TABLE OF CONTENTS

Mentor Consent Form

I hereby agree to be the mentor of the following Capstone Project Team

Project Title: Ecosync: Smart Sustainability Companion		
Roll No	**Name**	**Signatures**
102203641	Aditya Sharma	
102383029	Aryan Saxena	
102203849	Vedansh Purohit	
102203822	Saarthak	
102203200	Toshar Bhardwaj	

NAME of Mentor: ……… . . . .

SIGNATURE of Mentor: . . . .

NAME of Co-Mentor: ……… . . . .

SIGNATURE of Co-Mentor: . . . .

Project Overview

Tracking and lowering one's carbon footprint is enabled by the innovative mobile application, which employs an accessible platform to measure household energy usage, transportation, and dietary carbon emissions.Daily behavior is translated into quantifiable environmental impact by the application, resulting in the demystification of an individual's carbon footprint and rendering eco friendliness attainable and feasible.

User specific recommendations and advice are provided through the aggregation of data and the utilization of advanced analysis, so that intelligent choices regarding emission reduction can be made by users.Rich statistics and graphical trends are displayed to facilitate informed decisions, performance tracking, and strategic improvements, thereby allowing dense data to be converted into actionable steps toward sustainability.

In addition to customized monitoring and analysis features, the app will also maintain a carbon credit system based on blockchain. A cap-and-trade approach is used, where a company emitting below its allowance is can sell surplus credits, and a company exceeding their limits must purchase extra credits. With the help of blockchain technology, we ensure transparency, security, and integrity in monitoring and verifying carbon offset contributions, and thus promote users to engage more in green practices.

Through a synergistic use of technology and eco conservancy, awareness about personal carbon emissions is raised and an active strategy toward sustainability is instilled. An impetus toward positive change is offered by the application, with users being encouraged toward greener living habits that lead to a healthier world and a sustainable tomorrow.

Problem Statement

People and organizations want to lessen their carbon footprints as environmental concerns and climate change awareness grow.Nevertheless, a lot of individuals do not have access to data driven, easily navigable technologies that offer real time information into their environmental impact.Current solutions don't provide an integrated strategy that incorporates both tracking and monitoring of home appliances and carbon footprint estimates.All the major applications focused on carbon footprint tracking and reduction, such as Greenly, Klima, and Capture, originate from companies outside India. Additionally, there is no decentralized common baseline for carbon emission hence inconsistent measure for carbon credits valuation.

Need Analysis

In a report published in the year 2020 [1], the emphasis was given on how managing carbon footprint can contribute to the sustainability of the supply chain.Individuals are more conscious of the adverse impacts of climate change and carbon emissions due to increasing environmental awareness.Nevertheless, individuals still lack the ability to track and control their own contribution towards damaging the environment.There is a definite need for a solution that can simplify personal carbon footprints through comprehensible measurable data regarding daily household energy consumption, transport, and food related emissions.This absence of personalized data is a chance for a solution that interprets daily activities into real world environmental impacts.

The absence of personalized data makes it difficult for individuals to make well informed choices regarding sustainability, creating a need for data driven capabilities.Moreover, the need for such a solution is also increased by government and corporate initiatives towards sustainability and ESG (Environmental, Social, and Governance) objectives.Advanced analytics are utilized to provide users with personalized advice, enabling users to have the statistical reports they require to track their performance and identify areas for improvement, ensuring they are aligned with broader sustainability policies.

With the digital age, easy access through mobile devices is highly significant, and a smartphone based solution is provided as an ideal platform for tracking personal carbon footprints in real time.Monitoring emissions is simplified and instantaneous, making people inclined to alter their behavior. Additionally, there is a growing need for a blockchain-enabled carbon credit system that for actively reducing their carbon footprint. Additionally, it establishes trust in carbon credit markets by resolving fraud and incorrect tracking problems. Furthermore, the system aligns with global sustainability goals by harmonizing with government policies and corporate ESG goals, enabling easy participation in larger environmental programs. Blockchain technology used in carbon credit systems offers an accessible platform for facilitating a greener and more sustainable future.

Literature Survey

Human activities since the industrial revolution have led to significant anthropogenic CO_2 emissions, contributing to global warming and environmental degradation.The Paris Agreement mandates limiting global temperature rise to below 2 °C, necessitating a transition towards carbon neutrality by reducing CO_2 emissions and enhancing carbon sequestration.[2]

The term "carbon footprint" has gained popularity, but there is a lack of academic definitions distinguishing its meaning.A carbon footprint measures the total greenhouse gases emitted as a result of individual or organizational activities.It has two components: primary (direct emissions from fossil fuel combustion) and secondary (indirect emissions from product life cycles).Businesses and individuals are increasingly adopting carbon management strategies to reduce their climate change impact.The Kyoto Protocol sets binding emission reduction targets, influencing carbon footprint calculations for compliance.[3]

A study combines microdata from Japanese household consumption expenditures with a multi regional input output model to assess household carbon footprints (CFs).It identifies 25 factors, including socioeconomic and lifestyle choices, that affect household CF estimates and emissions.The analysis shows that owning fewer vehicles significantly contributes to reducing CO_2 emissions, with one less normal sized car saving about 922 kg CO_2 per household annually.Key demographic factors such as the number of children in a household positively correlate with higher CFs, suggesting that family size can impact emissions.Energy usage for household appliances like personal computers and bidets also adds significant carbon emissions, with specific appliance ownership linked to increased CO_2 output.[4]

Urbanization has led to a significant increase in the global demand for energy, necessitating effective energy conservation strategies in smart homes and cities.The COVID-19 pandemic has reshaped residential environments, increasing the importance of smart technologies in managing energy consumption for various activities like work and education.Smart homes, defined as integrated environments using advanced communication technologies, have the potential to reduce energy demand by 12% to 20% through smart appliances and management systems.[5]

Existing home automation devices like smart thermostats (like Nest and Ecobee) are revolutionizing home heating and cooling by learning our schedule and preferences to optimize energy use.They can turn off the heat or AC when we are not home or sleeping, potentially saving 10-15% on energy bills compared to traditional thermostats.These devices integrate with smart home systems, offering remote control and detailed energy usage insights.There are many Home Energy Management Systems (HEMS) like Sense and Neurio monitor and optimize overall energy usage, identifying high consumption appliances and providing detailed reports.They offer predictive analysis to help reduce energy waste, enhancing your home's energy efficiency and potentially lowering utility bills.Smart lights like Philips Hue and LIFX smart bulbs offer app control, scheduling, and energy efficient LED technology, reducing electricity waste by automatically turning lights off when not needed.They can save up to 80% energy compared to traditional bulbs, contributing significantly to energy conservation.Systems like Rachio adjust irrigation based on weather, preventing overwatering and saving water.Leak detection systems such as Flo by Moen detect and prevent leaks, conserving water and reducing potential damage.

These systems often integrate, creating a cohesive energy efficient home environment.By reducing energy and water consumption, they lower greenhouse gas emissions and conserve natural resources, appealing to eco conscious consumers.

But smart devices often come with a high upfront cost, which can be a barrier for widespread adoption. The benefits of home automation systems are maximized when widely adopted, but there is still resistance due to lack of awareness and trust.Increasing public awareness through education and demonstrating the long term benefits can encourage broader adoption.Different brands and systems may not always be compatible, creating a fragmented user experience.Development of universal standards and protocols can enhance interoperability between various devices and systems.

Systems to leverage more sophisticated AI algorithms to predict user behavior and optimize energy usage more effectively.Integrating home automation systems with carbon tracking apps can provide users with data on their carbon footprint.More intuitive and user friendly interfaces will make it easier for consumers to manage and control their smart home devices.Greater interconnectivity between various smart home devices will create a more seamless and efficient user experience.

The adoption of VCMs has become a necessity and is crucial for the transition towards net zero carbon emissions and thus meeting the 2015 Paris Agreement. However, the current carbon trading system faces transparency, traceability, and efficiency challenges.

Table 1: Comparison between existing carbon credit platforms

Paper Name & Authors	Objective	Results	Limitations
A Blockchain-based Carbon Credit Ecosystem by Soheil Saraji and Mike Borowczak[6]	To create a carbon credit ecosystem using blockchain technology to bring more transparency, accessibility, liquidity, and standardization to carbon markets.	The carbon credit ecosystem was created on the Ethereum blockchain, and it uses smart contracts to automate the process of buying and selling carbon credits.	The system is still in its early stages of development, and it has not yet been tested in a real-world setting.
Blockchain and IoT-Powered Carbon Credit Exchange for Achieving Pollution Reduction Goals by Darniss R, Jivthesh M R, Gaushik M R, Sai Shibu N B, and	To track and trade carbon credits using a blockchain and IoT-based framework.	The framework monitors the energy usage of each entity, recording real-time carbon emissions in a tamperproof	The framework is limited to the use case of electrical energy for carbon emission and credit trading.

Sethuraman N Rao[7]		blockchain ledger.	
Blockchain Technology in Carbon Trading Markets: Impacts, Benefits, and Challenges - A Case Study of the Shanghai Environment and Energy Exchange by Guocong Zhang, Sonia Chien-I Chen, and Xiucheng Yue[8]	To investigate the effects of blockchain technology applications on transaction prices within the carbon trading market.	Blockchain technology significantly enhances the transparency, security, and efficiency of the carbon market, thereby exerting a positive influence on transaction prices.	Blockchain applications face challenges such as increased costs, heightened energy consumption, transaction delays, and substantial learning costs.
Carbon Credit Transfer System using Blockchain by Shreyash Jawalkar, Rohan Shende, Rohit Selokar, Sahil Sendre, and Dr. Rupali Vairagde[9]	To develop a carbon credit ecosystem using blockchain technology to improve market consistency, liquidity, accessibility, and transparency in the carbon domain.	The carbon credit ecosystem was created on the Ethereum blockchain, and it uses smart contracts to automate the process of buying and selling carbon credits.	The system is still in its early stages of development, and it has not yet been tested in a real-world setting.
Carbon Credits on Blockchain by Dhiren Patel, Sanidhya Sharma, Yash Dusing, Benita Britto, Kaustubh Gaikwad, and Mrinal Gupta[10]	To propose a token-based economy for carbon trading using blockchain as a means of ensuring decentralization and transparency at a global level.	The token-based economy was created on the Ethereum blockchain, and it uses smart contracts to automate the process of buying and selling carbon credits.	The system is still in its early stages of development, and it has not yet been tested in a real-world setting.
Blockchain, IoT, and AI-based framework for traceability in carbon capture utilization storage (CCUS) supply chain by Pratyush Kumar Patro, Adolf Acquaye, Raja Jayaraman, and Khaled Salah[11]	To propose a framework that integrates blockchain, the Internet of Things (IoT), and Artificial Intelligence (AI) to enhance transparency and CCUS accounting in the supply chain.	The framework uses blockchain to create an immutable and decentralized ledger for recording CCUS-related transactions and data.	Effective governance of the said technology, scalability and Interoperability
A Low-Code Platform of Carbon Credit Trading Using Blockchain Technology: A Case Study in Nakhon Si Thammarat Province by Piyawadee Pengna, Adisorn Leelasantitham, and Yod Sukamongkol[12]	To develop a prototype of carbon credit trading platform using a low-code method along with blockchain technology.	The prototype platform was developed using Mendix and Hyperledger Fabric, and it allows users to buy and sell carbon credits.	Lack of government approval and Was just a case study and was not implemented into the real world.
Blockchain Powered Carbon Credit Marketplace by Kalaiselvan S.A, Prasanna Venkatesh J.S, Raghul Karthik K, and Vasanth Kumar A.M[13]	To develop a blockchain-based carbon credit ecosystem to address the challenges pervasive in existing carbon markets.	The ecosystem leverages a decentralized ledger and smart contracts to ensure transparency, traceability, and automation of carbon credit transactions.	The ecosystem is still in its early stages of development, and it has not yet been tested in a real-world setting.

Table 2: Comparison between existing applications and Ecosync

Features→ / Existing Apps ↓	Carbon footprint calculation for diet	Carbon footprint calculation for Transportation	India Based	Integrated Home Automation	Donate to carbon offsetting NGOs	Paid Subscription	Carbon credit trading
Klima[14]	Yes	No	No	No	Yes	Yes	No
Capture[15]	Yes	Yes	No	No	Yes	Yes	No
Dynatrace[16]	Yes	No	No	No	No	Yes	No
Myplan8[17]	Yes	Yes	No	No	Yes	No	No
Carbon Watch[18]	Yes	No	Yes	No	No	No	No
Greenly[19]	Yes	Yes	No	No	No	Yes	No
Pawprint[20]	Yes	No	No	No	Yes	No	No
Earth Hero[21]	Yes	No	No	No	No	No	No
Cool The Globe[22]	Yes	No	Yes	No	Yes	No	No
Ecosync (Our proposed solution)	Yes	Yes	Yes	Yes	No	No	Yes

Objectives

1. Since there have been studies proving that there are multiple factors that affect household carbon footprint estimates and emissions [4].Food and transportation are few of them.The **first objective** of our project focuses on carbon footprint emission and reduction analysis of an individual through a mobile application.

2. Research studies have concluded that smart homes have the potential to reduce energy demand by 12% to 20% through smart appliances and management systems.[5] and electricity consumption being one of the factors affecting the total carbon footprint estimates.Our **second objective** is to develop an IoT based system capable of monitoring and controlling home devices.

3. Since it takes time to adopt to some habits redundant design can lead to early drop off of the individual our **third objective** is to design user friendly application that provides easy to use understand application and personalized recommendations to encourage individual users to reduce their carbon footprint.

4. Our **last objective** is to design and implement a blockchain based carbon credit system for industries that ensures transparency, security, and decentralization in the tracking and trading of carbon credits

Methodology

Understanding the major sources of carbon emissions in everyday life is crucial for developing an effective solution.These sources include transportation, energy consumption, dietary choices, and waste disposal. Additionally, research into home automation technologies, such as smart thermostats, energy efficient lighting, and appliance monitoring, can help identify potential methods for reducing carbon emissions.The key functionalities of the proposed system will focus on carbon footprint tracking and seamless smart home integration to optimize energy use and minimize environmental impact.

The development of the application requires careful selection of appropriate technologies.For mobile app development, a framework such as React Native will be chosen for cross platform compatibility, or native Android development can be used for optimized performance.The backend infrastructure will rely on cloud services, such as Firebase and a Node.js based backend, ensuring scalability and real time data processing. An efficient database, such as Firestore, PostgreSQL, or MongoDB, will be selected to store user data and analytics.Furthermore, IoT and home automation integration will enable connectivity with smart home devices and sensors, utilizing communication protocols to ensure seamless interaction.

A well designed user interface is essential for maximizing engagement and usability.Wireframes and interactive prototypes will be developed using tools like Figma or Adobe XD.The interface will prioritize user friendliness by enabling effortless tracking of emissions and intuitive control of home automation features.Optimizing accessibility and simplicity will encourage users to adopt sustainable habits more effectively.

The development process will be divided into frontend and backend implementation.The frontend will involve building UI components, to help users understand their carbon footprint.The backend will focus on developing APIs for carbon footprint calculations, smart home device control, user authentication, and data storage.Integration with IoT devices will include implementing automation triggers, such as turning off lights when rooms are unoccupied, further contributing to energy conservation.

The application will use emission factor based calculations to estimate carbon footprints accurately.These calculations will consider factors such as kilograms of CO_2 emitted per kilowatt-hour of energy consumed and per kilometer traveled.By retrieving energy consumption data from smart devices, the system can offer precise and actionable insights into users carbon footprints.

To develop a blockchain based system for carbon credit management, selecting a suitable framework like Ethereum or Hyperledger Fabric is essential based on scalability, security, and smart contract capabilities. Smart contracts enable carbon credit issuance, verification, and trading, ensuring transparency and automation. A consensus mechanism validates transactions securely, maintaining the integrity and trustworthiness of the blockchain network. For enhanced security and authentication, Web3 technologies, JavaScript, the Ethereum blockchain, and MetaMask integration will be utilized, ensuring robust and decentralized user verification within the system.

A testing phase will ensure the reliability and efficiency of the application.Unit testing will be conducted to validate individual components, such as carbon tracking algorithms and automation controls.Integration testing will verify seamless connectivity between the mobile application and smart home devices, ensuring that all features function as intended before deployment.

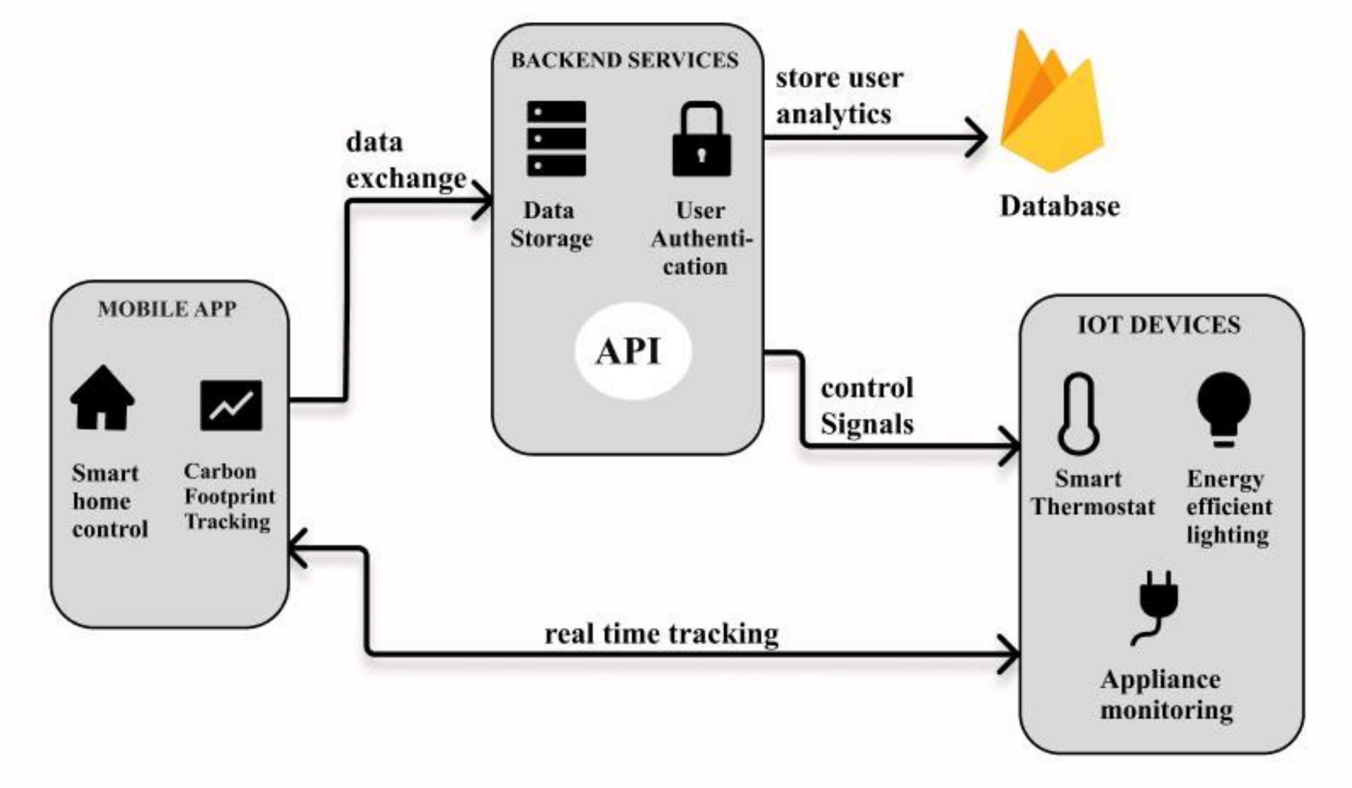

Figure 1: Visual representation of Individual Carbon monitoring part

Project Outcomes & Individual Roles

Outcomes

The proposed mobile application will be a fully functional tool designed to track and analyze an individual's carbon footprint based on key factors such as household energy usage, transportation, and dietary habits along with a blockchain based carbon credit trading platform for industires.It will feature a user friendly and intuitive interface, ensuring seamless interaction and easy data input for users of all technical backgrounds.To enhance user engagement, the application will include a personalized recommendation system that provides actionable insights for reducing carbon emissions. Additionally, graphical statistics and trend analysis will enable users to monitor their sustainability progress over time. The app will support offline functionality for diet and transportation carbon estimation, allowing users to log and analyze data without requiring a continuous internet connection.A secure, cloud integrated data storage system will ensure privacy and accessibility while maintaining data integrity.Designed as a robust, cost effective, and scalable solution, this application aims to promote eco friendly behavior and encourage sustainable living practices.

Individual Roles

Table 2: The list of the Individual roles

Name	**Role**	
Aryan Saxena	Blockchain	Backend
Aditya Sharma	Frontend	ML/AI
Vedansh Purohit	Hardware	ML/AI
Toshar Bhardwaj	Frontend	Backend
Saarthak	Documentation	Hardware

Work Plan

The work plan for developing the carbon footprint tracking mobile app is divided into phases, each specifying the most important tasks needed to execute the work successfully.The timeline is controlled to ensure smooth project progress.

The proposed work is divided into the following phases of significant work:

Phase 1: System Design and Core Development (March)

The objective is to design the system architecture and start core app development.The work includes finalizing use cases, system workflows, and the feature set, developing the software requirements specification (SRS), and starting mobile app development with significant UI components. Backend setup will be performed using Django and Node.js, including authentication and API endpoints. Work to integrate ML/AI models to provide personalized suggestions for carbon footprint reduction will start. Select a suitable blockchain framework (e.g., Ethereum, Hyperledger Fabric

Phase 2: Prototype Development and Integration (April – August)

The objective of the phase is to develop a working prototype integrating the software and hardware. Significant work includes implementing transport tracking, diet impact analysis, and electrical monitoring modules.IoT devices such as Arduino BLE33, ESP32,PZEM-004T and Raspberry Pi will be integrated for real time monitoring and control. Backend data pipelines will be established for acquiring and processing the user activity data.AI/ML models will be trained for analyzing carbon footprint trends and providing optimization suggestions.UI components will be developed for user input, real time feedback.Basic system testing will be conducted to assess data transmission, processing accuracy, and app performance. Create smart contracts to realize carbon credit issuance, verification, and trading.

Phase 3: System Refining and Testing (September – October)

This stage will be dedicated to enhancing system performance and reliability.Artificial intelligence models will be optimized to provide precise predictions and recommendations.Application programming interfaces and database queries will be optimized to provide a seamless user experience.Security and privacy controls will be implemented to safeguard user data.Integration testing will be performed to provide a seamless interaction between software, hardware, and AI elements.

Phase 4: Finalization and Deployment (November)

The last stage will be dedicated to completing testing, documentation, and preparation for deployment. Thorough testing will be performed to provide complete functionality, followed by final debugging and performance tuning.Technical documentation, reports, and presentations will be finalized.User manuals and deployment guides will be prepared.The project will be finalized with submission and a final demonstration.

REFERENCES

[1] Piya Ghosh, Ajay Jha, and RRK Sharma, "Managing carbon footprint for a sustainable supply chain: A systematic literature review", Modern Supply Chain Research and Applications, Vol. 2 No. 3, pp. 123-141, August 29, 2020

[2] Nikolay V. Lobus, Maria A. Knyazeva, Anna F. Popova, Maxim S. Kulikovskiy, "Carbon Footprint Reduction and Climate Change Mitigation: A Review of the Approaches, Technologies, and Implementation Challenges", Journal of Carbon Research, Vol 9 No. 120, December 15, 2023

[3] Neha Malik ,Yogita Bodwade and Government College of Engineering Jalgaon India, "Literature Review on Home Automation System ", International Journal of Advanced Research in Computer and Communication Engineering, Vol 6 No. 3, March 2017

[4] Yosuke Shigetomi, Keiichiro Kanemoto, Yuki Yamamoto and Yasushi Kondo, "Quantifying the carbon footprint reduction potential of lifestyle choices in Japan" , Environmental Research Letters, Volume 16 Number 6,pp. 064022, May 21, 2021

[5] Hakpyeong Kim, Heeju Choi, Hyuna Kang, Jongbaek An, Seungkeun Yeom, Taehoon Hong, "A systematic review of the smart energy conservation system: From smart homes to sustainable smart cities", Renewable and Sustainable Energy Reviews, Volume 140, pp. 110755, April 2021

[6] Soheil Saraji and Mike Borowczak, "A Blockchain-based Carbon Credit Ecosystem," in Proceedings of DOI:10.48550/arXiv.2107.00185 LicenseCC BY-NC-ND 4.0 June 2021

[7] Darniss R, Jivthesh M R, Gaushik M R, Sai Shibu N B, and Sethuraman N Rao, "Blockchain and IoT-Powered Carbon Credit Exchange for Achieving Pollution Reduction Goals",Version 1 posted 02 Mar, 2023.

[8] Guocong Zhang, Sonia Chien-I Chen, and Xiucheng Yue, "Blockchain Technology in Carbon Trading Markets: Impacts, Benefits, and Challenges - A Case Study of the Shanghai Environment and Energy Exchange". ,Energies, 5 July 2024.

[9] Shreyash Jawalkar, Rohan Shende, Rohit Selokar, Sahil Sendre, and Dr. Rupali Vairagde, "Carbon Credit Transfer System using Blockchain, International Workshop on Intelligent Networking and Collaborative Systems, 2024.

[10] Dhiren Patel, Sanidhya Sharma, Yash Dusing, Benita Britto, Kaustubh Gaikwad, and Mrinal Gupta, "Carbon Credits on Blockchain," ACM, DIS '22, June 13-June 17, 2021.

[11] Patyush Kumar Patro, Adolf Acquaye, Raja Jayaraman, and Khaled Salah, "Blockchain, IoT, and AI-based framework for traceability in carbon capture utilization storage (CCUS) supply chain", MDPI, June 2020

[12] Piyawadee Pengna, Adisorn Leelasantitham, and Yod Sukamongkol, "A Low-Code Platform of Carbon Credit Trading Using Blockchain Technology: A Case Study in Nakhon Si Thammarat Province," Wireless Personal Communications, December 2020

[13] Kalaiselvan S.A, Prasanna Venkatesh J.S, Raghul Karthik K, and Vasanth Kumar A.M, "Blockchain Powered Carbon Credit Marketplace", White paper, June 2021

[14] Klima Live carbon neutral, Climate Labs GmbH, Google Play, August 15, 2024

[15] Capture Carbon Footprint & CO2 Tracker, The Capture Club, Aptoide, June 02, 2023

[16] Dynatrace, dynaTrace Software GmbH, February 16, 2023

[17] Myplan8 Climate Action, KRNY Innovations Private Limited, Google Play, June 12, 2023

[18] CarbonWatch, Schneider Electric, Google Play, October 14, 2021

[19] Greenly, Greenly Tech, February 2021

[20] Pawprint Your Carbon Tracker, PawprintEco, Google Play, Aug 26, 2024

[21] Earth Hero Climate Change, Earth Hero, Google Play, 2019

[22] Cool The Globe, Cool the Clobe, Google Play, Jan 23 2024

18