

Blockchain Technologies for Eco-Friendly & Green Digital Organizational Transformation: *Impact, Trends and Issues*

P. K. Paul ¹, M. Daniel Rajkumar ², Manoj Deva Yeddu ³, S. K. Pattnayak ⁴, Biswajit Satpathy ⁵, Rohit K. Pal ⁶ & P. S. Aithal ⁷

¹ Executive Director (MCIS), Asst. Prof., Department of CIS, & Information Scientist (Offg.), Raiganj University, West Bengal, India. E-mail: pkpaul.infotech@gmail.com

² Postdoctoral Researcher (PDFC), Poornaprajna Institute of Scientific Research (PPISR), Bengaluru, Karnataka, India.

³ Asst, Professor, Department of Commerce & Management Studies, Adikavi Nannya University, Kakinada Campus, Andhra Pradesh, India.

⁴ Chair Professor, Dept. of Environmental Sciences, Sambalpur University, Odisha, India.

⁵ Retired Professor, Department of Business Administration, Sambalpur University, Odisha, India.

⁶ PDF (LGPR) Scholar, Lincoln University College, Malaysia.

⁷ Director, Poornaprajna Institute of Management (PIM), Udupi, Karnataka, India.

Area/Section: Technology Management.

Type of Paper: Exploratory Research.

Number of Peer Reviews: Two.

Type of Review: Peer Reviewed as per [C|O|P|E|](#) guidance.

Indexed in: OpenAIRE.

DOI: <https://doi.org/10.5281/zenodo.23451407>

Google Scholar Citation: [PIJET](#)

How to Cite this Paper:

Paul, P. K., Rajkumar, M. D., Yeddu, M. D., Pattnayak, S. K., Satpathy, B., Pal, R. K. & Aithal, P. S. (2026). Blockchain Technologies for Eco-Friendly & Green Digital Organizational Transformation: Impact, Trends and Issues. *Poornaprajna International Journal of Emerging Technologies (PIJET)*, 3(2), 175-187. DOI: <https://doi.org/10.5281/zenodo.23451407>

Poornaprajna International Journal of Emerging Technologies (PIJET)

A Refereed International Journal of Poornaprajna Publication, India.

ISSN: 3107-8486

Crossref DOI: <https://doi.org/10.64818/PIJET.3107.8486.0030>

Received on: 10/09/2026

Published on: 21/10/2026

© With Authors.



This work is licensed under a [Creative Commons Attribution-Non-Commercial 4.0 International License](#), subject to proper citation to the publication source of the work.

Disclaimer: The scholarly papers as reviewed and published by Poornaprajna Publication (P.P.), India, are the views and opinions of their respective authors and are not the views or opinions of the PP. The PP disclaims of any harm or loss caused due to the published content to any party.

Blockchain Technologies for Eco-Friendly & Green Digital Organizational Transformation: Impact, Trends and Issues

P. K. Paul ¹, M. Daniel Rajkumar ², Manoj Deva Yeddu ³, S. K. Pattnayak ⁴, Biswajit Satpathy ⁵, Rohit K. Pal ⁶ & P. S. Aithal ⁷

¹ Executive Director (MCIS), Asst. Prof., Department of CIS, & Information Scientist (Offg.), Raiganj University, West Bengal, India. E-mail: pkpaul.infotech@gmail.com

² Postdoctoral Researcher (PDFC), Poornaprajna Institute of Scientific Research (PPISR), Bengaluru, Karnataka, India.

³ Asst, Professor, Department of Commerce & Management Studies, Adikavi Nannya University, Kakinada Campus, Andhra Pradesh, India.

⁴ Chair Professor, Dept. of Environmental Sciences, Sambalpur University, Odisha, India

⁵ Retired Professor, Department of Business Administration, Sambalpur University, Odisha, India.

⁶ PDF (LGPR) Scholar, Lincoln University College, Malaysia.

⁷ Director, Poornaprajna Institute of Management (PIM), Udupi, Karnataka, India.

ABSTRACT

Purpose: The blockchain technology is one of the answers to this trust problem. It is a distributed, append-only ledger kept on several independent computers that allow multiple parties, for example a farmer, a shipper, a retailer and an auditor, to enter and disseminate data regarding a transaction without any single party being able to alter the record without anyone's knowledge following the entry. This paper is about the finding the impact and values of Blockchain technologies in contemporary business with green and eco-friendly solutions.

Methodology: This work is theoretical in nature and prepared based on existing literature related to the Blockchain technologies in business and organizations and thus existing works are collected, analyzed and documented in this work as theoretical and policy work.

Findings: This work reveals that Blockchain technologies are impactful in new age business transformation digitally using emerging technologies and intelligent systems. It has observed that Blockchain uses in business helps in green and ecological development.

Originality/Value: This paper is interdisciplinary in nature and theoretical and it is value addition to the existing knowledge considering as theoretical, policy-based works for the business houses and technological solutions providers for the digital transformation.

Type of the Paper: Exploratory Analysis.

Keywords: Digital Business Transformation, Business Informatics, Green Business, Eco Friendly Business, Organizational Development, Blockchain Technology, Environmental Management

1. INTRODUCTION :

Nowadays, environmental sustainability is no longer a footnote on the corporate social responsibility agenda, but a topic for the board. The regulatory push for greater transparency, investors are already actively considering the climate risks when evaluating investment choices, and customers are increasingly demanding evidence — and not just a good word — that their purchases were created responsibly (Alotaibi, et al. (2024) [1]). Today's most sustainability claims are based on paper that can readily be printed, yet cannot be easily verified: self-reported emissions estimates, laminated certificates and long supply chains with so many intermediaries that no one can be certain where a raw material is coming from. This has caught the eye of sustainability practitioners outside of the fintech space as well, thanks to the automatically-enforced “smart contracts” that can be programmed to execute specific transactions upon the fulfillment of stipulated conditions. This paper examines how that attention has manifested itself in working systems and the evidence available regarding impact requirements and the

energy appetite of the technology itself. While the promise of blockchain for sustainability seems to be gaining traction, there are some practical challenges that should not be overlooked (Bhatia et al. (2025) [2]; Biswas et al. (2024). [3]).

- Energy and scalability: Despite adoption of proof of stake, networks continue to be challenged when it comes to achieving decentralisation, security and having the throughput required for enterprise level supply chain or energy trading applications.
- Unspecific legal definitions: The majority of financial and environmental regulations focus on the traditional financial securities and paper bonds, and carbon certificates are in a grey area in many jurisdictions.
- Data integrity at entry time: A blockchain can verify that the data to which it refers has not been altered after it was written, but it may not be able to verify that the data was accurate in the first place — a farmer's harvest date, a factory's emissions reading. One of the things that is underrated, like so many others, is this “garbage in, garbage out” restriction.
- The technical capacity and the budget for introducing blockchain systems are limited among small and medium sized enterprises, which constitute a significant percentage of the volume of the global supply chain, thus potentially excluding them from the benefits.
- Security and data protection concerns: When using a shared ledger for storing sensitive information like commercial or personal data, the additional security measures that need to be implemented on top of the basic protocol become a significant concern.

2. OBJECTIVES OF THE PAPER :

- (1) To examine the role of blockchain technology in promoting eco-friendly and green digital organizational transformation.
- (2) To explore blockchain applications in sustainable supply chains, carbon markets, renewable energy, circular economies, and green finance.
- (3) To analyse emerging trends in energy-efficient blockchain technologies and their integration with artificial intelligence and the Internet of Things.
- (4) To identify the environmental, technical, financial, regulatory, and organizational challenges associated with blockchain adoption in green businesses.
- (5) To suggest strategies and policy measures for sustainable and inclusive blockchain adoption, particularly among Indian green organizations and MSMEs.

3. BLOCKCHAIN IN SUSTAINABLE DEVELOPMENT :

Figure 1. How a Shared Blockchain Ledger Underpins Green Business Functions

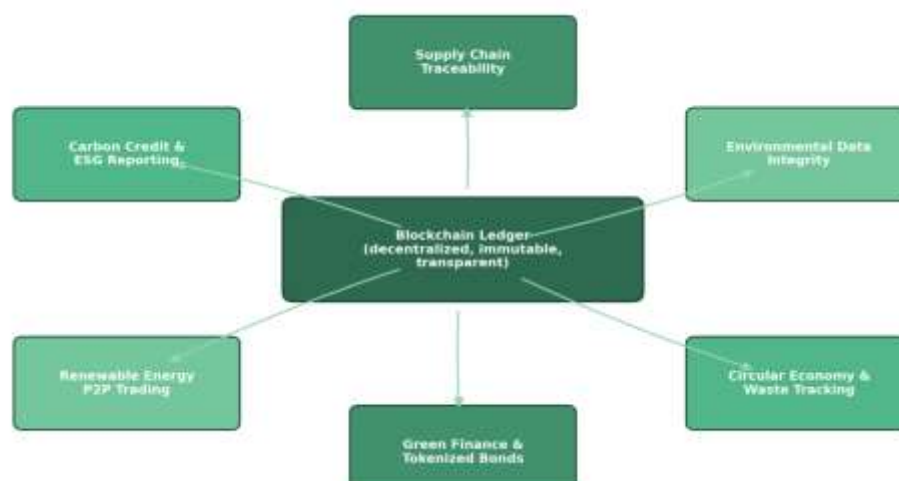


Fig. 1: A single shared ledger underpins several distinct green-business functions, from supply chain traceability to green finance.

Three conditions are crucial to sustainable business practice, and notoriously difficult to ensure at scale: certainty of what really happened, accountability (who did what?); verifiability (can the record be proved not to have been altered since its creation)? The decentralized structure of blockchain is directly

tackling these problems. Every copy of the ledger is kept on different nodes of a network and not by one company, therefore no one is able to alter the history; every transaction is cryptographically secured to the previous one, so that altering an old transaction would entail changing all following transactions, which is virtually impossible on a large enough network (refer Fig. 1). Which is always the reason technology always crops up in situations wherever sustainability matters don't initially relate to the cryptocurrency: following a bag of ground coffee beans back to a particular farm, showing that they have taken out one tonne of carbon from the air, or proving that a kilowatt-hour of electric powered has actually arrived from a rooftop solar panel and not a diesel generator (Böttcher et al., (2024). [4]). The core service blockchain serves in each instance is the same—the shared record is irrefutable, and a stranger may rely on a claim in it without relying on the other stranger. The core service blockchain serves in each case is the same: a shared record, irrefutable, with which a stranger can trust a claim without trusting the other stranger (Centobelli et al., (2021). [5]).

4. KEY APPLICATIONS IN GREEN BUSINESS :

4.1 Supply Chain Transparency and Ethical Sourcing:

The traceability properties of blockchain are the most apparent in action in supply chains. The shared ledger tracks the full journey of an item from harvest to processing to shipping to retail—companies and consumers can caption the entire lifecycle of a product without having to rely on a certificate from anywhere. Its most notable use is by retailers for tracing the origin of contaminated food products from days to seconds, a time saving that has been given special attention both from a public health perspective and in terms of food waste resulting from wide and precautionary recalls (Chen et al. (2025) [6]). Fashion and luxury brands have taken the same approach to overcome green washing and counterfeiting, with consumers being able to scan a code to check the materials used come from a lower impact certified supplier.

4.2 Carbon Credit Trading and ESG Reporting:

The challenge of voluntary carbon markets has long been a lack of credibility: the same carbon credit can be sold and reused, and it is not straightforward to determine if a carbon-removal initiative actually achieved what it claimed. By tokenizing carbon credits onto a blockchain, each credit is given a unique, traceable identity and used credit will be retired, eliminating the threat of double counting (Debut Infotech. (2025). [7]). More generally, blockchain-based ESG reporting tools enable companies to record emissions and use of resources in a way that is verifiable by regulators and auditors, without relying on trust.

4.3 Renewable Energy and Peer-to-Peer Trading:

In the energy industry, the use of blockchain has provided us with a truly novel business model: households and companies selling excess renewable energy directly to their neighbors – rather than just a utility – for energy trading as its core function. The most widely recognized example of the company is its trading platform for solar power, Power Ledger, which is a peer-to-peer tool. WePower, on the other hand, facilitates peer-to-peer solar trading between renewable-energy producers and corporate buyers, potentially making it easier to finance new wind and solar installations through tokenized power-purchase agreements before they are even built (Dorfleitner, G., et al., (2021) [8]; Al-Swidi, et al. (2024). [9]). The platforms also make it more difficult to double-sell Renewable Energy Certificates, a challenge which sometimes undermined the integrity of Renewable Energy pro-clamations in the past.

4.4 Circular Economy and Tokenized Assets:

Key to a circular economy is the knowledge of what a material is, what has happened to it, and where it is in its lifecycle — knowledge that the blockchain ledger is designed to capture. The electronics manufacturers tried blockchain tracking for e-waste, tracking the components of the device from manufacturing to end-of-life for the recycling of valuable components. In addition to tracking, tokenization enables recyclables or reusable assets to be digitally replaced by tokens that can be sold to provide a financial reward to the recyclers and reuse parties instead of just regulatory and goodwill offerings.

4.5 Green Finance and Tokenized Bonds and Green Aspects :

The impact of blockchain on green finance is certainly the most structural one. The Group of 20 has estimated the investments required by developing economies for green infrastructure will be around ninety-seven trillion dollars by 2040, which is significantly higher than the amount of money in public budgets (Al-Swidi, et al., (2024) [9]). With the introduction of “bonds as a service” on the blockchain, issuers can now compose and issue green bonds at a much lower cost than usual, while fractional tokenization makes each bond a very small unit allowing green investment to be opened to retail investors, in addition to institutions. Project Genesis at the Bank for International Settlements and Green Asset Wallet, an NGO, both illustrate this concept: a common, secure register of claims between small investors and validated green initiatives and automatic reporting of where the investment money went. This would not be a proper discussion without a discussion of the technology's own environmental history. Bitcoin and other blockchains that use the Proof-of-Work consensus, which involves different computers trying to solve energy-intensive puzzles to validate transactions, have been criticised for consuming too much electricity, some estimates ascribing the consumption to a mid-sized country. This is the paradox of ‘blockchain for sustainability’—the technology that's supposed to support sustainable information can itself be sustainable, depending on how it's designed. The industry's reaction has been generally moving towards PoS and similar consensus mechanisms, which choose validators on a basis other than consumption of computing power such as stake. Ethereum's move to Proof-of-Stake — an event widely referred to as “the Merge” — is the clearest data point: independent estimates put the resulting drop in the network's energy consumption at more than ninety-nine percent (Hong, Z., & Xiao, K. (2024). [10]). Newer networks such as Algorand, Cardano, and Solana were designed around low-energy consensus from the outset, and enterprise blockchains used for supply chain or ESG reporting typically use Proof-of-Authority, where a small number of pre-approved validators confirm transactions at a fraction of Proof-of-Work's energy cost, refer Fig. 2 (Hoque, M. M., & Lee, S.-J. (2025). [11]), (Cambridge Blockchain Network Sustainability Index: CBECI, n.d [31]; Price Waterhouse Coopers, 2023 [32]).

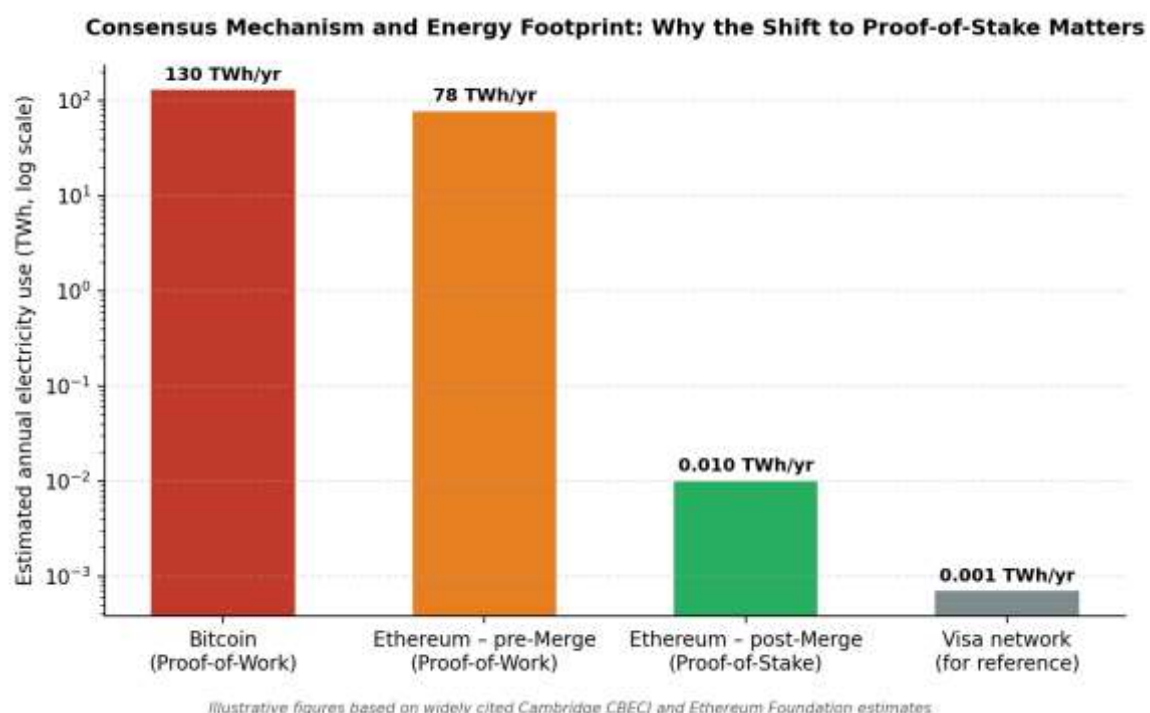


Fig 2: Estimated annual electricity consumption by consensus mechanism (log scale). The move from Proof-of-Work to Proof-of-Stake is the single largest lever for reducing blockchain's own footprint, consolidated by authors.

PwC's Blockchain Sustainability Framework, developed to help organizations quantify electricity use, emissions, e-waste, and embodied carbon across different networks, illustrates how this is being put into practice. In an assessment of the Stellar network, PwC found electricity use of roughly 481,000

kilowatt-hours per year, producing about 173,000 kilograms of carbon dioxide — comparable to the annual electricity emissions of around thirty-four U.S. homes (Kowalski et al. (2021). [12]; Lin et al. (2025). [13]). That figure gave the Stellar Development Foundation a concrete baseline from which to commit to removing its historical emissions, which is precisely the kind of accountability that climate-conscious investors and regulators, including under the European Union's MiCA regulation, are now beginning to expect as standard practice, refer Fig. 3 (Cambridge Blockchain Network Sustainability Index: CBECI, n.d [31]; Price Waterhouse Coopers (2023). [32]).

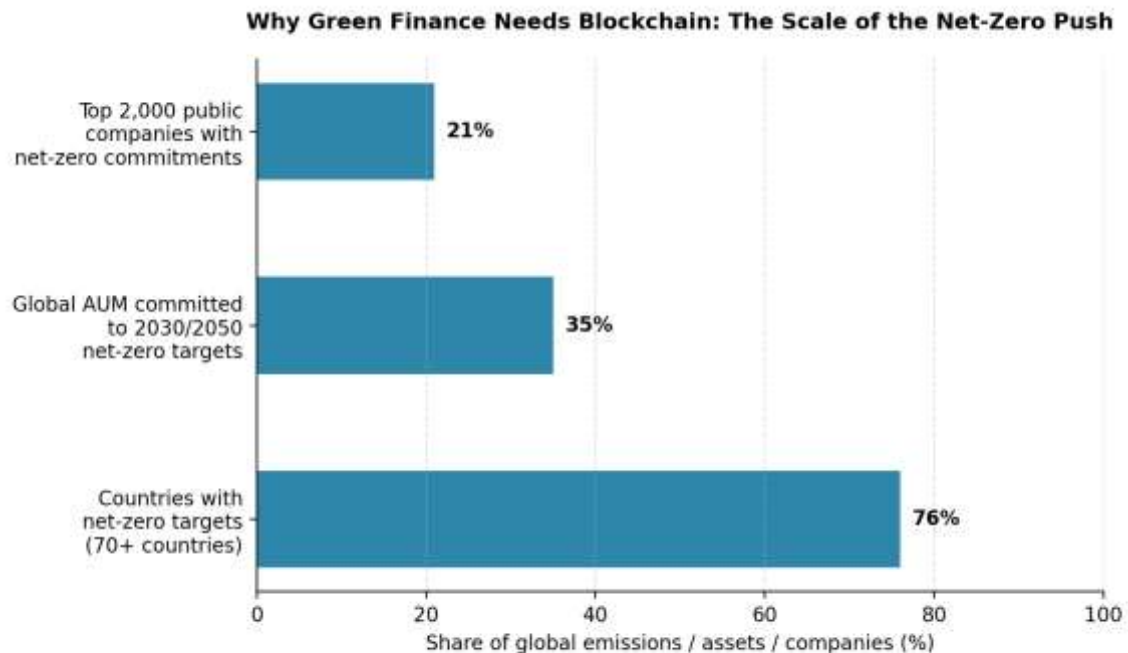


Fig. 3: The scale of global net-zero commitments across countries, asset managers, and large public companies is a major driver of demand for verifiable, blockchain-backed sustainability reporting; consolidated by authors.

5. SELECTED REAL WORLD APPLICATIONS :

The table below summarizes (Liu et. al. (2025).[14]; Naderi & Tian (2022). [15]) a cross-section of documented blockchain sustainability initiatives referenced throughout this paper, spanning energy, agriculture, finance, and network infrastructure.

Table 1: Summary of some of documented blockchain sustainability

Platform / Initiative	Sector	Green Function	Environmental Outcome
Power Ledger	Energy	Peer-to-peer trading of surplus rooftop solar between neighbours	Higher local renewable uptake; less reliance on fossil-fuel peaking plants
WePower	Energy	Tokenized power-purchase agreements linking producers and corporate buyers	Simplifies financing of new renewable-energy capacity
IBM Food Trust	Agriculture / Food	Immutable, shared ledger of a product's journey from farm to shelf	Faster contamination tracing; less food waste from blanket recalls
Project Genesis (BIS / HKMA)	Green Finance	Tokenized retail green bonds on a permissioned ledger	Wider investor access to finance for government green projects

Platform / Initiative	Sector	Green Function	Environmental Outcome
Green Asset Wallet	Green Finance	Verification and reporting platform for green-bond impact data	Greater transparency and trust in the green-debt market
KlimaDAO / Toucan Protocol	Carbon Markets	Tokenization of verified carbon credits	Reduced double-counting and fraud in voluntary carbon markets
Stellar Development Foundation	Network Infrastructure	Independent PwC assessment of network electricity use and emissions	Established a baseline for a carbon-dioxide-removal commitment

6. SUSTAINABLE GREEN BUSINESS USING INFORMATION TECHNOLOGY :

The rapid development of Information Technology (IT) has changed the way businesses create value manage resources and talk to stakeholders. At the time growing worries about the environment have made companies feel pressure to use sustainable business practices. Sustainable green business that uses Information Technology means using tools to make money while cutting down on harm to the planet and helping nature stay healthy for a long time. Recent studies keep finding that digital change is a driver of green innovation and new ways of running a business. One of the ways that Information Technology helps green business is by saving resources. Tools like cloud computing, the Internet of Things (IoT) big data analysis and smart information systems let companies watch how energy, water, raw materials, stock and waste they use. Real-time data helps companies spot waste and make production smoother. Digital change therefore lets companies create environmental value while staying competitive (Palmié et al. (2025). [16]). New evidence shows that digital change can make both better green inventions by companies.

Artificial Intelligence (AI) has made the power of Information Technology even stronger for business. AI can help forecast energy use keep machines working, run production improve supply chains and monitor the environment. New research says that using AI can push companies to make technology by encouraging research and development and helping companies use resources wisely. Other research says that AI can keep innovation going by making research stronger and by bringing in a variety of ideas. Information Technology also helps build business models. Of treating sustainability as an extra task companies can put environmental goals into their main business plans (Paul (2024). [17]). A recent review says that digital-sustainable business models are a research area where digital tools and sustainability are mixed together. Böttcher and colleagues also find types of digital sustainable business models, such as software that is green, product-service systems, sustainability intelligence and digital platforms that are green.

Another key use is for green supply-chain management. Digital tools can make tracking easier predict demand better improve logistics and watch suppliers. Blockchain, IoT and data analysis can make transparency higher. Help companies spot environmental risks in the whole supply chain. Thus, Information Technology can help cut waste move goods smarter buy responsibly and use circular-economy ideas. However, digitalisation also brings problems. Data centres, electronic gadgets, communication links and AI systems use a lot of power. Make electronic waste. Therefore, companies must do both Green IT and IT for Green. Green IT means cutting the eco-impact of technology itself while IT for Green means using tools to make other business activities more eco-friendly. In conclusion Information Technology has become a tool for green business. Digital change, AI, IoT analysis and digital platforms can help save resources, spark inventions make supply chains cleaner and build business plans that care for the planet. Yet technology alone cannot make everything green. Good rules, innovation, proper laws and company loyalty are needed (Paul, P. K. et al. (2023). [18]). The future of business depends on mixing digital change, with environmental change creating companies that are both new, competitive save resources and care for the planet.

6.1 Sustainable Green Business Using Blockchain Technology:

The rising urgency around climate change losing resources and the environment getting worse has made companies look for tools that help them be more sustainable. Blockchain technology has become a

digital choice for creating green businesses because it can offer clear information track things easily share data in a decentralised way and make sure transactions are safe. By making environmental and supply chain details more reliable blockchain can help companies include sustainability in their business activities. One of the uses of blockchain is in Green Supply Chain Management. Traditional supply chains often have issues like not having information not being able to track things well fake data and trouble checking if products and suppliers are good for the environment. Blockchain makes an hard-to-change digital record where details about where materials come from how they are made how they are moved and how they are distributed can be written down and checked. Recent studies show that using blockchain can make green supply chain methods better and help the environment improve. Blockchain can then make suppliers more responsible and push companies to use environmentally friendly ways to get materials and make things.

Blockchain also has a lot of promise for keeping track of carbon emissions and making sure companies are accountable. Businesses can put information about how energy they use how much greenhouse gases they produce, how they move things and how they deal with waste on blockchain systems. These clear records can help government officials, investors, people who buy things and others who work with the supply chain check how good a company is at being green (Paul, P. K. et al. (2023). [19]). Blockchain-based ways to track carbon can then make the reports companies give about their sustainability more trustworthy. Cut down on chances for fake claims or greenwashing. Another big use is in the economy. Circular business models try to make waste and use things again fix them improve them make them new again and recycle them. Blockchain can keep a record of where a product comes from who owns it what materials it is made of and its whole life history. This information can help track a product and make it easier to return it and recycle it. Recent studies say that blockchain can help supply chains by making it easier to share information and make circular economy methods work better. Blockchain can also help with green ideas and sustainable business methods. Smart contracts can do transactions automatically when certain environmental conditions are met. For example, money could be paid when recycled materials are proven to be delivered or when products are made in a way. Blockchain-based sharing of information can also help companies work together better and make products and processes that're better for the environment.

Even though there are these benefits blockchain is not naturally good for the environment. Some blockchain systems use a lot of power those that use energy-heavy ways to agree on information. Other problems include the cost to put it in place the hard technology to use, being able to work with systems, bad quality of data, security risks and not enough people who know how to use it. So companies should use blockchain that uses energy and combine it with other tools like the Internet of Things, artificial intelligence and clean energy systems. In the end blockchain can help make green businesses stronger by improving how supply chains work, tracking carbon making things more circular, encouraging ideas and building trust with people. The good things it brings depend on how it is used and how it is managed. Combining Blockchain with Green Supply Chains with Circular Economy with Carbon Accountability can be a way to make businesses more open use resources better and be more friendly, to the environment.

Blockchain technology has emerged as a transformative force for sustainability, offering transparency, traceability, and decentralization for green businesses. In India, where initiatives like LiFE (Lifestyle for Environment) and the National Green Hydrogen Mission are pushing corporates towards ESG compliance, blockchain is seen as an enabler for carbon credit trading, green supply chain verification, and circular economy models (PwC (2026). [20]). However, the concept is evident, while Blockchain mainly concentrates on Environmental Sustainability, its operational procedures and structural limitations will give significant challenges to Environmental friendly organizations. A technology designed to promote trust by itself becomes one of the barriers to achieving net-zero goals if it is not implemented judiciously. This examines the key issues and challenges faced by green businesses in adopting blockchain. For the green organizations, blockchains key value propositions have in three areas (Saber et al. (2019). [21]; Schulz & Feist (2021). [22]):

- Enhanced traceability of sustainable sourcing (e.g., organic cotton, recycled plastic),
- Immutable reporting for ESG and prevention of green washing, and
- Decentralized marketplaces for peer-to-peer (P2P) energy trading and carbon credits.

The conducted studies indicate that Blockchain can improve sustainability and transparency in supply chain systems; however, these are limited in terms of energy and measurability, which remain important aspects for large-scale green tech adoption.

7. MAJOR ISSUES AND CHALLENGES :

7.1 High Energy Consumption and Carbon Footprint:

The most important criticism of blockchain technology is its energy-intensive consensus mechanism. The traditional use of the Proof-of-Work (PoW) model, as used by Bitcoin, requires massive computational power. Recent research estimates that a single PoW transaction consumes the energy equivalent of many days of domestic electricity consumption. A green organization claiming carbon neutrality and deploying a PoW-based system itself is a difficult task. Although the best alternative, such as proof of stake (PoS), has reduced energy consumption by 99.95% (as claimed by Ethereum Post Merge) (Jasrotia et al., (2024). [23]; Sujee et al. (2024). [24]), many enterprises continue to work on energy-heavy models. Indian MSMEs in the green sector, which is highly cost-sensitive, have energy costs that directly reflect operational expenditure and increase Scope 2 emissions.

7.2 Scalability, Throughput and Transaction Cost:

Green businesses, especially those involved in IoT-enabled waste management, smart grids, and agro-supply chain management systems, will generate multiple huge transactions per second. Public blockchains face a scalability trilemma: balancing decentralization, security, and scalability. For example, Bitcoin processes ~7 transactions per second (TPS), and Ethereum ~15-30 TPS, compared to VISA's 24,000 TPS. This leads to network congestion and high gas fees during peak times (Uddin et al. (2021) [25]). For a small organic farmer producer organization (FPO) in Andhra Pradesh trying to record daily harvests on-chain, paying Rs. 500-1000 as transaction fee is economically unviable. This limits the inclusive potential of blockchain for grassroots green enterprises (Umar & Rana (2024). [26]).

7.3 E-Waste Generation and Hardware Obsolescence:

Less discussed but equally critical is the issue of e-waste. The PoW Mining systems requires "application specific integrated circuits" (ASICs) which have a limited lifecycle about 1.5 to 2 years. Rapid Obsolescence leads to Electronic waste generation containing hazardous materials. This will directly impacts the basic principal of a circular economy that Green Businesses advocate. The ethical life cycle of Blockchain Technology hardware is Important concern that is Often Overlooked in Sustainability discourse (Upadhyay et al. (2021). [27]).

7.4 Interoperability and Lack of Standardization:

India's green ecosystem is fragmented. A carbon credit generated in Gujarat may need to be verified on a platform used by a corporate buyer in Bengaluru, which may use a different blockchain protocol (e.g., Hyperledger Fabric vs. Polygon). Currently, there is no universal standard for sustainability data, what constitutes "green," how carbon is measured, and how it is tokenized. This lack of interoperability creates data silos. Green organizations are forced to choose a platform without clarity on long-term compatibility, leading to vendor lock-in and duplication of efforts. For regulators such as SEBI, which now mandates BRSR (Business Responsibility and Sustainability Reporting), the absence of standardized blockchain reporting formats creates audit challenges (Vasileiou et al. (2025). [28]).

7.5 Data Privacy, Security and Greenwashing Risks:

Blockchain is immutable, which is its strength and also its weakness. If erroneous or fraudulently claimed "green" data is entered at source (e.g., false organic certification), it becomes permanently recorded "Garbage In, Garbage Out" at scale. This is known as the Oracle Problem. Furthermore, while transparency is desirable, green businesses also need to protect competitive trade secrets, such as their sustainable supplier lists or proprietary low-carbon formulations. Complete transparency on a public ledger can compromise business confidentiality (Ventura et al. (2025) [29]). Balancing transparency with privacy under India's DPDP Act, 2023 is a complex legal challenge for organizations.

7.6 High Initial Implementation and Skill Gap:

Adoption of blockchain requires significant investment in infrastructure, smart contract development and change management. For Indian green startups and NGOs, the cost of hiring blockchain developers is prohibitive. Additionally, there is a lack of awareness and digital literacy among stakeholders at the bottom of the green value chain - farmers, waste pickers, Artisans (Wang et al. (2021). [33]). Without their active participation, the blockchain ledger remains incomplete. Studies on Green IoT integration highlight that organizational readiness and technical competence are major barriers to adoption in developing economies (Xue et al. (2025). [34]).

7.7 Regulatory and Ethical Uncertainties:

The regulatory landscape for blockchain, crypto-assets and tokenized carbon credits in India is still evolving. The lack of legal clarity on whether a tokenized carbon credit is a security, commodity or utility token creates compliance risks for green businesses. Ethical issues related to decentralization, who governs the chain, and concentration of power among a few validators also contradict the decentralized ethos of community based environmental movements.

8. IMPLICATIONS FOR INDIAN GREEN ORGANIZATIONS :

For Indian context, the challenges are amplified. The MSME sector contributes ~30% to GDP and is being pushed to adopt green practices. For them, blockchain should be a low-cost, low-energy, vernacular solution. Current high-tech, high-energy models are misaligned with the ground reality. There is a need for "Frugal Blockchain" - lightweight, PoS or Proof-of-Authority (PoA) based, operating on low bandwidth and mobile-first architecture. Blockchain is not a Solution for sustainability (Yoshino, N., et al., (2021) [35]; Yulianti, U. H., et al., (2026). [33]). The future lies in shifting from energy-intensive PoW to energy-efficient consensus mechanisms, developing India-specific standards for green data tokenization under the aegis of BIS and MeitY, and promoting hybrid models where only critical verification data is stored on-chain while bulk data remains off-chain. For environmentally friendly organizations, the adoption strategy should be "Sustainability First, Blockchain Second" - evaluating whether blockchain is truly needed or whether a centralized database with third-party audit can achieve the same green outcome with a lower carbon footprint.

9. CONCLUDING REMARKS :

Blockchain will not alone eradicate climate change or cause a reversal of the depletion of resources. Its role and indeed one it can accomplish and is, in the examples surveyed here, actualizing is to make it materially difficult for a company to promote a green outcome for which it has not delivered. Blockchain's impact on sustainability is all about verification and trust – from tracing a shirt back to the cotton field it came from, to making it possible for a household to sell its rooftop solar power directly to a neighbor, and to making it possible to give a retail investor confidence that their money actually reached the wind farm. It will only be those who see it as a governance and transparency instrument, not a marketing badge, that will reap the benefits of that trust to become a competitive and environmental force for good. The path that this evidence indicates is a slow, cumulative process that is not one giant leap. The energy consumption of blockchain networks is now measurably decreasing, sustainability reporting standards are increasingly referring to blockchain-verifiable data as a normal part of the business, and blockchain's combination with IoT and AI is beginning to enable sustainability metrics to be automatically captured at the source and not typed in after the fact. None of these are a silver bullet for blockchain. The value of its exists as infrastructure for trust, that is, a mechanism that makes sustainability claims verifiable and not just self-serving assertions, and that will only be as sustainable as, and useful as, the governance, regulation and honest data on which it sits.

REFERENCES :

- [1] Alotaibi, E. M., Khallaf, A., Abdallah, A. A. N., Zoubi, T., &Alnesafi, A. (2024). Blockchain-driven carbon accountability in supply chains. Sustainability, 16(24), 10872. <https://doi.org/10.3390/su162410872>
- [2] Bhatia, M. S., & Gangwani, K. K. (2025). Towards circular economy: Leveraging blockchain technology for circular supply chain. Journal of Environmental Management, 380, 125039. <https://doi.org/10.1016/j.jenvman.2025.125039>

- [3] Biswas, K., Chowdhury, M. J. M., & Usman, M. (2024). Blockchain of things: Benefits, challenges and future directions. *Sensors*, 24(3), 934. <https://doi.org/10.3390/s24030934>
- [4] Böttcher, T. P., Empelmann, S., Weking, J., Hein, A., & others. (2024). Digital sustainable business models: Using digital technology to integrate ecological sustainability into the core of business models. *Information Systems Journal*, 34(3), 736–761. <https://onlinelibrary.wiley.com/doi/abs/10.1111/isj.12436>
- [5] Centobelli, P., Cerchione, R., Del Vecchio, P., Oropallo, E., &Secundo, G. (2021). Blockchain technology for bridging trust, traceability and transparency in circular supply chain. *Information & Management*, 103508. <https://www.sciencedirect.com/science/article/pii/S0378720621000823>
- [6] Chen, L., Li, S., & She, Z. (2025). A study on the impact of artificial intelligence applications on corporate green technological innovation: A mechanism analysis from multiple perspectives. *International Review of Economics & Finance*, 103, 104490. <https://www.sciencedirect.com/science/article/pii/S1059056025006537>
- [7] Debut Infotech. (2025). Blockchain for sustainability: How green solutions are transforming the industry. <https://www.debutinfotech.com/blog/blockchain-for-sustainability>
- [8] Dorfleitner, G., Muck, F., &Scheckenbach, I. (2021). Blockchain applications for climate protection: A global empirical investigation. *Renewable and Sustainable Energy Reviews*, 149, 111378. <https://www.sciencedirect.com/science/article/pii/S1364032121006638>
- [9] Green innovation for sustainable development: Leveraging green knowledge integration, blockchain technology and green supply chain integration. (2024). *Journal of Knowledge Management*, 28(6), 1746–1770. <https://doi.org/10.1108/JKM-12-2022-0939>
- [10] Hong, Z., & Xiao, K. (2024). Digital economy structuring for sustainable development: The role of blockchain and artificial intelligence in improving supply chain and reducing negative environmental impacts. *Scientific Reports*, 14, 3912. <https://doi.org/10.1038/s41598-024-53760-3>
- [11] Hoque, M. M., & Lee, S.-J. (2025). How digital transformation drives green innovation: An empirical study. *Journal of Cleaner Production*, 522, 146236. <https://www.sciencedirect.com/science/article/pii/S0959652625015860>
- [12] Kowalski, M., Lee, Z. W. Y., & Chan, T. K. H. (2021). Blockchain technology and trust relationships in trade finance. *Technological Forecasting and Social Change*, 166, 120641. <https://www.sciencedirect.com/science/article/pii/S0040162521000731>
- [13] Lin, W. L., Yang, Y., Leow, N. X., Lim, W. M., Khee, P. C., & Yip, N. (2025). Trends in the dynamic evolution of blockchain and circular economy: A literature review and bibliometric analysis. *Business Strategy and the Environment*, 34(1), 1062–1084. <https://onlinelibrary.wiley.com/doi/abs/10.1002/bse.4027>
- [14] Liu, Y., Shen, F., Guo, J., Hu, G., & Song, Y. (2025). Can artificial intelligence technology improve companies' capacity for green innovation? Evidence from listed companies in China. *Energy Economics*, 143, 108103. <https://www.sciencedirect.com/science/article/pii/S0140988325001033>
- [15] Naderi, N., & Tian, Y. (2022). Leveraging blockchain technology and tokenizing green assets to fill the green finance gap. *Energy Research Letters*, 3(3). <https://doi.org/10.46557/001c.33907>
- [16] Palmié, M., Oghazi, P., Pashkevich, N., & Gassmann, O. (2025). Digital-sustainable business models: Definition, systematic literature review, integrative framework and research agenda from a strategic management perspective. *International Journal of Management Reviews*, 27(3), 346–374. <https://onlinelibrary.wiley.com/doi/abs/10.1111/ijmr.12380>
- [17] Paul, P. K. (2024). Blockchain technology vis-à-vis financial sector: A contemporary review & policy framework in Indian context. In R. Kaakandikar, K. Kaushik, P. Tiwari, & S. S. Ningule (Eds.), *Fintech, and Blockchains Trends in The Financial Sector* (pp. 115–131). Bentham Science Publishers. <https://www.benthamdirect.com/content/books/9789815256833.chapter-8>

- [18] Paul, P. K., Kumar, S., Aithal, P. S., & Ghosh, S. (2023). Enhancing & implementing emerging ICT in sophisticated business informatics practice for successful organizations and institutions. In P. K. Paul, S. Sharma, & E. R. Krishnan (Eds.), *Advances in Business Informatics empowered by AI & Intelligent Systems* (pp. 1–19) Book: *Advances in Business Informatics empowered by AI* CSMFL Publications. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4490900
- [19] Paul, P. K., Sharma, S., & Krishnan, E. R. (2023). Editorial: Advancing digital organizations powered by ICT & computing—A business informatics perspective. In P. K. Paul, S. Sharma, & E. R. Krishnan (Eds.), *Advances in Business Informatics empowered by AI & Intelligent Systems*. CSMFL Publications. <https://books.csmflpublications.com/9788195732203-introduction/>
- [20] PwC. (2026). Embracing sustainable innovation: Understanding the environmental impacts of blockchain technology. <https://www.pwc.com/us/en/services/digital-assets/blockchain-environmental-impact.html>
- [21] Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research*, 57(7), 2117–2135. <https://www.tandfonline.com/doi/abs/10.1080/00207543.2018.1533261>
- [22] Schulz, K., & Feist, M. (2021). Leveraging blockchain technology for innovative climate finance under the Green Climate Fund. *Earth System Governance*, 7, 100084. <https://www.sciencedirect.com/science/article/pii/S2589811620300434>
- [23] Stage-wise green supply chain management and environmental performance: Impact of blockchain technology. (2024). *International Journal of Information Management Data Insights*, 4(2), 100241. <https://doi.org/10.1016/j.jjime.2024.100241>
- [24] Sujee, S., Solanki, R., & Dalwai, T. (2024). Empowering Business Growth: Unleashing AI, IoT, and Blockchain Integration Strategies. In *International Conference on Business and Technology* (pp. 350-359). Cham: Springer Nature Switzerland. https://link.springer.com/chapter/10.1007/978-3-031-67437-2_33
- [25] Uddin, M., Khalique, A., Jumani, A. K., Ullah, S. S., & Hussain, S. (2021). Next-generation blockchain-enabled virtualized cloud security solutions: review and open challenges. *Electronics*, 10(20), 2493. <https://www.mdpi.com/2079-9292/10/20/2493>
- [26] Umar, U. S., & Rana, M. E. (2024). Cloud revolution in manufacturing: Exploring benefits, applications, and challenges in the era of digital transformation. In *2024 ASU international conference in emerging technologies for sustainability and intelligent systems (ICETSIS)* (pp. 1890-1897). IEEE. <https://ieeexplore.ieee.org/abstract/document/10459473/>
- [27] Upadhyay, A., Mukhuty, S., Kumar, V., & Kazancoglu, Y. (2021). Blockchain technology and the circular economy: Implications for sustainability and social responsibility. *Journal of cleaner production*, 293, 126130. <https://www.sciencedirect.com/science/article/pii/S0959652621003504>
- [28] Vasileiou, M., Kyrgiakos, L. S., Kleisiari, C., Lappas, P. Z., Tsinopoulos, C., Kleftodimos, G., ... & Vlontzos, G. (2025). Digital Transformation of Food Supply Chain Management Using Blockchain: A Systematic Literature Review Towards Food Safety and Traceability: M. Vasileiou et al. *Business & Information Systems Engineering*, 1-28. <https://link.springer.com/article/10.1007/s12599-025-00948-0>
- [29] Ventura, V., La Monica, M., Bortolini, M., & Cutaia, L. (2025). Blockchain and industrial symbiosis: A preliminary two-step framework to green circular supply chains. *International Journal of Environmental Science and Technology*, 22, 17–30. <https://doi.org/10.1007/s13762-024-05611-x>
- [30] Yulianti, U. H., Tanjung, Y. I., Rahardja, U., Lutfiani, N., & Valerry, A. (2026). Integration of iot and blockchain for business data security. *Blockchain Frontier Technology*, 6(1), 62-73. <https://journal.pandawan.id/b-front/article/view/1040>

- [31] Cambridge Blockchain Network Sustainability Index: CBECI. (n.d).
https://ccaf.io/cbsi/cbeci?utm_source=chatgpt.com
- [32] Price Waterhouse Coopers (2023). Net Zero Economy Index: The Pivotal Decade. PwC.
<https://www.pwc.co.uk/services/sustainability-climate-change/insights/net-zero-economy-index.html>
- [33] Wang, L., Luo, X., Lee, F., & Benitez, J. (2021). Value creation in blockchain-driven supply chain finance. Information & Management, 2021, 103510.
<https://www.sciencedirect.com/science/article/pii/S0378720621000847>
- [34] Xue, J., Li, G., & Ivanov, D. (2025). Digital transformation in the blockchain era: Balancing efficiency and resilience in operations management. International Journal of Production Economics, 282, 109525. <https://www.sciencedirect.com/science/article/pii/S0925527325000106>
- [35] Yoshino, N., Schloesser, T., & Taghizadeh-Hesary, F. (2021). Social funding of green financing: An application of distributed ledger technologies. International Journal of Finance & Economics, 26(4), 6060–6073. <https://onlinelibrary.wiley.com/doi/abs/10.1002/ijfe.2108>
