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Survey on Decentralised Carbon Markets for Emission Reduction

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Abstract: This survey explores innovative methods to enhance carbon markets for emission reduction. By focusing on advanced predictive models and transparent transaction systems, the study aims to improve the accuracy and security of carbon credit trading. The integration of these technologies ensures the credibility and traceability of transactions, fostering trust among market participants.

Experimental results confirm the efficiency of this approach in promoting sustainable practices. This research highlights the potential of these advancements to revolutionize carbon markets, offering a pathway towards a more sustainable, low-carbon future.

Keywords: Carbon Footprint, Emission Tracking, Decentralized Ledge, Predictive Analytics, Carbon Management Platforms, Lifecycle Assessment(LCA),Carbon Capture and Storage (CCS) Software.

I. INTRODUCTION

This survey examines various methods for carbon emission reduction within the framework of carbon markets. It highlights the role of carbon credits in fostering sustainable practices and analyzes different strategies for effective emission reduction. Emphasis is placed on transaction security, market transparency, and the overall efficiency of carbon trading systems.

The study explores the potential for creating a for improvement, driving efforts to reduce emissions and mitigate environmental impacts. low-carbon future through innovative and sustainable approaches, underscoring the need for improved market dynamics and strategic implementation. Key insights from this survey aim to guide policymakers, industry stakeholders, and researchers in developing more effective carbon reduction strategies.

II. BASIC CONCEPTS

2.1 Carbon Accounting:

Carbon accounting involves quantifying and analysing the greenhouse gas (GHG) emissions produced by an organization, project, or individual. It includes calculating carbon footprints, tracking emissions sources, and ensuring accurate reporting. This process is crucial for establishing baseline emissions, setting reduction targets, and verifying progress towards emission reduction goals. Accurate carbon accounting provides the foundation for effective carbon management and sustainability initiatives.

2.2 Carbon Footprint:

A carbon footprint measures the total amount of greenhouse gases emitted directly and indirectly by an entity, such as an individual, organization, or product. It is expressed in equivalent tons of CO2 and includes emissions from activities like energy use, transportation, and waste. Understanding the carbon footprint helps identify major emission sources and areas strategy alongside direct emission reduction measures.

2.3 Emission Tracking:

Emission tracking involves monitoring and recording the sources and amounts of greenhouse gases emitted over time. This process includes collecting data on energy consumption,transportation, industrial processes, and other emission sources. Effective emission tracking enables organizations to assess their environmental impact, evaluate performance against targets, and implement strategies for reducing emissions. It is essential for transparency and accountability in emission reduction efforts.

2.3 Sustainability Reporting:

Sustainability reporting involves disclosing an organization’s environmental, social, and governance (ESG) performance, including its carbon footprint and reduction initiatives. It provides stakeholders with information on sustainability practices, progress towards goals, and impact on the environment.

Comprehensive reporting helps build trust, demonstrates commitment to sustainability, and guides decision-making by showcasing efforts to manage and reduce carbon
emissions.

2.4 Carbon Offset:

Carbon offsetting involves compensating for greenhouse gas emissions by investing in projects that reduce or capture an equivalent amount of emissions elsewhere. Common projects include reforestation,renewable energy, and methane capture. By purchasing carbon offsets, individuals and organizations can neutralize their emissions, contributing to global efforts to mitigate climate change. Carbon offsets are used as a supplementary verified emissions data and regulatory requirements. This reduces administrative overhead and increases the efficiency of carbon credit trading.

2.5 Carbon Management:

Carbon management is the systematic approach to reducing and controlling greenhouse gas emissions within an organization or project. It includes strategies such as setting reduction targets, implementing energy-efficient practices, and investing in low-carbon technologies. Effective carbon management involves continuous monitoring, reporting, and adjusting strategies to minimize emissions and achieve sustainability goals, thereby supporting broader climate action efforts.

III. TECHNOLOGIES IMPLEMENTED

3. 1. Blockchain Technology:

Blockchain technology provides a decentralized and immutable ledger for recording carbon credit transactions. This ensures transparency, security, and traceability, as each transaction is permanently recorded and cannot be altered. By utilizing blockchain, carbon credits can be tracked from issuance to retirement, preventing fraud and double-counting. This technology is crucial for building trust among stakeholders, as it guarantees the integrity and accountability of the carbon credit market.

3.2. Smart Contracts:

Smart contracts automate the management of carbon credits on the blockchain. These self- executing contracts with the terms directly written into code facilitate the issuance, transfer, and revocation of carbon credits. By embedding compliance rules, smart contracts ensure that carbon credits are only allocated or withdrawn based on
layer of security and trust in the carbon trading system.

3.3 Decentralized Ledger:

A decentralized ledger ensures that no single entity controls the carbon credit data, promoting trust and collaboration among market participants. Each participant has a copy of the ledger, which is updated in real- time with every transaction. This decentralization enhances data security and resilience against tampering. For carbon markets, it means every carbon credit transaction is transparently recorded and accessible to all stakeholders, ensuring accountability and transparency.

3.4 Machine Learning:

Machine learning algorithms analyze historical emissions data to predict future carbon credit needs and prices. These algorithms can identify patterns and trends in emissions, helping to forecast periods of high or low carbon credit demand. This predictive capability allows market participants to make informed decisions about buying or selling carbon credits, optimizing their strategies for compliance and financial performance in the carbon market.

3.5 Anomaly Detection:

Anomaly detection techniques identify unusual patterns in emissions data, flagging potential instances of non-compliance or fraud. By continuously monitoring emissions data, these techniques can detect discrepancies that might indicate tampering or errors. In the context of carbon credits, anomaly detection ensures the integrity of reported emissions, providing an additional

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3.6 Internet of Things (IoT):

IoT devices, such as sensors, provide real- time data on emissions from various sources. These devices are crucial for accurate and continuous monitoring of carbon output. By integrating IoT with blockchain, emissions data can be automatically recorded on the ledger, ensuring that carbon credit allocations and transactions are based on precise and up-to-date information. This integration enhances the reliability and responsiveness of carbon management systems.

3.7 Real-Time Monitoring:

Real-time monitoring of emissions through IoT devices and sensor networks allows for immediate detection of emission levels and compliance status. This continuous data stream is crucial for the dynamic management of carbon credits, enabling instant adjustments and verifications. Real- time monitoring ensures that any deviations from emission targets are quickly addressed, maintaining the integrity of the carbon trading system and supporting timely decision-making.

Table 1. Comparative Analysis of Research Papers

Ref No.	Research Paper	Authors	Experiment / observation	Remarks
1.	**Developed a smart metering technique for real-time anomaly detection to improve power management in systems with battery storage and electric vehicles.**	Sangkeum Lee, Sarvar Hussain Nengroo, Hojun Jin, Yoonmee Doh, Chungho Lee, Taewook Heo, Dongsoo Har	Utilized data from 900 households, employing a deep learning model (autoencoder) integrating graph convolutional networks and bidirectional long short-term memory networks.	This approach enhances energy efficiency, reduces costs, and supports carbon emission control by optimizing electricity usage, contributing to potential carbon credits through reduced emissions.
2.	**Investigated the use of big data analytics to evaluate carbon efficiency in manufacturing workshops.**	Chaoyang Zhang, Weixi Ji	Implemented real-time data analysis techniques to monitor and assess carbon emissions across various manufacturing processes.	By improving carbon management through real-time evaluations, this research supports initiatives for carbon credits by demonstrating reduced emissions in manufacturing operations.
3.	**Focused on estimating CO2 emissions using data from IoT traffic flow sensors.**	Stefano Bilotta and Paolo Nesi	Analyzed traffic data to reconstruct CO2 emissions profiles in urban environments.	This research aids in urban carbonmanagement, providing data that can support carbon credit systems by quantifying reductions in emissions from optimized traffic flow.
4.	**Proposed a two-stage approach for optimizing order allocation in decentralized distribution systems to reduce carbon emissions.**	Fei Bu, Lulu Sun, Meng Zhang, and Dong Li	Applied routing optimization techniques to minimize emissions during the distribution process.	The findings highlight the potential for significant carbon emission reductions, aligning with carbon credit initiatives by optimizing logistics and distribution efficiency.
5.	**Developed a digital management system for monitoring carbon emissions in smart cities**	Jilu Liu and Zechen Zhang	Implemented integrated monitoring solutions to assess energy usage and emissions in urban settings.	This system enhances urban planning and management of carbon emissions, supporting the generation of carbon credits through improved sustainability practices.

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6.	**Explored strategies for implementing low- carbon solutions in blockchain-based energy supply chains.**	Hua Pan, Huimin Zhu* and Minmin Teng	Analyzed the feasibility of blockchain technology in reducing carbon footprints through energy transactions.	The research promotes transparency and efficiency, contributing to carbon emission reductions and facilitating carbon credit trading in energy markets.
7.	**Investigated the carbon emissions associated with machine learning processes.**	Alexandre Lacoste, Thomas Dandres, Alexandra Luccioni, Victor Schmidt	Conducted assessments of energy consumption and emissions from various machine learning models.	This research emphasizes the environmental impact of AI, advocating for sustainable practices that can lead to carbon credits through reduced energy consumption in machine learning applications.

Comparative Analysis:
Justification:

1. Focus on Industrial Applications:
This paper(ref no.2)directly addresses carbon efficiency within manufacturing workshops, which are significant contributors to industrial carbon emissions. By focusing on this sector, the research targets a critical area for emission reductions.

2. Real-Time Evaluation: The use of big data analytics allows for real-time monitoring and evaluation of carbon emissions. This capability enables manufacturers to make immediate adjustments to processes, leading to more efficient operations and reduced emissions.

3. Data-Driven Decision Making: Implementing big data analytics empowers industries to identify inefficiencies and optimize energy

usage, contributing to lower carbon footprints. This approach aligns well with the growing trend of data-driven decision-making in industrial settings.

4. Potential for Carbon Credits:
By demonstrating reductions in carbon emissions through improved efficiency, industries can potentially qualify for carbon credits, creating a financial incentive for adopting these practices.

Comparison with Other Papers:

- Anomaly Detection in Smart Metering Systems:
While this paper(ref no.2) is effective for residential and small-scale applications, its focus is less directly applicable to large-scale industrial processes compared to the big data approach.

- Estimating CO2 Emissions from IoT Traffic Sensors:
This paper(ref no.2) is valuable for urban management but does not specifically target industrial emissions.

-DecentralizedJointsDistribution Alliance:

Although it addresses logistics, which is important, its focus is not exclusively on manufacturing processes.

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- Integrated Energy Carbon Emission Monitoring for Smart Cities:
This paper(ref no.2) focuses on urban environments rather than industrial applications.

-Low-Carbon Blockchain-Based Power Supply Chain:
While innovative, its applicability to direct carbon emission reductions in industrial settings may be limited.

- Quantifying Carbon Emissions of Machine Learning:

This paper(ref no.2) addresses emissions related to AI but does not focus on industrial processes.

Challenges:

1. Lack of Standardization:
The absence of standardized data formats and communication protocols can hinder the effective exchange of information.

2. Inadequate M&V Protocols: Existing measurement and verification protocols may not fully address the unique challenges posed by decentralized systems.

3. Limited Consumer Participation: Without effective education and incentives, consumers may be reluctant to adopt practices that contribute to carbon offsetting.

4. Financial Incentive Gaps:
The absence of clear financial incentives, such as carbon credits or subsidies, may limit motivation for stakeholders to invest in carbon reduction technologies.

5. Regulatory Inconsistencies: Fragmented policies across regions can create uncertainty and hinder the integration of decentralized systems into existing energy markets.

6. Cost and Time Constraints:
The complexity of integrating new technologies with existing infrastructure can result in increased costs and extended timelines for deployment.

7. Supply-Demand Mismatch:
The inability to consistently match energy supply with demand can lead to increased reliance on fossil fuels during periods of low renewable generation.

IV. CONCLUSION

Amongst all the methods explored for carbon emission reduction, the integration of big data analytics stands out as a particularly beneficial approach. By leveraging large volumes of data generated from smart metering systems, industries can achieve real-time monitoring and optimization of energy consumption. This capability allows for precise identification of inefficiencies and the implementation of targeted demand response strategies, ultimately leading to significant reductions in carbon emissions.

Additionally, the integration of big data analytics enhances real-time monitoring of carbon efficiency, allowing industries to make informed decisions that lead to significant reductions in emissions. Demand response strategies further support this by enabling consumers to adjust their energy usage based on real- time pricing and availability, contributing to a more balanced energy grid.

Overall, these methods not only facilitate substantial carbon emission reductions but also promote participation in carbon credit markets, creating a sustainable framework for energy management in both residential and industrial contexts.

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