International Journal of Basic and Applied Sciences, 14 (8) (2025) 717-722

International Journal of Basic and Applied Sciences

Website: www.sciencepubco.com/index.php/IJBAS
https://doi.org/10.14419/x3h64t90
Research paper

Sustainable AI and Blockchain: Optimizing Energy Efficiency in Data Engineering Infrastructure

Bhumika Shah *

University of the Cumberlands
**Corresponding author E-mail: bhumishah000.bs@gmail.com*

Abstract

The societal perspectives on energy use and sustainability are further complicated by incredible advancements in systems that inform through data-intensive information engineering. Artificial Intelligence (AI) provides data-rich capability in data-rich environments, while the energy system uses much less energy in aggregate as an energy system comparable to blockchain applications. As predictive and adaptive intelligence has proven to be more efficient, energy utilization is also evolving in AI and its resource and data management ecologies. The decentralized elements, such as openness and security of blockchain applications, also greatly add to contact reliability of the energy operative performance of the entire ecosystem by reducing wasted and/or non-usage of energy and/or other resource domains through information engineering systems. The current use of smart grids as important for smart grids considering edge computing/applications and thermal fluid systems applications for city microclimate controls for developing economies is included and analyzed. The paper is a thoroughly informative presentation of smart cities with AI, blockchain technology, and sustainable resource consumption and use, based on emergent literature to communicate meaningful contributions to the discourse area.

Keywords: *AI-Driven Energy Optimization; Blockchain-Based Sustainability; Green Data Engineering; Decentralized Infrastructure.*

1. Introduction

As globalization progresses around the world, the trend of increasing energy use for the luxury of data engineering also progresses. The carbon footprint created by these new emerging technologies, Artificial Intelligence (AI) and Blockchain technologies, has a very high carbon footprint. AI and Blockchain technologies centered around sustainability are a shift from the original consumption of data systems leveraging data to reducing energy consumption in data engineering. These technologies create efficiencies in data consumption in data centers, regenerate energy produced and consumed, make more intelligent distributions of energy, and create decentralized energy management systems aligned with global sustainability initiatives.

Although AI is part of smart automation, regardless of the right to make decisions, blockchain will act as a source of transparency, traceability, and immutability that one will be compelled to follow and monitor in energy flows. The convergence of all these technologies combined as energy-intensive data infrastructures would raise sustainable systems that have the ability to self-optimize and respond to change. This paper's primary contribution lies in presenting a structured synthesis that integrates AI-driven optimization and blockchain-enabled decentralization into a unified analytical framework for sustainable data engineering infrastructures. By examining cross-domain applications—including smart grids, edge computing, thermal management, cybersecurity, and technical education—the manuscript moves beyond descriptive review and offers conceptual integration with attention to architectural trade-offs and infrastructure-level energy implications.

1.1. Research methodology

This study adopts a structured narrative literature review approach to examine the intersection of artificial intelligence (AI), blockchain technology, and energy-efficient data engineering infrastructure. Although the paper is conceptual in orientation, the literature review was conducted systematically to ensure academic rigor and comprehensiveness.

The literature search was performed across major scientific databases including IEEE Xplore, ScienceDirect, SpringerLink, ACM Digital Library, Web of Science, and Google Scholar. These databases were selected due to their extensive coverage of peer-reviewed research in computer science, energy systems, sustainability, and information engineering. The primary search period covered publications from 2018 to 2025, reflecting the most recent advancements in sustainable AI, green computing, blockchain integration, and smart grid technologies. Search keywords included combinations of:

- "Sustainable AI"
- "Green Artificial Intelligence"
- "Blockchain energy efficiency"
- "Smart grids and AI"

- "Decentralized energy systems"
- "Edge computing sustainability"
- "Thermal management in data centers"
- "AI-driven energy optimization"
- "Blockchain-based sustainability frameworks"

Boolean operators (AND, OR) were used to refine results, and duplicate entries were removed during screening.
Inclusion Criteria

- Peer-reviewed journal articles
- Publications focusing on energy efficiency, sustainability, AI optimization, or blockchain-based infrastructure
- Studies presenting empirical, experimental, simulation-based, or theoretical frameworks
- Research directly applicable to data engineering, smart grids, or energy systems

Exclusion Criteria

- Non-peer-reviewed blogs or opinion pieces
- Studies without clear methodological grounding
- Research unrelated to energy optimization or sustainable computing

A total of approximately 165 publications were initially identified. After title and abstract screening, 73 papers were shortlisted for full-text evaluation. Ultimately, 41 high-quality sources were selected to inform the conceptual synthesis presented in this paper.
The review emphasizes integration and synthesis rather than meta-analysis. While quantitative comparison across studies is discussed where available, the primary objective is to conceptualize a unified framework that integrates AI-driven optimization and blockchain-based decentralization for sustainable data engineering infrastructures.

2. Sustainable Data Infrastructures through AI and Blockchain Integration

The improvement of energy requirements among the most critical data engineering problems should be mentioned since data and computing operations are becoming more interdependent. Conventional centralized systems cannot be highly scalable and flexible enough to meet real-time energy management demands. Conversely, AI systems on blockchain offer the perspective of a distributed model, which has the features of autonomous monitoring and controlling the power consumption of data infrastructure.
Singh et al. (2025) propose a blockchain-integrated AI framework for smart grids in which machine learning models perform predictive load balancing while blockchain-based smart contracts ensure decentralized validation of energy transactions. Their empirical evaluation demonstrates improved demand-response coordination and measurable reductions in grid inefficiencies compared to conventional centralized management approaches [1]. This evidence-based integration illustrates how AI-driven optimization and blockchain-enabled verification can jointly address energy wastage within digital infrastructure systems.
Decentralized edge computing can reduce network transmission energy by processing data closer to the source, with distributed AI frameworks reporting reductions in transmission energy of up to 30% compared to fully centralized architectures (Sultana et al., 2025). However, decentralized systems may operate at lower hardware utilization efficiency than hyperscale cloud data centers, which typically achieve Power Usage Effectiveness (PUE) values near 1.1–1.2. Additionally, blockchain-based validation introduces computational overhead depending on the consensus mechanism employed. Therefore, the sustainability advantage of AI–blockchain integration depends not merely on decentralization, but on optimized workload distribution, lightweight consensus protocols, and lifecycle energy assessment [2].
Moreover, blockchain will create an energy consumption audit trail between edge nodes that cannot be altered. The dynamics of the workload can also be traced with the implementation of AI in such nodes, allowing them to respond by fully allocating resources dynamically. The design promotes the principles of green computing that should lead to a self-governing computing system in which energy leakages are minimized and computational capabilities are maximized to an optimum level [2].

3. Enhancing Energy Efficiency with Green AI

Another goal of Green AI is the design and implementation of energy-efficient and environmentally friendly AI models. General deep learning models lack scalability with regard to training and inference. Nonetheless, Green AI projects support the creation of light and energy-sensitive algorithms that are fast and less power-consuming.
The carbon footprint of data-driven systems can also be reduced according to Green AI, which enables algorithms to make energy-conscious decisions at the algorithmic level. Additional optimizations include model pruning, knowledge distillation, and quantization, which simplify and reduce the size of models. These techniques are also significant in reducing the energy used in inference, excluding training [3].
Intelligent workload allocation schemes are also considered part of Green Artificial Intelligence. One of them involves renewable sources of energy, whereby the availability of renewable energy is utilized in the allocation of computation jobs through energy-conscious scheduling tools that minimize energy consumption in data centers. Blockchain will enhance this practice since it will be able to offer a secure platform through which the authenticity of energy credits and the assurance that all systems are running on green energy can be determined [3].

4. Urban Microclimate Management with Energy-Efficient Infrastructures

The management of microclimates is also problematic, and a specificity of cities is connected to the large-scale construction of infrastructures and the efforts toward increased energy consumption as urbanization advances. Smarter urban environments should provide technologies that would not only make the energy-saving process easier but also dynamic to environmental changes. It has suggested the implementation of a new collection of IoT and AI that operate on blockchain-based energy in an attempt to deal with these urban issues by ensuring the sustainability of the microclimate.
The role of AI within the framework of the city environment is not only important in the overall analysis of environmental data and the prediction of weather trends but also in isolated real-time adaptive responses. Along with blockchain, this kind of AI system receives an opportunity to store and demonstrate environmental data safely, which guarantees the accuracy and reliability of responses in the

information base. The sensors, AI programs, and validation systems will be integrated into a robust network that will have blockchain-based verification systems and AI programs and will be able to independently manage the climate [4].
The smart ventilators of buildings could be controlled with the assistance of AI-based models in cases where information concerning temperature, humidity, and air conditions can be analyzed. The information they provide undergoes verification and is embedded in blockchain through which HVAC systems are managed decently and correctly. This saves energy wastage and even renders urban habitats thermally comfortable [4].
AI, blockchain, and IoT can be combined to create sustainable management of the urban microclimate, as shown in Figure 1.

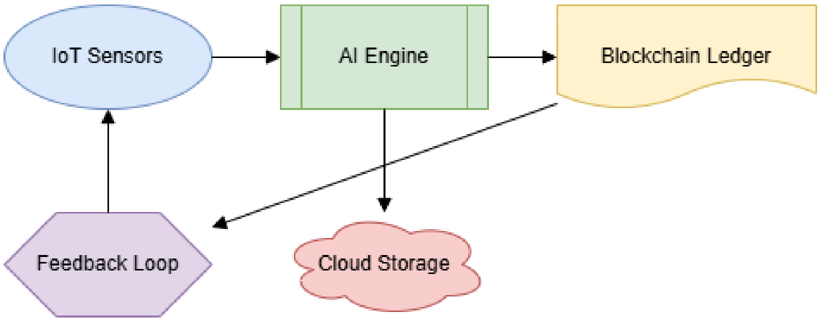

Fig. 1: Conceptual Architecture of AI–Blockchain Integration for Urban Microclimate Management, Illustrating IoT Sensor Inputs, AI-Based Environmental Prediction, and Blockchain-Enabled Data Verification for Adaptive Climate Control.

Source: [4]

5. Blockchain and AI in Thermal Fluid Systems and Energy Conservation

Thermal fluid systems are a very necessary component of massive data centers and industrial power systems. The cooling system is directly dependent on the amount of energy used and the lifecycle of the systems. Thermal systems, with the help of AI, help to forecast maintenance, live control of temperature, and energy control based on work trends.
This would also be an area where blockchain would find its applications, as it would mean decentralized power and thermal documents that can never be broken. This will define the kind of thermal control procedures that will be adhered to at the point and mitigate inefficiency with manual operations. The idea behind AI-controlled thermal fluids, in this case, is that previous data are considered to predict thermal loads and automate cooling systems in a manner that they do not overcool and consume as much energy as possible [5].
Moreover, the data engineering environment has thermal sensors, and the sensors constantly provide the AI models in the environment with data to enable them to examine trends and abnormalities. Its smart contract blockchain is used to guarantee the same level of thermal stability and energy usage and to activate cooling settings automatically or inform about maintenance. The systems help minimize downtime and operational costs in high-performance computing systems considerably [5].

6. Sustainable Cybersecurity in Data Centers

Since the networks within data centers have grown to be highly intricate and energy-consuming, the necessity to ensure that energy-sensitive cybersecurity solutions are in effect has taken precedence. The attributes of cybersecurity infrastructures are that, in most cases, they comprise a huge volume of computation capable of overwhelming energy infrastructures. Nevertheless, AI models developed with sustainability in mind and focused on cybersecurity will be able to support human beings in both forms: safe data infrastructure and energy consumption optimization.
The AI architectures that are to ensure cybersecurity are based on lightweight encryption, real-time identification, and effective authentication. These models are expected to be instigated with a bare minimum presumption of computational background for the energy commitment allowed to security endeavors. Pattern recognition could help recognize malicious intent such as DDoS attacks or unauthorized access to the system by AI and can also perform the exercise without engaging in power-intensive optimization [6].
Blockchain is an appendix to these systems which keep logs and history of use that is kept in an unchangeable registry. This makes it accountable and traceable for the cyber defense systems lacking centralized monitoring systems, which more likely would be a bottleneck of energy. In a highly decentralized type of environment, block nodes validation and security are conducted without a two-way validation, and in this case, the distribution of energy load is less lopsided [6].

Table 1: Comparative Framework of AI and Blockchain in Sustainable Data Infrastructure

Technology / Architecture	Primary Energy Benefit	Key Energy Overhead	Sustainability Trade-off	Suitable Context
AI (Centralized Training)	Improved demand prediction; optimized resource allocation	High training energy consumption; GPU-intensive workloads	Long-term operational savings vs short-term training cost	Large-scale analytics, smart grids
AI (Edge-Based Processing)	Reduced transmission energy; lower latency	Lower hardware utilization; distributed compute redundancy	Transmission savings vs infrastructure duplication	IoT systems, microgrids
Blockchain (Proof-of-Work)	Strong decentralization and security	Extremely high computational energy use	Maximum security vs environmental cost	Public cryptocurrency networks
Blockchain (Proof-of-Stake / Permissioned)	Decentralized validation with low energy usage	Governance centralization risks	Reduced energy cost vs reduced openness	Enterprise smart grids, IoT systems
Centralized Cloud Infrastructure	High hardware utilization; optimized PUE (≈1.1–1.2)	Data transmission energy; central bottlenecks	Efficiency of scale vs latency and trust concerns	Hyperscale data centers
Decentralized AI–Blockchain Integration	Transparency + adaptive optimization	Consensus overhead + distributed compute energy	Governance transparency vs computational duplication	Smart grids, distributed energy markets

7. AI Optimization in Data Engineering Workflows

The related process that entails the element of data acquirement, data pre-processing, data transformation and data storing comes under the categorization of the data engineering process, and this is a resource-consuming process in nature. The introduction of AI has automated all these processes and has made them more accurate, albeit introducing an issue of consuming more computational power. Such is the goal of AI-data engineering optimization — to simplify the procedures through intelligent coordination and resource allocation and minimize energy wastage.

Dynamic optimization of ETL (Extract, Transform, Load) is also one of the applications of AI in the field. The processes are also applicable to large-scale clusters, and they can be energy-intensive in cases where they are not well planned. The type of artificial intelligence applicable is to research the trends of the workloads over time and identify the optimal time to execute the tasks based on the cost of power, the load of the servers, and the availability of renewable sources of power [7].

Secondly, AI decreases the data being transmitted or stored, whereby the data is decreased before it is transferred or stored; hence, it decreases the magnitude of energy utilized in sending or storage. Proactive scaling of the infrastructure may also be done through predictive modeling, whereby the computing resources would not be issued unless they are utilized. A blockchain-compatible version of such an infrastructure is able to provide decentralized information provenance, eliminate the redundancy of processing work, and make computing more viable [7].

8. Smart Grid Transformation through AI and Blockchain

The combination of AI and blockchain is what will provide the further transformation of traditional electrical grids to become intelligent, autonomous, and sustainable systems. The smart grids and intelligent systems should be able to observe and regulate the energy flows in real time to prevent wastage of energy and to increase the resilience and adaptability of renewable energy outlets such as solar or wind energy.

AI may also take a significant role regarding the requirement of energy prediction, anomaly alerts, and automation of energy distribution. Machine learning models can be fed with consumption history, weather patterns, and past usage to make highly accurate predictions of what the energy demand would be. Such estimates help in better planning of generation and distribution, and less power is produced as wastage is reduced [8].

This is complemented with blockchain, which will give an explicit and secure view of all energy transactions. Blockchain is one such solution in which the amount of energy generated, used, and stored within the system is recorded in a decentralized system that does not require a central organization in the smart grid. This enables the prosumers (producing and consuming energy) to engage in peer-to-peer energy exchange and, therefore, optimize the energy balance within the locality and reduce transmission loss [8].

9. Data-Driven Energy Efficiency and Future Trends

Big data analytics and AI-blockchain technology lead to the creation of data-driven energy efficiency frameworks. The information generated by operating these systems is so abundant that it can ascertain trends, inefficiencies, and opportunities for streamlining various industries such as manufacturing, transportation, and infrastructure.

Comparative analysis within the literature reveals important distinctions in energy overheads across technologies. AI systems primarily consume energy during model training and large-scale inference, whereas blockchain energy costs are largely determined by the consensus mechanism employed. Proof-of-Work (PoW) architectures are widely recognized as energy-intensive, while Proof-of-Stake (PoS) and permissioned blockchain frameworks reduce energy consumption by several orders of magnitude (Tiwari & Tyagi, 2025). Similarly, centralized hyperscale cloud infrastructures often achieve high hardware utilization and optimized Power Usage Effectiveness (PUE), whereas edge-based AI processing reduces transmission energy and latency but may operate with lower utilization efficiency. These comparisons indicate that sustainability outcomes depend not on the technologies themselves, but on implementation design and architectural trade-offs [9], [10].

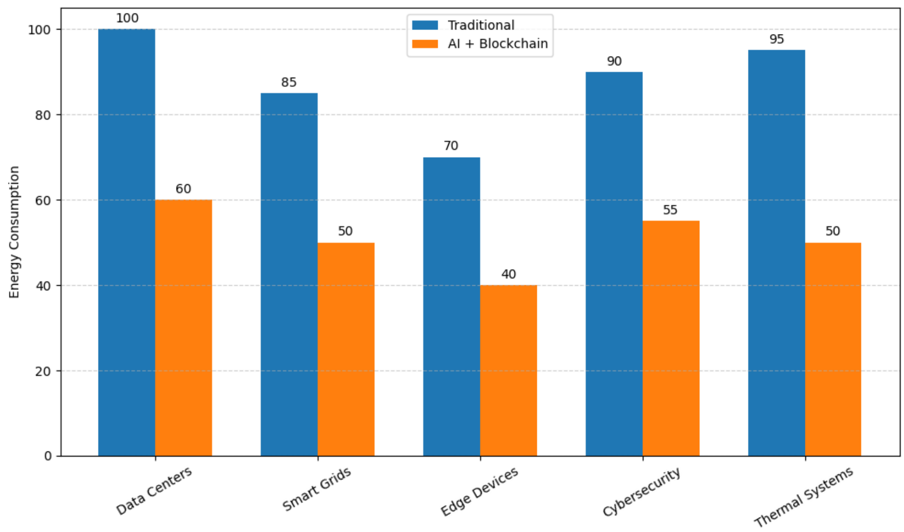

Fig. 2: Comparative Illustration of Estimated Energy Consumption Reductions Across Key Infrastructure Components When AI-Driven Optimization and Blockchain-Based Validation Mechanisms Are Implemented, Relative to Conventional Centralized Systems.

Figure 2 illustrates the comparative reduction in energy consumption across key infrastructure components when using AI and blockchain integration versus traditional systems.

Future developments in sustainable AI–blockchain infrastructures can be categorized according to technical maturity and implementation feasibility. In the short term, engineering-focused solutions such as Green AI model optimization, federated and edge learning deployment, and blockchain-enabled energy auditing systems are immediately actionable within existing infrastructure constraints. In contrast, long-term research challenges include large-scale decentralized energy governance models, quantum-assisted optimization, and globally interoperable blockchain frameworks for cross-border energy markets, all of which require regulatory alignment, infrastructure redesign, and broader policy coordination. Distinguishing between near-term engineering implementation and long-term systemic transformation enables a more realistic roadmap for sustainable digital infrastructure development [9], [10].

10. Technical Foundations and Applications in Smart Grids

To obtain the perspective of the underlying architecture that can support sustainable AI and blockchain applications, i.e., in smart grids, the technical methods will be taken into account. It is based on layered structures, which ensure modularity, scalability, and resilience. These are claimed to be energy-efficient architectures and never secondary.

The built smart grid systems with layered data engineering models adopt the planning of the use of AI to maximize energy among the different levels that encompass the stages of data collection, analysis, decision-making, and actuation. The two significant attributes of blockchain use are the degree of integrity of data and verification of transactions. They can build a group in order to create a guarded and responsive system that is dynamically adapted to energy requirements and supply [10].

Another similarity of such applications is that they apply federated learning and distributed instances of AI models in which the end devices can potentially have the capacity to train local models without transferring the raw data to central servers. This will conserve a lot of network traffic and the energy used in the same. The blockchain-coordinated model is synchronized by the consensus mechanism in a bid to provide trust without overwhelming the computing resource system [10].

Otherwise, some of the uses of these technologies are demand-side energy management, dynamic pricing mechanisms, fault detection of the distribution networks, and the integration of distributed energy resources. The positive aspect of this type of system is that it is dynamic, which is an important factor in managing greater complexity and decentralization of the modern-day energy system [10].

11. Building Sustainable and Secure Ecosystems

The issue of maintenance of alignment and security alignment is extremely acute with respect to remotely designed digital ecosystems. There is also a rise in energy requirements and the attack surface as the data engineering architecture expands. AI and blockchain implementation will be one of the possible solutions for safe systems that are also not energy-consuming.

AI has been employed to minimize vulnerabilities and counter adversarial measures, though blockchain does not allow altering the system in any way since it is secure and audit-trailed. These properties allow the development of robust security structures without intrusive research, which can take excessive power or human real-time monitoring. They are independent systems instead and perform certified tasks according to real-time threat assessment [11].

In their turn, AI and blockchain will be able to create sustainability, security, and adaptability of ecosystems, along with their intelligibility. They can be readily incorporated so that it becomes convenient to design infrastructures with a view of the ever-changing environmental, economic, and technological environments [11].

12. AI and Data Engineering in Sustainable Technical Education

The substantial input into the process of realizing sustainable digital transformation is currently in progress within technical education institutions, which presupposes the incorporation of Artificial Intelligence (AI) and Data Engineering into the curriculum and institutional practices. By introducing AI-based systems to the learning environment, the system will not only contribute to improving learning outcomes, but it will also assist in achieving sustainability — i.e., the maximization of resources and energy use in technical and vocational education and training (TVET) systems.

Smart building infrastructure also involves the use of AI algorithms that manage lighting, air conditioning, and computer facilities depending on usage patterns. These intelligent systems can process real-time information collected from devices and sensors and dynamically manipulate the functions in a way that leads to the reduction of unnecessary energy consumption. Data engineering helps the systems organize, clean, and compute gathered data and navigate it to train AI models based on what the data of interest needs to be valuable and of high quality to make more efficient decisions [12].

Furthermore, organizations are also shifting to the usage of electronic resources, which are not associated with printed materials and physical units, at educational locations as well. The ultimate result of AI in saving institutional computing resources is its ability to customize student learning paths to minimize redundant course activities and optimize learning delivery. When such individualized learning takes place, it decreases the power consumption of devices and servers, particularly in situations where platforms are deployed in cloud-based and AI-driven environments [12].

Development also involves the incorporation of sustainable technologies in curriculum development. Since the TVET curriculum has incorporated AI and data engineering, learning institutions are educating their students on how to design and operate in a green digital ecosystem. This, besides making the education sector cleaner and greener, also indicates that the sector now has personnel equipped to implement sustainability solutions in industries [12].

Additionally, education credentialing is starting to be utilized in blockchain technology that potentially could solve some administrative problems and maintain a transparent and tamper-proof record. Artificial Intelligence is going to support and enable predictive student analytics, resource planning, and institutional analytics for progress toward performance analytics, as well as intelligent design that is energy-efficient [12]-[13].

Furthermore, the relationship between artificial intelligence and the engineering of education in technical education is a major opportunity for achieving sustainability; education should model responsible energy consumption and innovations in sustainability to their students by modeling the use of new technologies and practices.

13. Conclusion

The fusion of artificial intelligence (AI) and blockchain technology holds promise in being an exciting area of capability with respect to sustainable and resilient infrastructures for data engineering. The integration of AI-driven optimization and blockchain-based decentralization provides not only a technological advancement but also a governance-oriented framework capable of enhancing energy accountability, strengthening environmental resilience, and informing sustainable policy design within data-intensive infrastructures. The collision of AI and blockchain also refers to the potential of the combination of the underlying technologies to improve smart grids, optimize thermal or edge computing, or enhance operational transparency for use in cybersecurity in a resilient, scalable green digital ecosystem.
Although AI-based services are fast becoming the norm, it becomes even more critical to understand how to define such services from the issue of sustainability we identified. The more general issues of epistemology and practice, related in varying degrees to concerns regarding sustainability design and implementation, highlight the need for energy-environmentally responsible design approaches, regardless of how significant the technological advances, in any regard of decentralized control. AI and blockchain, in addition to creating resilient or smart infrastructure, must also be a cog in a system's response toward more sustainable digital ecosystems.

References

[1] Singh, K., Goyal, S.B., Rajawat, A.S. and Waked, H.N. (2025) 'A blockchain-integrated AI framework for enhancing energy efficiency and sustainability in smart grids', Procedia Computer Science, 258, pp. 2302–2311. https://doi.org/10.1016/j.procs.2025.04.485

[2] Sultana, K.S., Begum, M., Abed, J., Siam, M.A., Sadnan, G.A., Shatyi, S.S. and Billah, M. (2025) 'Blockchain-based green edge computing: Optimizing energy efficiency with decentralized AI frameworks', Journal of Computer Science and Technology Studies, 7(1), pp. 386–408. https://doi.org/10.32996/jcsts.2025.7.1.29.

[3] Dash, S. (2025) 'Green AI: Enhancing sustainability and energy efficiency in AI-integrated enterprise systems', IEEE Access. https://doi.org/10.1109/ACCESS.2025.3532838.

[4] Krishnaraj, N., Alsolai, H., Al-Wesabi, F.N., Said, Y., Alqazzaz, A., Priya, S.G. et al. (2025) 'Energy-efficient blockchain-integrated IoT and AI framework for sustainable urban microclimate management', Sustainable Computing: Informatics and Systems, Article 101137. https://doi.org/10.1016/j.suscom.2025.101137.

[5] Khan, A.A., Laghari, A.A., Inam, S.A., Ullah, S. and Nadeem, L. (2025) 'A review on artificial intelligence thermal fluids and the integration of energy conservation with blockchain technology', Discover Sustainability, 6(1), pp. 1–18. https://doi.org/10.1007/s43621-025-01124-w.

[6] Karamchand, G. (2025) 'Sustainable cybersecurity: Green AI models for securing data center infrastructure', International Journal of Humanities and Information Technology, 7(02), pp. 06–16.

[7] Jonnalagadda, A.K., Dutta, K.P., Ranjan, P. and Myakala, P.K. (2025) 'AI and optimization: Transforming data engineering applications', in Recent Advances in Artificial Intelligence for Sustainable Development (RAISD 2025), pp. 686–702. Atlantis Press. https://doi.org/10.2991/978-94-6463-787-8_52.

[8] Rajaperumal, T.A. and Columbus, C.C. (2025) 'Transforming the electrical grid: The role of AI in advancing smart, sustainable, and secure energy systems', Energy Informatics, 8(1), Article 51. https://doi.org/10.1186/s42162-024-00461-w.

[9] Joshua, C. and Jide, M. (2025) 'Future trends in data-driven energy efficiency solutions'.

[10] Tiwari, S. and Tyagi, A.K. (eds.) (2025) AI and Blockchain in Smart Grids: Fundamentals, Methods, and Applications. CRC Press. https://doi.org/10.1201/9781003500391.

[11] Sahana, B., Rai, P., Chickmath, P.V., Karthik, P.K., Malvi, N.B. and Prabhakar, D. (2025) 'Synergizing AI and blockchain: Building secure and sustainable digital ecosystems', in Sustainable Information Security in the Age of AI and Green Computing, pp. 271–294. IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3693-8034-5.ch014.

[12] Reddy, K.J. and Pamaiahgari, V.P.R. (2025) 'AI and data engineering transforming technical education for sustainability', in Integrating AI and Sustainability in Technical and Vocational Education and Training (TVET), pp. 83–100. IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3373-1142-5.ch004.

[13] Kumar, P. (2025) 'Securing digital-first healthcare: AI, blockchain, and cloud architectures for personal health data protection', Internatinal Journal of Applied Mathematics, 38(7s). https://doi.org/10.12732/ijam.v38i7s.526.