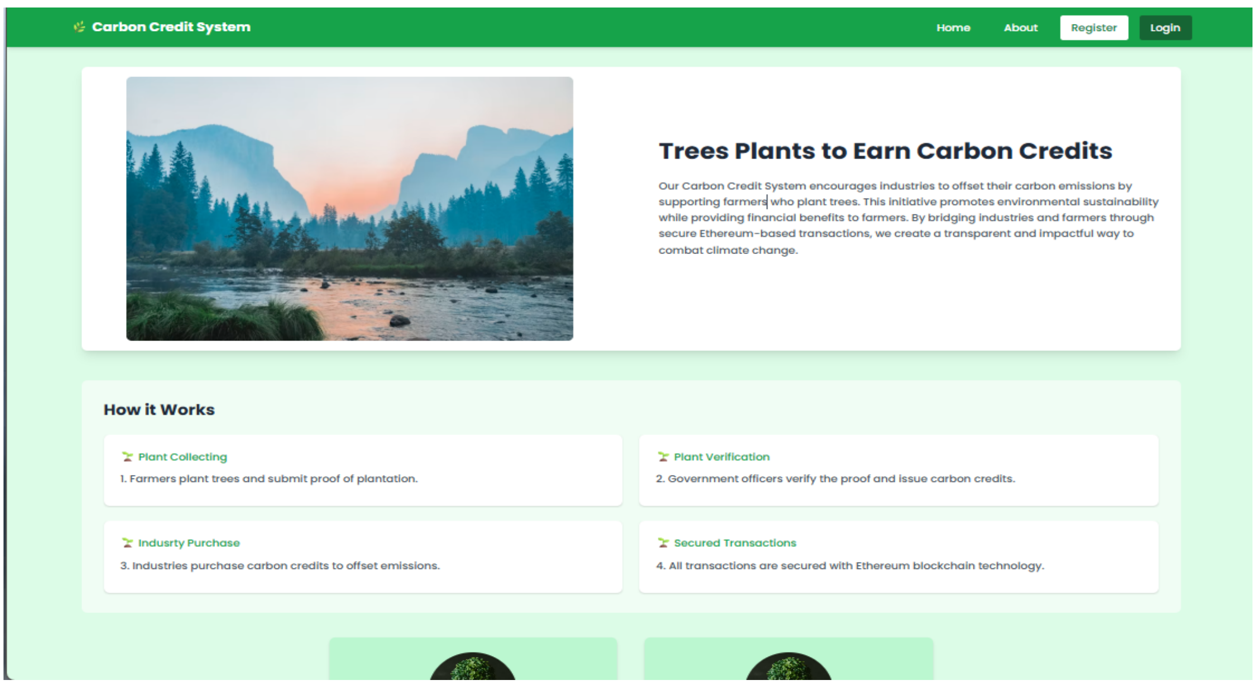


Figure 7.2: Home page

Description: The home page provides an introduction to the platform and allows users to navigate to login or registration. It serves as the main entry point for all types of users.

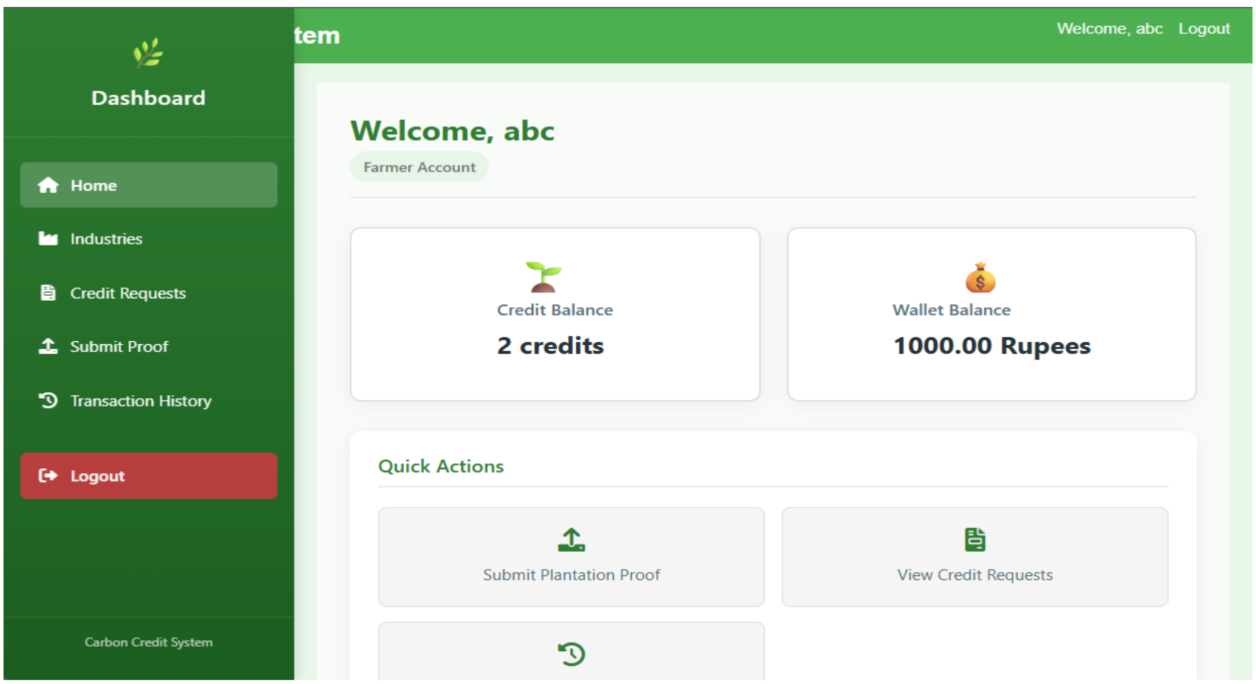


Figure 7.3: Farmer Dashboard

Description: This dashboard is designed for farmers. It displays the number of credits earned, the available wallet balance, and provides options to submit plantation proof, view credit requests, and track past actions.

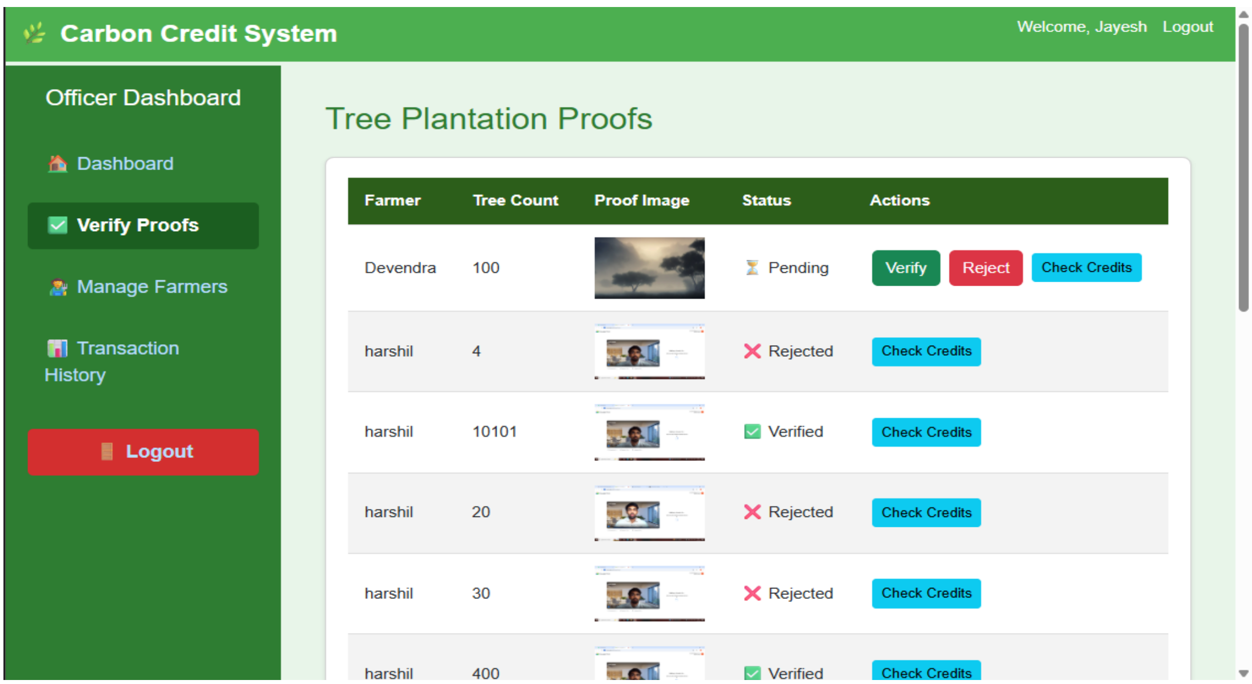


Figure 7.4: Government Validation Page

Description: This page is used by the admin to review proof submitted by farmers. The admin can approve or reject the submissions after checking the details.

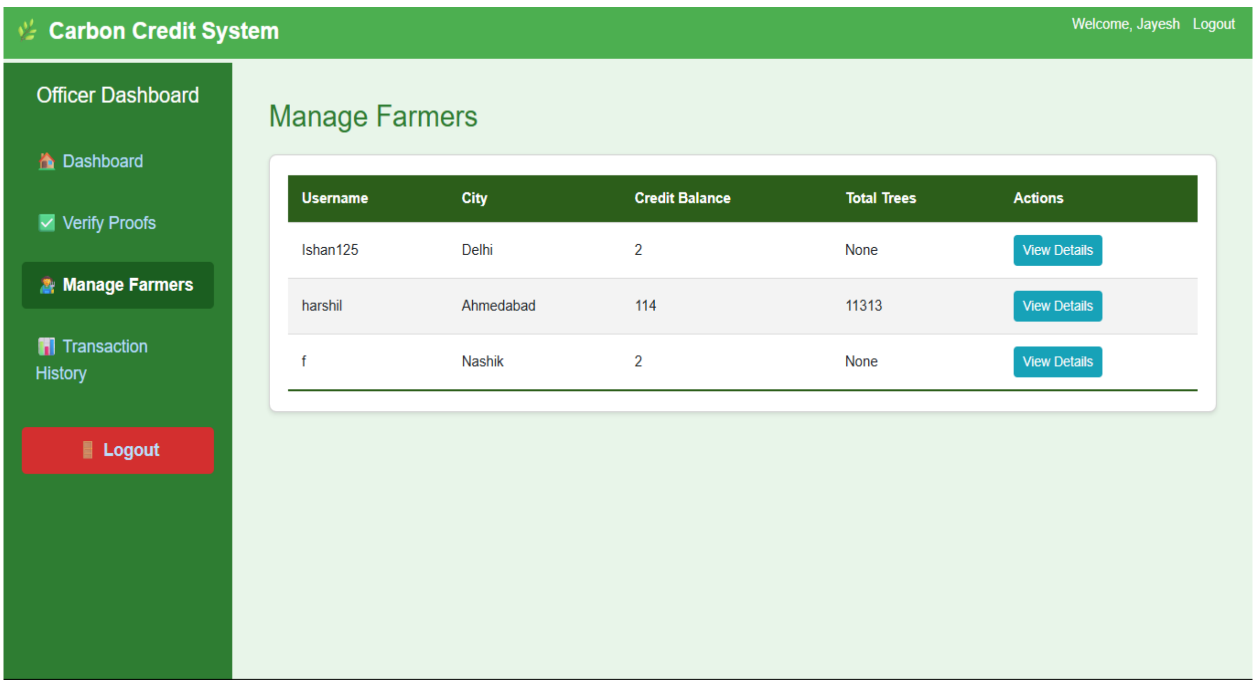


Figure 7.5: Farmers Information Page

Description: This page shows a list of farmers along with details of their submissions. The admin can view and manage the status of credits for each farmer from this page.

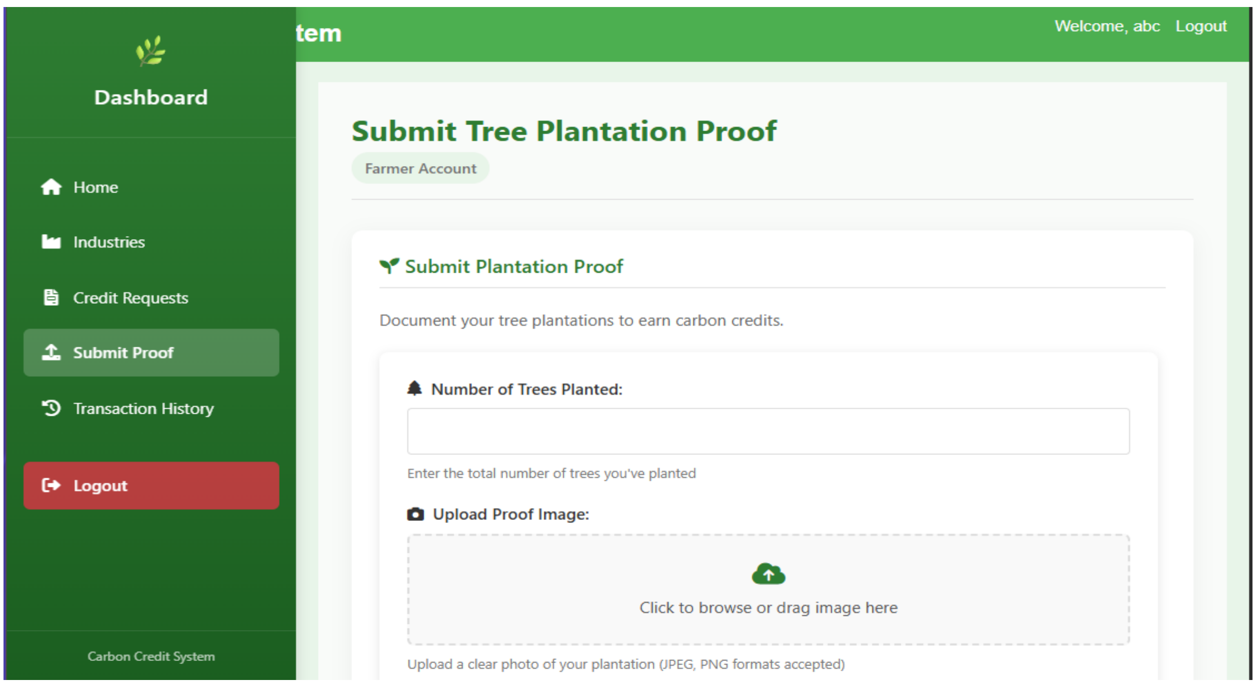


Figure 7.6: Proof Submission Page

Description: Farmers use this page to upload pictures and enter details of their tree plantations. These submissions are sent to the admin for checking and approval.

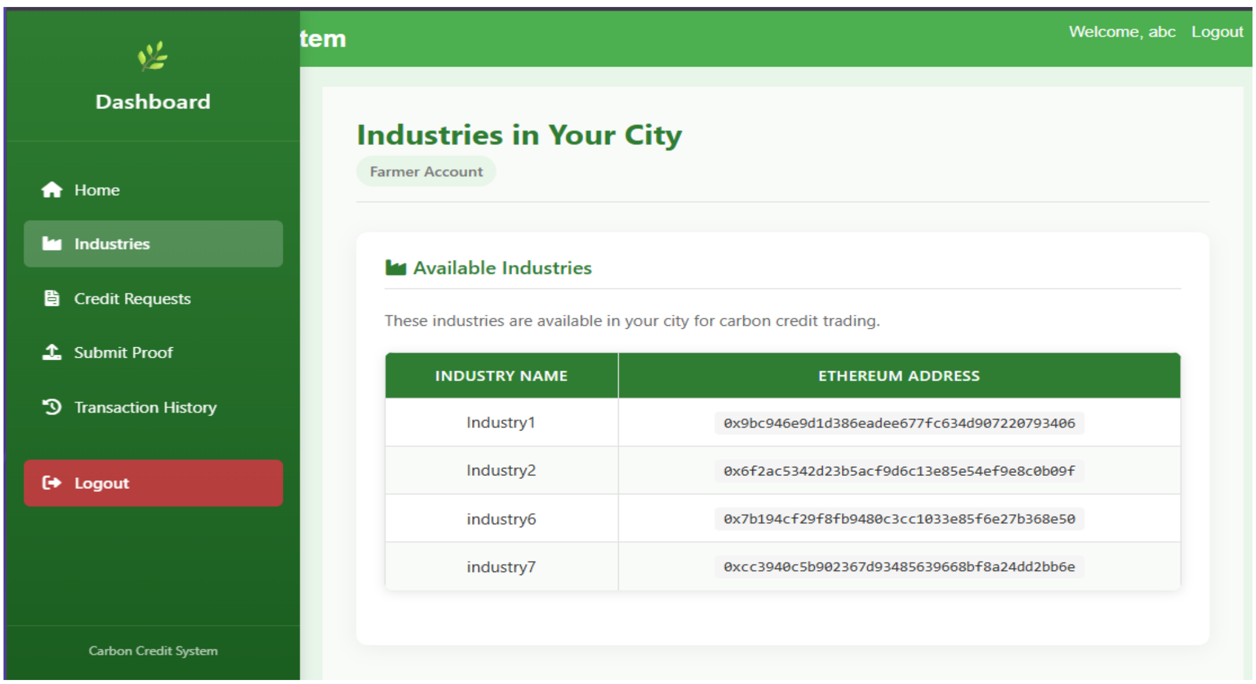


Figure 7.7: City industries overview

Description: This page gives a view of different industries based on their city. It shows information like how many credits they have used and how many they still need.

Chapter 8

FUTURE SCOPE

Future Scope of Blockchain-Based Carbon Credit Ecosystem

1. Integration with Carbon Credit Marketplaces

Explore integration with global carbon credit marketplaces to enable seamless trading across different platforms. This could increase the liquidity and accessibility of carbon credits, allowing users to trade with other participants beyond the local ecosystem.

2. Advanced Smart Contract Capabilities

Enhance the smart contract functionalities to automate more complex processes within the carbon credit lifecycle, such as automated credit verification, trading, and retirement. This could reduce the need for manual intervention and increase system efficiency.

3. Expansion of Verification Networks

Expand the verification network to include a larger number of trusted third-party auditors and verification organizations. This would ensure that carbon credits registered on the platform meet the highest standards of authenticity and legitimacy.

4. Integration with IoT for Real-Time Data Collection

Implement Internet of Things (IoT) sensors to collect real-time environmental data, such as carbon emission levels, forestation metrics, or renewable energy generation. This data could be used to automatically generate and register carbon credits, improving the transparency and accuracy of the system.

5. Carbon Credit Retirement Automation

Develop automation tools for carbon credit retirement, allowing users to retire credits directly from their accounts after completing specific actions such as funding environmental projects or achieving sustainability goals. This would streamline the process and ensure accurate record-keeping on the blockchain.

6. Partnerships with Environmental Organizations

Explore collaborations with environmental organizations and governmental bodies to expand the ecosystem's credibility. These partnerships could integrate third-party validation systems, ensuring that the carbon credits are aligned with global environmental standards.

7. Enhanced User Interface and User Experience

Improve the user interface (UI) and user experience (UX) to make the platform more accessible to a wider audience. Simplifying the carbon credit registration, trading, and verification processes through an intuitive design will enhance user engagement.

8. Cross-Platform Mobile Application

Develop a cross-platform mobile application to increase accessibility. This would allow users to easily manage their carbon credit transactions, track their sustainability contributions, and access real-time data on carbon credit prices and market trends.

9. AI-Powered Sustainability Insights

Incorporate artificial intelligence (AI) to provide users with actionable insights into their carbon credit portfolio, including predictive analytics on carbon credit prices and market trends. AI could also help users optimize their carbon credit trading strategies for better returns.

10. Privacy and Security Measures

Continuously enhance privacy and security protocols to protect sensitive user and transaction data. Compliance with global data protection regulations, such as GDPR, and implementing advanced encryption methods for blockchain transactions will be essential to ensure user trust and platform integrity.

Chapter 9

Conclusion

The Blockchain-Based Carbon Credit Ecosystem developed in this project marks a transformative step toward building a sustainable and transparent framework for managing carbon emissions. By leveraging blockchain technology and smart contracts, the system offers a secure and tamper-proof platform that manages the entire lifecycle of carbon credits—right from issuance and verification to trading and retirement.This system enables farmers to be fairly rewarded for their environmental contributions, such as tree plantation, while offering industries a reliable and traceable mechanism to offset their carbon footprints. The direct peer-to-peer trading model eliminates intermediaries, reduces delays, and builds trust among stakeholders by ensuring every transaction is transparently recorded on the blockchain.Unlike traditional systems, which often suffer from inefficiencies, manual verification, and lack of accountability, this platform uses decentralized architecture and automated smart contracts to make the carbon credit process more efficient, auditable, and accessible. Technologies like Web3.js, Django, and React are used to ensure real-time performance, security, and a smooth user experience for all roles—be it farmers, industries, or administrators.

This project is not just a technical implementation, but a mission-driven initiative aimed at bringing positive environmental and social impact. It encourages farmers to adopt sustainable practices by offering tangible incentives, and helps industries align with national and international carbon regulations through transparent offsetting mechanisms.Ultimately, this ecosystem sets a foundation for large-scale participation in carbon trading, promoting climate responsibility at both grassroots and industrial levels.

Project Gantt Chart

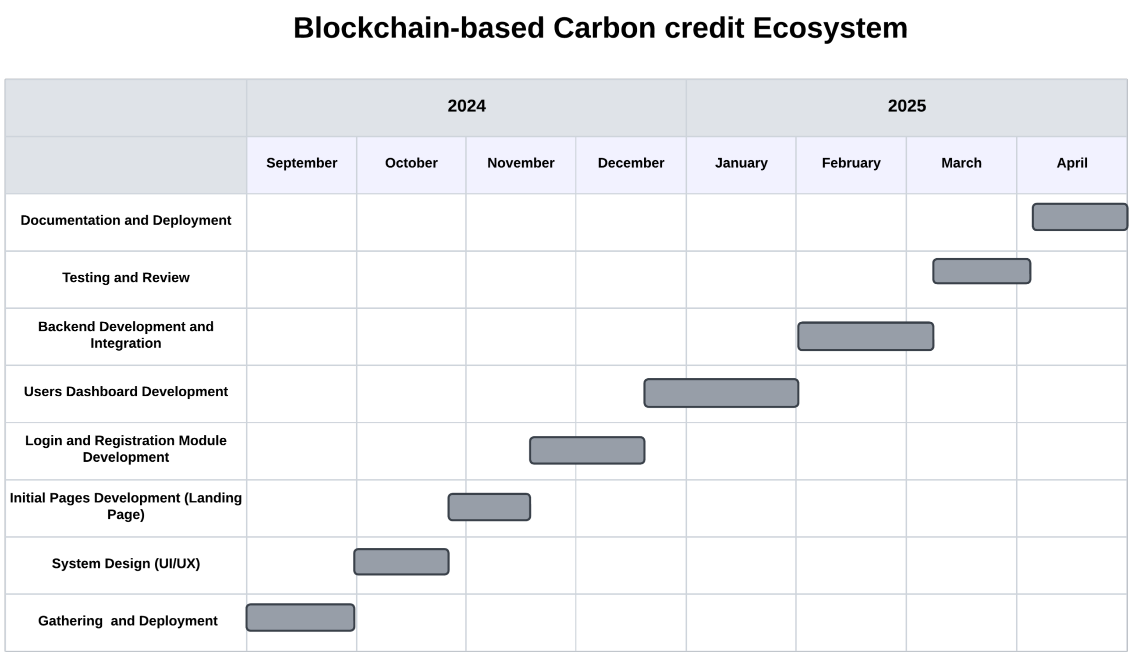


Figure 9.1: Gantt chart of Carbon Credit System

Published/Presented Paper, Certificates of Participation

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BLOCKCHAIN-BASED CARBON CREDIT ECOSYSTEM

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ABSTRACT

Blockchain-Based Carbon Credit Ecosystem enables transparent, secure, and efficient management of carbon credits by leveraging blockchain technology. This paper presents a framework for managing, verifying, and trading carbon credits across various stakeholders, including farmers, industries, and government bodies. The proposed model consists of a decentralized application and a smart contract system, where the application manages user actions and the contracts enforce logic. Through transparent operations, all participants interact securely, resulting in a system that closely mirrors real-world environmental transactions.

I. INTRODUCTION

Carbon credit management is a rapidly evolving domain in environmental technology, driven by the demand for sustainable and transparent systems to monitor and regulate carbon emissions across industries and agriculture. Traditional methods of credit allocation and tracking often rely on centralized databases or manual processes, which are limited in terms of transparency, security, and scalability.

Blockchain technology, first popularized by Bitcoin and later Ethereum, has emerged as a powerful solution to this challenge by leveraging decentralized networks to record immutable and verifiable transactions.

Blockchain-based systems consist of smart contracts and distributed ledgers that cooperate in a peer-to-peer network. Smart contracts automate carbon credit issuance and trade, while the ledger stores all activity in a tamper-proof format.

These systems are developed and maintained together, with the goal of ensuring secure and transparent interactions among stakeholders. This decentralized approach results in highly reliable operations, capable of handling complex compliance rules and emission data in real time.

In this paper, we explore the architecture of blockchain platforms and the methods used to manage carbon credit flows within a decentralized ecosystem. We also discuss improvements to traditional credit systems, such as smart contracts for automation and Web3 interfaces for user control. The practical applications of blockchain in environmental protection, compliance, and green innovation are also explored.

II. LITERATURE REVIEW

Blockchain technology has significantly impacted the field of digital systems, particularly in secure and transparent transaction management. This section reviews recent advancements in blockchain ecosystems, focusing on innovations that enhance scalability, security, and automation.

The original blockchain model introduced by Nakamoto (2008) demonstrated that decentralized consensus could be used to record transactions securely by utilizing peer-to-peer networks and proof-of-work mechanisms. However, this approach faced challenges like high energy consumption and limited throughput. To address these issues, Buterin (2015) proposed the Ethereum platform, which introduced smart contracts to enable programmable and autonomous operations. This technique has become a widely adopted solution in blockchain development Permissioned blockchains, introduced by Hyperledger Fabric (2016), marked a significant improvement by enabling network governance and access control for enterprise applications. This allowed for controlled participation, making permissioned systems useful in tasks like supply chain tracking .

Web3.js, developed by the Ethereum Foundation, represented another breakthrough by decoupling frontend interfaces from blockchain layers, allowing for seamless user interaction with smart contracts. The introduction of frameworks like Truffle and Hardhat further refined development and eliminated common issues with

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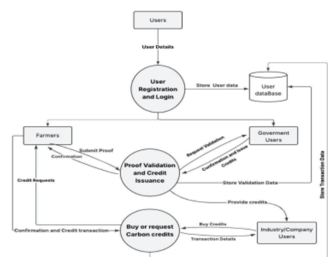
contract deployment, making them powerful tools for decentralized app development. In addition to architectural improvements, research has also explored blockchain applications. For instance, Sharma et al. (2020) demonstrated the effectiveness of blockchain in carbon trading by creating a transparent registry for emission credits. Similarly, Zhou et al. (2019) developed a decentralized solution for environmental monitoring using IoT and blockchain integration.

Recent studies also focus on the integration of IPFS and identity management systems into blockchain workflows, as seen in the work by Patel et al. (2022). These advancements help to reduce data tampering risks and improve transparency across the carbon credit lifecycle.

III. METHODOLOGY

Our carbon credit management architecture focuses on combining blockchain-based smart contracts with modern web technologies like Web3.js, IPFS, and secure backend logic to enhance automation, transparency, and traceability in credit distribution. The system's smart contracts are responsible for issuing, verifying, and transferring carbon credits between stakeholders—farmers, industries, and the government—based on predefined logic. These contracts are deployed on the Ethereum blockchain and triggered through frontend interactions, enabling real-time execution without manual intervention. The contract logic ensures that only verified farmers receive credits and that industries exceeding limits must purchase extra credits, preserving fairness and compliance.

On the other hand, the backend (built using Django) plays a crucial supportive role by handling user authentication, managing data synchronization with the blockchain, and storing off-chain records in the MySQL database. It also coordinates with IPFS to securely store and retrieve proof images submitted by farmers, ensuring integrity and auditability. The frontend, developed in React.js and connected using Web3.js, enables users to interact seamlessly with smart contracts, showing live credit balances, transaction history, and verification statuses. This coordinated communication between the frontend, backend, and blockchain enables a cohesive, secure system that automates credit management.



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3.1. System Architecture

The proposed system consists of three main components:

• Smart Contracts: Smart contracts are deployed on the Ethereum blockchain and are responsible for issuing, transferring, and verifying carbon credits. These contracts encode business logic such as credit limits, eligibility, and transaction conditions.

• Web Interface & Wallet Integration: The user interface is built using React.js and integrates MetaMask for wallet-based authentication and blockchain transactions. It enables real-time credit tracking, transaction execution, and proof submission.

• Backend Server: Built with Django, the backend handles user registration, off-chain data management, and communication between the frontend and smart contracts using Web3.py. It also stores structured data in MySQL and proof images in IPFS.

3.2 Credit Verification and Transaction Flow

The credit flow process involves verifying farmer submissions, issuing credits, and enabling peer-to-peer transactions. The logic for each operation is:

• Farmer Credit Issuance: Farmers upload tree-planting proof images, which are hashed and stored using IPFS. Admins verify submissions and trigger smart contract functions to assign corresponding carbon credits.

• Industry Credit Usage: Industries consuming more than their allocated credits must purchase additional credits from nearby verified farmers via the platform.

To ensure fair distribution and reduce fraud, each transaction is recorded on the blockchain, and real-time updates are synced across the frontend and backend using REST APIs and Web3.js. This creates a secure audit trail and automates policy enforcement.

3.3 Conditional Policies and Smart Contract Logic

Conditional execution is integrated into the smart contracts to manage credit limits, geographic restrictions, and role-based access. Conditional Credit Allocation ensures that contracts issue credits only to farmers within verified regions and after successful proof validation. Controlled Credit Purchase restricts industries to purchasing credits only when they exceed their emission limits and only from approved farmers in the same city.

To further improve traceability and transparency, we implement event-based logging using Solidity emit functions. The integration of IPFS ensures the authenticity of submitted proofs, while role-based admin controls enable government verifiers to monitor and audit carbon credit activity effectively.

IV. RESULTS AND DISCUSSION

Experimental results show that integrating conditional smart contracts and decentralized components into our framework substantially improves the reliability and transparency of carbon credit management. The model was tested using sample datasets involving farmers and industries across defined regions. Evaluation metrics like transaction validity, verification accuracy, and system latency were used to assess performance. Compared to centralized systems, our implementation ensures high traceability and real-time auditing through Solidity-based events and IPFS-stored image proofs. Smart contracts controlled credit distribution based on role and location, ensuring policy compliance. Django and MySQL supported stable backend performance, while React.js enabled a responsive interface for user roles. Our approach eliminates manual bottlenecks, reduces fraud risk, and achieves secure and scalable carbon credit exchange using blockchain and role-based verification logic.

V. CONCLUSION

Blockchain-based carbon credit ecosystems have become a transformative solution for ensuring transparency and accountability in environmental sustainability efforts. This paper has demonstrated how smart contract frameworks—such as conditional execution, geographic filtering, and role-based access—significantly improve the accuracy, traceability, and compliance of credit allocation. Our results show that Web3.js-enabled contracts ensure real-time enforcement, while IPFS secures proof authenticity in a decentralized manner.

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Figure 9.2: IEEE Project Competition Certificate

Figure 9.3: IEEE Project Competition Certificate

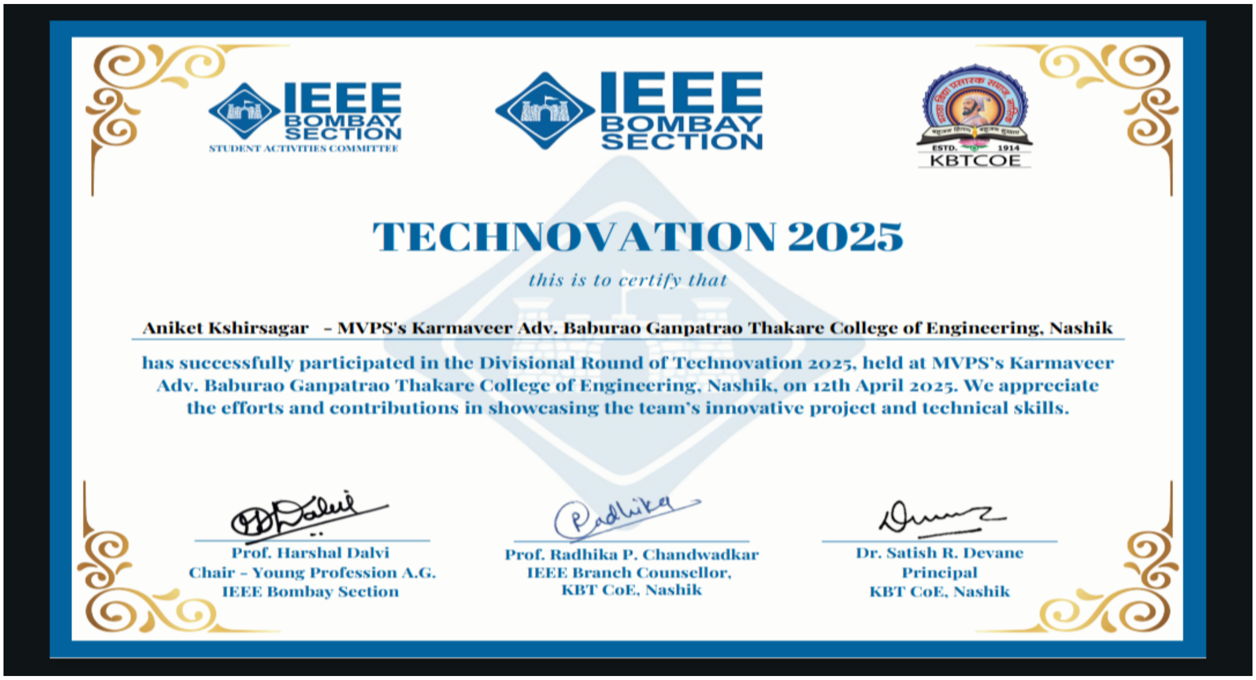

Figure 9.4: IEEE Project Competition Certificate

Figure 9.5: IEEE Project Competition Certificate

Figure 9.6: Certificate of Publication

Figure 9.7: Certificate of Publication

Figure 9.8: Certificate of Publication

Figure 9.9: Certificate of Publication

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