Advancing Digital Sustainability through Block chain and AI for Emission Monitoring and Environmental Accountability

Ch. V. L. L. Kusuma Kumari[1] | Dr. B. Amarnath Reddy[2]

ABSTRACT

The urgency of the situation in combating climate change has been a strain on the need to use clean and acceptable machinery to trace and reduce greenhouse gas emissions. Enhancement of time-honoured methods of emissions monitoring usually encompasses the disadvantage of fragmented information, reporting lags as well as opportunities of manipulation, and it is everything violating on the assumptions of organizations that may be confided and are liable in whatever they do. The solutions to these issues can be found in new digital technologies, i.e., Blockchain, and Artificial Intelligence (AI). Various blockchain will ensure transparent records of emissions and carbon credits are tampered with and AI can generate real-time monitoring and presumptive analytics, besides resource optimization.

This paper proposes a conceptual framework, positioning Blockchain, as well as AI, as the area with the aim of highlighting a greater relationship between Blockchain and AI, and environmental responsibility and assistance in deploying the conception of sustainability reporting systems such as the Paris Agreement and UN Sustainable Development Goals (SDGs). This paper analyzes carbon market usage, supply chain visibility and garbage administration by review of the literature, comparative case study and synthesis or integration of the methodologies. It also dwells on the social front of equity i.e., inclusivity in the case of the developing economies and small businesses. The close analysis of such obstacles as scalability, regulatory culture, and information privacy is carried out. Based on the results, Blockchain and AI could become the catalysts of digital sustainability and foster the even distribution of the global breakdown and environmental accountability.

Keywords: Digital Sustainability, Blockchain, Artificial Intelligence, Emission Tracking, Environmental Accountability, Social Equity, ESG Reporting, Circular Economy.

INTRODUCTION

The push in the world towards application of sustainable development is more than urgent. With governments, corporations and citizens putting progressively more pressure on one another to execute some of the most measurable, verifiable and transparent sustainability behaviours, as is emphasized in the Intergovernmental panel on climate change (IPCC, 2023) shock of discovery is the irreversible outcomes forecastable on the environment, should the reduction of carbon emissions not be instituted radically. However, there have been several gaps in the measure that have blemished the systems that are set up in data monitoring and data reporting which include manual data entry, isolated databases, unequal parameter in which data is measured

[1]Assistant Professor, Department of Management Science, Vallurupalli Nageswara Rao Vignana Jyothi Institute of Engineering and Technology (VNR VJIET), Hyderabad
[2]Assistant Professor, Department of Finance & Marketing, Vignana Jyothi Institute of Management, Hyderabad.

the potential of manipulating data favourably. These blemishes cast suspicion on such proclamations of sustainability, and those gains of global climate vows such as the Paris Agreement and the United Nations Sustainable Development Goals (SDGs).

One of the most recent paradigms developed is digital sustainability as the merger of discontinuing technological communities with the administration of the environment over the recent past years. Those are Blockchain and Artificial Intelligence (AI) that gained significant attention because of the possibility to make the emission monitoring process transparent, accountable, and efficient. A decentralized and mutable system of insurability (blockchain) allows keeping the records of the carbon gas emission, carbon credits, and supply chain operations error-free. However, AI can be helpful with its ability in the field of automation, anomaly detectors, and predictive modelling, which allow organisations to replicate the effects of pollution into the environment, and utilize the bed of resources in the most efficient manner. The two technologies are able to offer scalable and real-time, and dependable answers to environmental accountability.

Along with technological advantages, the actual conduct of the implementations of the emission tracking through the application of the Blockchain and AI also raises serious questions regarding social equity and inclusiveness. Who will be the beneficiary of these technologies? What are the ways of designing them in a manner that they can be affordable to small and medium enterprises (SMEs), developing countries and the disadvantaged populations? Respondent to these questions, digital sustainability could no longer emphasize efficiency improvements to facilitate a just transition a just, accessible, collectively responsible transition balancing the demands of the ecology with those of equity and fairness.

This paper is aimed at recognizing the ways in which Blockchain and AI can be employed to monitor emissions and offer environmental responsibility to the larger parameter of digital sustainability. Specifically, it seeks to:

1. Provide a systematic literature review of existing academic and industrial insights.
2. Propose a conceptual framework that integrates Blockchain and AI for sustainable environmental governance.
3. Analyse case studies of digital sustainability applications across industries.
4. Investigate the challenges, barriers, and equity implications of these technologies.
5. Identify future directions for policy, research, and implementation.

The research links theory to practice, and it can benefit the fields of the study as well as the practical decision-making within the dynamically emerging environmentally accountable world. And, after all, this paper finds that (unlike the mere technological concepts) Blockchain and AI can and will be instrumental in helping the world to behave in a sustainable way as it may redefine the way the societies observe, work, and manage the emissions.

LITERATURE REVIEW

The field of digital technologies / environmental sustainability intersection has been experiencing scholarly and business attention throughout the past decade. Early researchers focused on Blockchain emphasized decentralized and immutable ability to manage data (especially in finances transactions) with Blockchain (Nakamoto, 2008). In more modern applications, the concepts of Blockchain have been used to provide more transparency in supply chains and verify carbon certification to solve the problem of double-counting, fraud, and greenwashing of supply chain models (Bhatt, 2025; Alotaibi, 2024).

Simultaneously, Artificial Intelligence (AI) studies have highlighted the effectiveness of using AI to process data, predictive models, and anomalies detection in environmental surveillance.

The IoT sensors might monitor a large amount of data, which can be analysed with AI-powered tools and used to track the emissions in real-time and implement proactive measures (Stanford, 2024). Research has established that AI is useful in forecasting the suitable degree of pollution, energy-saving, and any circular economy initiative (Hong, 2024).

The use of AI with Blockchain can be discussed as complementary technologies, which are discussed in the latest contributions. A blockchain system offers reliability and safety and AI raises intelligence and automatization (Khan and Ahmad, 2022). The example of DCarbonX illustrates that decentralized carbon markets can happen, in which AI authenticates data on emissions and Blockchain makes such data traceable (Quigley et al., 2025). Nevertheless, the areas of difficulty wear as energy intensity, interoperability and regulatory uncertainty and thus additional research and standardization is necessary.

OBJECTIVES

1. To analyse the role of Blockchain and AI in emission tracking and environmental accountability.
2. To review existing literature and identify gaps in current approaches to digital sustainability.
3. To propose a conceptual framework integrating Blockchain and AI for sustainable governance.
4. To explore the social equity dimensions of adopting digital sustainability technologies.
5. To evaluate case studies and provide comparative insights across industries.
6. To identify challenges, barriers, and policy implications for scaling these technologies.
7. To outline future directions for research, innovation, and implementation.

RESEARCH METHODOLOGY

This study employs a qualitative, exploratory research design, focusing on secondary data and case-based analysis.

1. **Case Studies:** Selected real-world applications Blockchain framework, DCarbonX) were analysed to demonstrate the practical relevance and limitations of Blockchain and AI in environmental contexts.

2. **Comparative Insights:** Cross-case comparison was employed to identify best practices, success factors, and challenges across different sectors, including waste management, supply chain transparency, and carbon trading.

3. **Conceptual Framework Development:** Insights from literature and case studies were synthesized into a conceptual framework showing how Blockchain and AI can jointly enhance emission tracking, accountability, and social equity.

This methodology ensures a balanced perspective, combining theoretical depth with practical applicability, thereby contributing to both academic scholarship and policy development.

Conceptual Framework

A proposed framework integrates Blockchain and AI for digital sustainability:

1. **Data Acquisition:** IoT sensors and monitoring devices collect real-time environmental data.

2. **AI Analytics:** Machine learning algorithms analyse data for emission patterns, anomalies, and predictive insights.

3. **Blockchain Ledger:** Blockchain records all the data and transactions making it immutable and traceable.

4. **Decision-Making & Reporting:** Live dashboards allow monitoring compliance, reporting ESG, and making policy decisions.

Social Equity Dimensions

The interventions of digital sustainability should be mindful of equity in access, distribution of resources, and impact on the society. Key considerations include:

1. **Inclusive Access:** Ensuring small and medium enterprises (SMEs) and developing regions can adopt digital tools.

2. **Transparent Reporting:** Publicly available Blockchain records prevent exploitation or bias in emission accounting.

3. **Participatory Governance:** Stakeholders from marginalized communities can engage in decision-making through open digital platforms.

Case Studies / Comparative Insights

The possibilities of the Blockchain and Artificial intelligence (AI) to become an emission-tracking and environment-responsibility indicator ceased to be a far-fetched concept, thus, it is being researched in the industry and implemented in practice. The possibilities of such technologies as a transformative one can be traced with the help of case studies, and the obstacles to the implementation of the technology will also be disclosed.

CleanHub: AI-Powered Plastic Waste Management

CleanHub works based on the concept of the AI-based data platforms to monitor the plastic waste in the coastal areas specifically with Southeast and Africa. The evidence is uploaded by waste collection partners and is identified with the assistance of AI image recognition and analysed against community reports. It is designed in a way that every kilogram of plastic that is collected can be tracked down and traced. CleanHub facilitates corporate environmentally responsible behaviour by connecting collection activities with sustainability-oriented companies and increasing the strength of the local population.

1. **Key Strengths:** High transparency in plastic waste management, improved accountability for brands, and inclusive participation of local actors.

2. **Limitations:** Reliance on internet connectivity and digital literacy in developing regions may restrict scalability.

3. **PwC's Blockchain Framework for Emission Tracking**

PwC came up with the framework of Blockchain wherein it determines the cumulative environmental footprint of digital activity, such as energy usage and greenhouse gas (GHG) generation. The system combines smart contracts in order to automate the process of reporting compliance as well as to minimize the danger of a human error. Providing real-time performance dashboards also enables organizations to track the performance on regulation performance regulations including the EU Emissions Trading Scheme (ETS).

1. **Key Strengths:** Enhanced compliance monitoring reduced administrative burden, and immutable reporting structure.

2. **Limitations:** Implementation costs are high, and the energy footprint of Blockchain itself must be carefully managed.

DCarbonX: Decentralized Carbon Market

The decentralized application (dApp) called DCarbonX is an application that feeds on Blockchain and AI to trade carbon credits. The AI will verify the data on emission submitted by enterprises, whereas Blockchain will guarantee traceability and efforts to eliminate duplication. Smart contracts are applied in enabling transactions via the platform to clean up greenwashing fears that permeate voluntary carbon markets much of the time.

1. **Key Strengths:** Transparency in credit issuance, reduction of fraud, and increased trust in carbon markets.

2. **Limitations:** Regulatory uncertainties and lack of international standardization hinder cross-border trading.

Comparative Insights

A critique of the case studies has established similarities and differences in assessing the scope of use of Blockchain and AI toward sustainability.

Case Study	Technology Focus	Primary Application	Key Benefits	Limitations
CleanHub	AI (image recognition, data verification)	Plastic waste management	Community engagement, traceability of waste	Dependence on connectivity and training
Framework	Blockchain (smart contracts, ledgers)	Corporate emission tracking	Automated compliance, immutable data	High costs, Blockchain's energy use
DCarbonX	Blockchain + AI (integration)	Carbon market trading	Fraud reduction, transparency in credits	Regulatory fragmentation

Implications for Research and Practice

As discussed in the further cases, Blockchain and AI are not a one-victorious opportunity; it is a digital ecosystem, which must be coordinated with the policy, financial incentives, and the community participation. There are intuitive signs that intuitive solutions (to organize AI and accountability with the help of Blockchain) will take up the lead in the next genre of digital sustainability striving.

Challenges and Barriers

1. **Technological Barriers:** High computational requirements of AI and scalability issues in Blockchain.

2. **Data Privacy:** Transparency vs. confidentiality tensions in Blockchain systems.

3. **Regulatory Gaps:** Existing policies (e.g., GDPR, EU AI Act) are not fully aligned with digital sustainability needs.

4. **Financial Costs:** Implementation and maintenance of integrated systems may be prohibitive for SMEs.

Future Directions

1. **IoT and 5G Integration:** Real-time, high-resolution emission monitoring for cities and industrial sectors.

2. **Circular Economy Enablement:** Blockchain can track material flows to support reuse and recycling initiatives.

3. **Sustainable AI Practices:** Energy-efficient AI models to reduce digital carbon footprints.

Global Standards: Harmonized frameworks for Blockchain and AI applications in environmental accountability.

CONCLUSION

The environment cannot be sustainable on unrealistic statements but through financial statements, true and reliable frameworks to regulate the emissions. Data abuse, ineffectiveness and unreliability are also characteristics of the old form of reporting. The current paper illustrates the following shortcomings that can be addressed using the new solutions, which are provided by Blockchain and Artificial Intelligence (AI) in essence.

The solutions of blockchain are unchangeable, traceable and decentralized whereas the solutions of AI are predictive, monitored, and real-time analytics. Together, they are a whole system that makes the data more autonomous besides efficient. The case of AI waste management created by CleanHub and waste management fundable with Blockchain created by PwC and the decentralized carbon markets created by DCarbonX demonstrate that these technologies negatively affect us through their use. They also convey the notion that, the hybridism of the AI-responsibility combination models would dominate in the future emission tracking framework.

Anyhow, adoption does not come easy. Scalability issues, fragmentation of regulations, energy utilization, as well as equitable access are also major challenges. Moreover, the unavailability of the strategies to incorporate the digital alternatives will create the risk that the benefits of the digital sustainability solutions will be received only by big companies, and the smaller ones, third-world nations will be left behind.

The future is looking bright regardless of such impediments. Then, the emission monitoring worldwide in real-time can be conducted along with other emerging technologies such as the Internet of Things, and smart city facilities. Of no less significant significance, the policy frameworks and international standards also should be subjected to changes in order to offer trust, interoperability and inclusiveness.

Conclusively, AI and Blockchain are equally digital as well as a strategy as enabling tools of sustainability. Their use would ensure the process of tracking of the emissions becomes a clear, verifiable and a socially just process. The problems that are encountered by researcher-policymaker-practitioners is how to make these solutions both in responsibly finer scale yet remain answerable to the demands of the environment as well as social equality. Among the factors that will be taken into consideration when the technologies are incorporated, there could be a factor that will allow a faster realization of the world that is environmentally friendly, responsible, and climate stable.

REFERENCES

1. Haryono (2025) – AI + Blockchain in carbon trading (very relevant).

2. Merlo, A. L., Mendonça, D. S., Santos, J., Carvalho, S. T., Guerra, R., & Brandão, D. (2025). Blockchain for the carbon market: a literature review. Discover Environment, 3(1), 68.

3. Parhamfar, M., Sadeghkhani, I., & Adeli, A. M. (2024). Towards the net zero carbon future: A review of blockchain-enabled peer-to-peer carbon trading. Energy Science & Engineering, 12 (3), 1242–1264..

4. Wu & Pu (2024) – Blockchain adoption for emission reduction.

5. Zhang C. et al. (2025) – Blockchain + IoT for carbon-credit market.

6. Zhang H. et al. (2023) – Blockchain & environmental sustainability review.

7. Zhao et al. (2025) – Blockchain in green finance.

8. Zhou et al. (2024) – Blockchain + IoT for carbon credit exchange.

9. El Hathat et al. (2024) – Blockchain + AI for GHG traceability in supply chain.

10. Goean et al. (2024) – Blockchain to reduce emissions in tourism economy.

11. Baklaga (2024) – AI + Blockchain for decentralized carbon markets.

12. Liu et al. (2024) – Blockchain in carbon trading (substations).

13. AI-Driven Carbon Footprint Tracking (2024) – AI for emission tracking.

14. Toward a Greener Future (2024) – Blockchain sustainability survey.

Identifying Key Digital Enablers (2024) – AI, Big Data, Blockchain for carbon reduction.