Digital Innovation and Clear Energy: A Study on Environmental Taxation of Crypto Assets

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Abstract. The development of digital technology has created new opportunities to support sustainable environmental policies. One prominent innovation is the use of blockchain technology, which, despite offering efficiency and transparency, raises concerns about energy consumption and environmental impact and particularly in Proof-of-Work (PoW) systems. On the other hand, fiscal instruments such as green taxes can be used to encourage the adoption of environmentally friendly technologies and mitigate negative externalities. This study aims to analyze the relationship between digital innovation and fiscal policy in promoting energy efficiency and implementing green policies. Using a descriptive qualitative approach and literature review, this paper examines blockchain's contribution to energy efficiency and best practices from several countries. The findings indicate that integrating environmental taxation with digital technologies, especially in the cryptocurrency sector, holds significant potential to support the clean energy transition and enhance environmental governance in the digital era.

1 Introduction

Energy generation is a primary catalyst for economic progress and societal welfare globally. The utilisation of traditional energy sources, like coal, oil, and natural gas, adversely affects the environment and human health[1]. In recent decades, the globe has encountered unparalleled global energy difficulties, marked by rising energy consumption, reliance on fossil fuels, and escalating environmental damage. The escalating demand for energy, driven by swift industrialisation, digitalisation, and urbanisation, directly contributes to rising greenhouse gas emissions and heightens the risk of climate change[2].

In the context of the climate problem and rising global energy consumption, energy efficiency is paramount in sustainable development initiatives. Digital economic activities, such as cryptocurrency mining, have imposed an additional strain on global energy usage. This necessitates an approach that is both economical and environmentally sustainable in the management of digital innovation. Digital innovation has been instrumental in bolstering environmental protection and energy efficiency alongside the advancements of the modern era. New Artificial intelligence (AI), Internet of Things (IoT), and big data tools have improved energy consumption tracking, pollution monitoring, and supply chain visibility. Emergence of phenomena like blockchain and cryptocurrency as a result of technological advancements has the potential to bring both new opportunities and new challenges to the environmental setting[3].

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One of the potential benefits of blockchain technology is that it has the potential to bring about efficiency, transparency, and decentralisation across a variety of industries, including renewable energy[4]. Nevertheless, on the other hand, it is well-known that the process of transaction validation on blockchain networks like Bitcoin is known to have a very high energy consumption. As a result, this may give rise to worries over the influence that crypto assets have on the environment, particularly in relation to their carbon footprint and the amount of electricity that is consumed worldwide. Fiscal policy, particularly through green taxation, can serve as an effective mechanism to promote the transition to more environmentally sustainable technology. Taxes on cryptocurrency assets, if structured with an appropriate environmental perspective, can serve as both a source of government revenue and a mechanism to internalise the adverse externalities associated with energy-intensive digital activity[5].

The rapid growth of the digital economy and the decentralized nature of blockchain technologies have challenged traditional legal and fiscal frameworks[6]. While many countries focus on financial stability and consumer protection in regulating cryptocurrencies, the environmental impact particularly from energy-intensive Proof-of-Work (PoW) mining, remains largely overlooked. There is an urgent need to integrate environmental considerations into fiscal and regulatory policies, including comparative assessments of consensus mechanisms such as PoW and Proof-of-Stake (PoS)[7]. The lack of standardized global tax policies for digital assets has enabled regulatory arbitrage, allowing mining operations to migrate to jurisdictions with weaker environmental controls. This not only undermines global climate efforts but also disincentivizes innovation in energy-efficient blockchain solutions. Therefore, environmental taxation must align with both national interests and international sustainability commitments[8].

Environmental taxation on crypto assets should be justified not only through its alignment with the Paris Agreement and global energy transition agendas but also through empirically measurable outcomes. In accordance with SDG 13 (Climate Action), policy effectiveness may be assessed through indicators such as the percentage reduction in CO_2 emissions from mining activities, while contributions to SDG 12 (Sustainable Consumption and Production) can be observed in the increased adoption of energy-efficient consensus mechanisms, such as Proof-of-Stake, incentivized through fiscal policy [9]. This necessitates a structured evaluation framework encompassing input (tax policy design), output (cost adjustments and fiscal incentives), outcome (technological shifts toward low-energy systems), and impact (decline in emissions), supported by reliable baseline data. For example, Indonesia's crypto mining sector consumes approximately 0.016–0.05 TWh of electricity annually and generates an estimated 0.01–0.03 $MtCO_2$, which may serve as a reference point for pre- and post-policy impact assessment[10].

Against this backdrop, it becomes increasingly vital to examine how the convergence of digital innovation, clean energy policies, and environmental taxation can be strategically leveraged to advance sustainable development goals. Although recent scholarship has explored the energy-intensive nature of blockchain technology and proposed more sustainable consensus mechanisms such as PoS, limited attention has been given to how fiscal instruments particularly environmental taxes can be designed to regulate and incentivize cleaner digital infrastructures. Furthermore, while energy tax frameworks have been applied in conventional sectors, their extension to the rapidly expanding crypto asset economy remains largely unexplored [11].

This research seeks to address that gap by analysing the contribution of blockchain technology to energy efficiency, investigating the potential of taxation to support clean energy transitions, and identifying best practices for integrating green fiscal policy into digital activities. By doing so, this study contributes to the emerging interdisciplinary discourse that links digital economic growth with environmental governance, offering

insights relevant not only to technical innovation but also to the formulation of adaptive, sustainability-oriented fiscal policy frameworks in developing countries such as Indonesia.

This research uses a descriptive qualitative approach. The method is used to analyze the relationship between digital innovation and fiscal policy in promoting energy efficiency and implementing green policies. The main focus is on a comprehensive literature review, where data and information are collected from various academic and professional sources. This approach allows researchers to examine the contribution of blockchain to energy efficiency and best practices from several countries. As a result, this method allows for an in-depth exploration of the complex and interdisciplinary phenomenon that connects the digital economy, technology, and environmental policy.

2 Efficiency Energy from Technology Blockchain

Blockchain technology has emerged as a transformative force across various sectors, particularly in digital finance, yet its environmental implications have sparked growing concern. As blockchain systems expand, so too does their energy consumption, and most prominently observed in consensus mechanisms such as Proof-of-Work (PoW). PoW, the original algorithm powering networks like Bitcoin, relies on energy-intensive computations and specialized hardware such as Application-Specific Integrated Circuits (ASIC) to validate transactions. The global Bitcoin network alone consumes approximately 100 terawatt-hours (TWh) of electricity annually, a figure comparable to the total energy usage of nations such as Argentina, raising alarms about carbon footprints and global sustainability [11].

Proof-of-Stake (PoS) has emerged as a more energy-efficient alternative to Proof-of-Work (PoW), entrusting transaction validation to participants who stake their crypto assets, thereby eliminating energy-intensive computational races and enhancing scalability and sustainability. Given the unsustainable nature of PoW in the face of global climate challenges, countries like China have implemented regulatory measures against PoW-based mining, emphasizing the need for environmentally aligned blockchain innovation. PoS systems offer a viable path forward with significantly lower energy consumption and greater compatibility with emerging environmental regulations and green taxation frameworks.

The comparison between PoW and PoS unequivocally demonstrates that, in terms of energy efficiency and environmental sustainability, the PoS system is an eco-friendly alternative. Consequently, the formulation of environmental tax policy for digital assets must consider these technological disparities. Taxes based on energy consumption can be implemented to deter PoW systems and, conversely, to incentivise PoS initiatives or other environmentally sustainable solutions. Considering this, the incorporation of digital innovations like blockchain should be executed judiciously and supported by a policy framework that harmonizes digital economic advancement with environmental conservation.

Ethereum's transition from Proof-of-Work to Proof-of-Stake in 2022, known as "The Merge," as the second-largest blockchain, Ethereum’s upgrade reduced its energy consumption from roughly 80–90 TWh annually to just 0.01 TWh, a reduction exceeding 99.9%. Its carbon emissions dropped dramatically, transforming Ethereum into one of the most energy-efficient and high-performance public blockchains. Moreover, PoS has reinforced Ethereum’s decentralization and resistance to 51% attacks, safeguarding its broad ecosystem of decentralized applications (dApps), including Decentralized Finance (DeFi) and Non-Fungible Tokens (NFTs). This success presents a model for other blockchains, particularly Bitcoin, to pursue greener alternatives without compromising performance or security [12].

Another notable example is the Chia Network, founded in 2021 by Bram Cohen, which introduced a unique consensus model called Proof-of-Space and Time (PoST). Unlike PoW, Chia utilizes unused hard drive space for “farming,” replacing computation-intensive mining with storage-based validation. This approach significantly reduces energy requirements and

democratizes participation by lowering technical barriers, enabling individuals with standard hardware to engage in network security. PoST thus supports decentralization and energy efficiency, aligning with broader national environmental and fiscal objectives.

Although Chia's Proof-of-Space-and-Time model is more energy-efficient than PoW, it involves high disk usage that may accelerate hardware degradation, raising concerns about e-waste and lifecycle sustainability. Although Chia's Proof-of-Space-and-Time model is more energy-efficient than PoW, it involves high disk usage that may accelerate hardware degradation, raising concerns about e-waste and lifecycle sustainability.

3 Tax Integrity and Technology: Case Study and Best Practice

As the digital economy continues to expand, integrating environmental sustainability into fiscal systems has become a pressing priority for many countries. The rise of energy-intensive technologies, such as blockchain and cryptocurrency mining, underscores the need for tax policies that are both environmentally conscious and technologically adaptive. While global approaches vary, several jurisdictions have begun experimenting with mechanisms, both direct and indirect to align digital taxation with climate objectives [13].

Norway and Germany provide important insights but also show crypto mining environmental regulation problems. Norwegian mining emissions are reduced by high electricity prices and hydropower, although miners may move to nations with cheaper fossil fuels. Germany's carbon pricing forces miners to use renewable energy but causes industrial opposition and competitiveness issues. Indonesia can learn from these examples that indirect environmental taxes through energy pricing or carbon programs can work, but must be tailored to its coal-dependent energy system and legal-fiscal capabilities. Indonesia should adopt a mixed approach that penalizes energy-intensive mining with higher tariffs or carbon pricing and rewards hydroelectric and geothermal enterprises.

Other countries have also taken notable steps. Sweden has advocated for the European Union to consider banning PoW mining due to its excessive energy use. In the United States, individual states such as New York have imposed moratoriums on fossil fuel, based PoW mining, thereby nudging miners toward more sustainable practices. These regulatory efforts, though not always framed as taxation, function as de facto environmental policies by reshaping operational incentives. Collectively, these cases illustrate the potential for integrating environmental considerations into the taxation of crypto assets, even in the absence of dedicated green crypto taxes. Carbon pricing, tiered electricity tariffs, and green energy subsidies serve as effective fiscal levers for achieving environmentally aligned digital governance [10].

Indonesia, with its rapidly growing digital economy and increasing focus on sustainable development, presents a compelling case for adopting green taxation in the digital sector. The country's expanding crypto asset market and its ambitious decarbonization targets highlight the urgent need to address the environmental impact of energy-intensive digital activities. Introducing taxes based on carbon intensity or energy consumption could not only generate public revenue for climate-related projects but also encourage cleaner technological practices. However, practical challenges remain. Accurately measuring and attributing environmental externalities in decentralized digital ecosystems is complex. Crypto mining operations, often dispersed and pseudonymous, are difficult to monitor. Excessive tax burdens may also risk stifling innovation or driving operators to jurisdictions with more lenient rules [14].

Institutional capacity is another critical factor. Effective green tax implementation in Indonesia will require robust infrastructure for energy use reporting, verifiable environmental metrics, and comprehensive inter-agency coordination, particularly among the ministries of finance, environment, energy, and communications. Without sufficient oversight and stakeholder engagement, well-intentioned green taxes could backfire, reducing sector

competitiveness or undermining public trust. Nonetheless, if designed incrementally and supported by targeted incentives, Indonesia's green tax initiative could steer the digital sector toward environmental responsibility while reinforcing its clean energy roadmap.

A promising enabler for such reforms is blockchain technology itself. Known for its transparency, decentralization, and immutability, blockchain can be leveraged to enhance fiscal integrity and environmental tax compliance. Its distributed ledger architecture enables secure and tamper-proof recording of energy usage or carbon emissions associated with digital activities. By tokenizing energy data or integrating smart meters with blockchain systems, authorities could automate the reporting of electricity consumption, energy source (renewable vs. fossil), and corresponding emissions. This data can form the basis for accurate and auditable environmental tax assessments [15].

Further, blockchain platforms can support carbon credit markets through the tokenization of emission rights. Every transaction, whether a purchase, sale, or offset, can be logged immutably, ensuring transparency and preventing double-counting. This facilitates compliance with carbon pricing regimes and fosters trust among stakeholders, including regulators and businesses. Moreover, the use of smart contracts enables automatic tax deductions or incentives based on pre-defined environmental criteria, reducing administrative burdens and increasing efficiency. Despite these advantages, concerns remain regarding the scalability of blockchain solutions, interoperability with existing tax systems, and legal recognition of blockchain-stored data for compliance purposes.

In conclusion, global best practices demonstrate that environmental considerations can be embedded into crypto taxation through a mix of direct and indirect approaches. Indonesia stands to benefit significantly from such a model, provided it navigates implementation challenges thoughtfully. With the support of blockchain for real-time monitoring and reporting, the integration of tax integrity and environmental sustainability in the digital sector is not only feasible but essential for achieving long-term climate and fiscal objectives.

4 Conclusion

The integration of digital innovation, particularly blockchain technology, with environmental regulation and green taxation, offers transformative opportunities for sustainable development. The transition from energy-intensive consensus mechanisms like Proof of Work (PoW) to more energy-efficient alternatives such as Proof of Stake (PoS) and Proof of Space and Time (PoST), as seen in Ethereum and Chia Network, has proven to significantly reduce carbon emissions. These technological evolutions reflect a broader shift toward cleaner blockchain systems and illustrate how digital infrastructure can align with global climate targets when guided by responsible design and regulation.

Environmental taxation serves as a critical fiscal instrument to internalize negative externalities from digital economic activities. In this context, green taxes not only disincentivize high-carbon operations like PoW mining but also generate revenue for sustainability initiatives. While implementation challenges persist, particularly regarding data transparency, miner mobility, and inter-agency coordination blockchain itself offers solutions through automated and immutable energy reporting systems. Learning from international best practices and reinforcing domestic regulatory capacity, countries such as Indonesia can develop adaptive, technology-driven fiscal frameworks to promote environmental accountability and digital innovation simultaneously.

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