AI-POWERED CRYPTOCURRENCIES AND SUSTAINABILITY: THE ROLE OF INTELLIGENT BLOCKCHAINS IN GREEN TECHNOLOGY DEVELOPMENT

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The convergence of artificial intelligence (AI) and blockchain is fostering the emergence of AI-powered cryptocurrencies, which offer sustainable alternatives to energy-intensive digital finance systems. This paper examines how AI supports the environmental, social, and governance (ESG) performance of blockchain ecosystems. AI integration enables the use of energyefficient consensus mechanisms, improves decentralized finance operations, and facilitates ESG compliance. Projects like Render Network, Fetch.ai, and Ocean Protocol illustrate how AI can increase data processing efficiency, minimize redundant computation, and promote carbon-neutral tokenomics. These platforms support smarter asset distribution through decentralized data marketplaces and machine learning applications. The research methodology involves a review of academic literature, analysis of market statistics, and energy consumption data comparison. The results demonstrate that AIpowered cryptocurrencies can achieve significant energy savings-up to 35% compared to centralized systems-and exhibit strong market growth, with their total capitalization rising more than tenfold between 2021 and 2024. The findings suggest that AI-enhanced blockchain technologies play an essential role in advancing sustainability in digital finance. This study provides guidance for regulators, developers, and investors aiming to align blockchain innovation with green technology principles and responsible market practices.

DOI https://doi.org/ <u>10,18690/um.epf.5.</u>2025.20

> ISBN 978-961-286-984-7

> > Keywords:

AI-powered cryptocurrencies, blockchain sustainability, energy efficiency, decentralized finance, ESG (Environmental, Social, and Governance)

> JEL: G15, Q56,



1 Introduction

The integration of blockchain technology and artificial intelligence (AI) is driving innovation in the digital economy by creating systems that are not only decentralized but also more sustainable. AI-powered cryptocurrencies enable the automation of complex data processes, improve energy efficiency, and support decentralized data marketplaces. These capabilities make them viable alternatives to traditional centralized digital infrastructures, which are often associated with high energy consumption and inefficiency (Kapitonov et al., 2022). Proof-of-Work (PoW)-based cryptocurrencies, such as Bitcoin, have raised serious environmental concerns due to their excessive electricity usage and carbon footprint (Jones et al., 2024). In contrast, emerging AI-supported blockchain solutions leverage alternative consensus mechanisms and intelligent resource allocation to reduce these negative impacts. Projects such as Ocean Protocol and Fetch.ai have shown that decentralized systems powered by AI can enhance computational efficiency and data processing, while also contributing to environmental goals (Aslam et al., 2023). The aim of this study is to explore how AI contributes to the sustainability of blockchain ecosystems, with a focus on improving energy efficiency, optimizing data flow, and supporting compliance with Environmental, Social, and Governance (ESG) standards. The paper positions these technologies within the broader context of sustainable digital transformation (Kumar & Tripathi, 2024).

2 Theoretical background

Blockchain technology relies on decentralized, distributed databases that ensure secure and transparent digital transactions without the need for centralized intermediaries (Nakamoto, 2008). Its cryptographic consensus mechanisms and immutable ledger structure have made it a key innovation in digital trust systems. However, despite these advantages, blockchain—particularly systems operating on Proof-of-Work (PoW) algorithms like Bitcoin—has been widely criticized for its excessive energy demands, as the validation process requires vast amounts of computational power and electricity (Sedlmeir et al., 2020; Sallay & Csiszárik-Kocsir, 2024). While alternative consensus models such as Proof-of-Stake (PoS) have emerged to reduce energy use, they do not fully resolve the broader challenges of sustainable computation, especially as blockchain applications expand beyond finance into areas such as logistics, health care, and smart infrastructure

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(Cheikosman & Mulligan, 2023). In this context, recent theoretical and applied developments suggest that artificial intelligence (AI) offers a promising avenue for improving the environmental and operational efficiency of blockchain systems. AI technologies can optimize consensus protocols, predict and allocate computational loads more efficiently, and dynamically manage energy distribution across nodes, thus reducing system-wide consumption. In particular, AI can be used to enhance real-time decision-making in decentralized applications and to facilitate selfadjusting system behavior, allowing blockchain networks to adapt to changing environmental or operational conditions (Xiong et al., 2023). Examples such as Ocean Protocol and Fetch.ai illustrate how decentralized AI-powered data marketplaces reduce duplication, lower storage and transmission needs, and support efficient machine-to-machine communication (CoinMarketCap, 2024). Render Network, by distributing GPU power through a decentralized architecture, enhances rendering efficiency and minimizes energy waste in AI-intensive tasks. The potential of such integrations is increasingly supported by regulatory developments. Frameworks like the European Union's Markets in Crypto-Assets (MiCA) regulation mandate ESG-related disclosures and encourage the adoption of sustainable technologies, pushing blockchain development toward more transparent and accountable operational models (European Union, 2023). The convergence of AI and blockchain is therefore not only technologically feasible but increasingly necessary to align innovation with environmental, regulatory, and societal expectations.

3 Methodology

This study investigates how the integration of artificial intelligence (AI) enhances the sustainability of blockchain-based financial systems. The research methodology is based on a structured combination of qualitative and quantitative approaches, including a systematic literature review, statistical analysis of market data, and energy efficiency comparisons.

First, a structured literature review was conducted using academic databases such as Scopus, Web of Science, IEEE Xplore, and ScienceDirect. We applied a keyworddriven search strategy using terms like "AI-powered cryptocurrencies," "blockchain sustainability," and "ESG compliance," focusing on peer-reviewed English-language articles published between 2018 and early 2024. Based on predefined inclusion criteria, 41 relevant publications were selected and analyzed for their conceptual and empirical contributions to the integration of AI and blockchain in sustainable digital finance.

Second, we analyzed market data for 18 AI-related cryptocurrencies, selected from CoinMarketCap and CoinGecko under the "AI & Big Data" category. The dataset spanned January 2021 to March 2024 and included daily metrics such as market capitalization, trading volume, and token price. These data were processed in Microsoft Excel using descriptive statistical methods to identify trends in asset growth and sustainability-oriented investor behavior.

Third, energy consumption was assessed by comparing blockchain consensus protocols using data from the Cambridge Bitcoin Electricity Consumption Index (CBECI, 2024). The environmental performance of AI-supported platforms such as Ocean Protocol and Render Network was evaluated based on public whitepapers, ESG reports, and third-party energy audits. Additionally, seven institutional reports from global organizations including the IMF and the World Economic Forum were reviewed to contextualize the findings within current ESG and regulatory developments in digital technologies.

4 Results

Empirical observations and market statistics confirm that the integration of artificial intelligence (AI) into blockchain technology has significantly enhanced the sustainability profile of several cryptocurrencies. The development of AI-based cryptocurrencies has accelerated rapidly, especially between 2021 and 2024. According to data from CoinMarketCap (2024) and CoinGecko (2024), the total market capitalization of selected AI-related crypto assets increased from approximately USD 2.7 billion in early 2021 to over USD 39 billion in early 2024. This remarkable growth—more than a 14-fold increase—is visualized in Figure 1, which illustrates the expanding role of AI in blockchain ecosystems.



Figure 1: Growth of AI-based Cryptocurrencies Market Cap (2021-2024) Source: Own edited figure based on data from CoinMarketCap and CoinGecko (2024)

Prominent AI tokens such as Render Token (RNDR) and Fetch.ai (FET) experienced price gains between 200% and 600% during the same period (CoinDesk, 2024). These trends reflect not only the technological appeal of AI integration but also the growing investor demand for blockchain solutions with sustainability-oriented value propositions.

Regarding energy efficiency, the adoption of decentralized, AI-enhanced blockchain platforms has resulted in measurable improvements. Based on data from the Cambridge Bitcoin Electricity Consumption Index (CBECI, 2024), such platforms consume between 25% and 40% less electricity compared to centralized data centers performing similar computational tasks. For instance, Ocean Protocol's decentralized data marketplaces reduce energy usage by up to 30% by minimizing redundant processing and enabling more efficient resource allocation (Xu et al., 2024; Kapitonov et al., 2022). Similarly, Render Network enhances energy efficiency through decentralized GPU resource sharing, further reducing overall consumption.

The potential of these technologies is further reinforced by evolving regulatory requirements. The European Union's Markets in Crypto-Assets (MiCA) regulation, effective from 2024, mandates ESG metric disclosures from cryptocurrency service

providers. This has led to increased publication of sustainability reports by platforms like Ocean Protocol and Fetch.ai, which helps improve transparency and build trust among investors (European Union, 2023; Kumar & Tripathi, 2024).

Broader institutional perspectives also support these findings. Reports from the International Monetary Fund (IMF, 2024) and the World Economic Forum (2023) emphasize the role of AI-embedded blockchain networks in achieving ESG objectives and long-term regulatory alignment. The World Economic Forum, in particular, highlights how AI-based decentralization enhances transparency and facilitates public acceptance of blockchain innovations.

5 Discussion

The findings of this study support the hypothesis that the integration of artificial intelligence (AI) into blockchain systems contributes meaningfully to the sustainability of cryptocurrency technologies. The substantial increase in the market capitalization of AI-based tokens and the growing interest in ESG-aligned financial assets indicate that market participants increasingly prioritize energy-efficient and socially responsible solutions (Peschko & Zölitz, 2025; Kumar & Tripathi, 2024). This trend highlights the strategic importance of embedding sustainability into the design and operation of decentralized financial infrastructures. Projects such as Ocean Protocol, Fetch.ai, and Render Network illustrate the practical advantages of combining AI with blockchain, particularly in terms of improving computational efficiency, minimizing redundant processing, and optimizing the use of distributed resources (Aslam et al., 2023; Xu et al., 2024). These systems significantly reduce energy consumption and carbon emissions when compared to traditional centralized infrastructures, and thus play a leading role in the shift towards green digital ecosystems (Farkas & Kucséber, 2021).

It is essential to recognize, however, that the application of AI technologies within blockchain ecosystems is not without limitations. Although AI significantly contributes to decision-making efficiency and the optimization of resource allocation, its deployment—particularly in machine learning and high-performance computing contexts—requires substantial computational power, which may result in increased energy consumption if not carefully managed. As highlighted in prior studies, the sustainability benefits of AI integration are contingent not only upon its functionality but also upon the conditions of its implementation. These benefits are maximized when decentralized infrastructures are combined with energy-aware algorithmic design and hardware configurations that prioritize computational efficiency (Kapitonov et al., 2022). Absent such considerations, the introduction of AI may paradoxically exacerbate environmental burdens instead of mitigating them.

At the same time, regulatory developments—most notably the EU's Markets in Crypto-Assets (MiCA) framework—are pushing cryptocurrency developers toward greater transparency and ESG compliance. This evolving regulatory environment presents both opportunities and constraints: it fosters innovation in reporting and energy monitoring, while also raising the bar for compliance and operational standards. The success of AI-powered blockchain platforms will largely depend on their ability to demonstrate measurable sustainability impacts, adapt to regulatory requirements, and maintain technological relevance in an increasingly ESG-focused digital economy (European Union, 2023; Kumar & Tripathi, 2024).

6 Conclusions

This study investigated the extent to which the integration of artificial intelligence (AI) into blockchain technologies can support the development of more sustainable cryptocurrency systems. The analysis confirms that AI-powered blockchain solutions offer measurable benefits in terms of environmental sustainability, particularly through reduced energy consumption, improved resource allocation, and support for compliance with Environmental, Social, and Governance (ESG) frameworks. The substantial growth in the market capitalization of AI-related cryptocurrencies—rising from approximately USD 2.7 billion in early 2021 to over USD 39 billion in 2024—indicates that investors increasingly value platforms that combine technological innovation with sustainability objectives (CoinGecko, 2024; CoinMarketCap, 2024). Moreover, decentralized infrastructures that incorporate AI have demonstrated up to 35% greater energy efficiency than their centralized counterparts, resulting in lower overall electricity usage and a reduced environmental footprint (Kapitonov et al., 2022). These developments are closely aligned with regulatory trends, such as the European Union's MiCA regulation, which mandates ESG disclosures for crypto service providers and encourages the adoption of greener practices across the industry (European Union, 2023; Kumar & Tripathi, 2024). In light of these findings, it can be concluded that AI-supported blockchain

systems have the potential to play a key role in the transition to a more sustainable digital economy. Their continued advancement may not only contribute to climate goals and energy reduction efforts but also provide new opportunities for regulatory alignment, economic value creation, and technological competitiveness in a rapidly evolving global financial landscape.

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