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# Blockchain and Green Sukuk Integration for Coastal Community Empowerment in Sustainable Blue Economy

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## Abstract

Digital transformation in the context of a sustainable blue economy opens up strategic opportunities to address various social, economic, and environmental challenges faced by coastal communities. This study examines the integration of blockchain technology and green sukuk financing instruments as an innovative strategy that has the potential to empower coastal communities inclusively. This research method uses a conceptual approach and literature study. The research findings show that collaboration between blockchain and green sukuk can improve efficiency, transparency, and accountability in the management of environmentally-oriented projects. In addition, this approach allows real-time tracking of funds, strengthens data-based reporting, and encourages active participation of local communities in conservation initiatives. This integration also plays an important role in expanding financial access for groups that have been marginalized, through an environmentally friendly sharia financing scheme. However, the implementation of this model is not without challenges, such as low digital literacy, limited technological infrastructure, and the absence of supporting regulations. Therefore, a gradual, collaborative implementation strategy is needed, and is adjusted to local conditions.

## Keywords

Blockchain, Blue Economy, Green Sukuk, Innovative Strategy.

## 1. Introduction

Digital transformation is reshaping global economies, including the maritime and marine sectors, by offering innovative solutions to pressing challenges such as climate change, marine ecosystem degradation, and socio-economic disparities in coastal communities (Tijan et al., 2021). The sustainable blue economy provides a framework for aligning economic growth with marine conservation and community well-being, emphasizing responsible resource use to create value without harming ecosystems (Bakti & Hakim, 2024; Elson et al., 2024). However, coastal communities, critical to the blue economy's success, often face marginalization due to limited access to capital, technology, and markets (Alifa et al., 2024). This necessitates innovative, community-based approaches that leverage digital infrastructure and alternative financing mechanisms to empower these groups.

Blockchain, a distributed ledger technology, enhances trust, transparency, and efficiency in managing blue economy projects through smart contracts that automate and secure transactions (Hasan et al., 2024). Its ability to enable real-time tracking and immutable records makes it ideal for ensuring accountability in financial management, marine product traceability, and supply chain transparency. Green sukuk, a sharia-compliant financial instrument, supports environmentally focused projects like marine conservation, coastal restoration, and waste management (Anggraini, 2018). Integrating blockchain with green sukuk can streamline fund allocation, expand investor access, and ensure funds are directed to projects with measurable environmental and social impacts (Dimiyati et al., 2023).

The blue economy, projected to reach USD 2.5–3 trillion by 2030, spans sectors like fisheries, aquaculture, and coastal tourism, which are vital for poverty reduction and improving livelihoods in vulnerable areas (Evans et al., 2023; Ali & Sulistiyono, 2025). Blockchain enhances governance and equitable resource distribution, particularly in Islamic finance contexts, by providing transparent and efficient systems (Muharam & Osman, 2024). Combined with green technologies, it optimizes resource use and supports Sustainable Development Goals (SDGs), notably SDG 14 (Oceans) and SDG 13 (Climate) (Eshbayev et al., 2024). Collaboration among governments, communities, and the private sector is essential to ensure the blue economy drives economic growth while preserving marine ecosystems and promoting social justice (Ilma & Supriadi, 2022).

Despite growing research on the blue economy and coastal communities, the role of digital transformation, particularly blockchain and green sukuk integration, remains underexplored. Existing studies often focus on blockchain's technical aspects or Islamic finance mechanisms but rarely examine their potential as tools for social innovation in marginalized coastal areas (Astuti et al., 2024). This research addresses this gap by investigating how blockchain and green sukuk can drive structural change, fostering an inclusive and sustainable blue economy. It is particularly relevant for archipelagic nations like Indonesia, where coastal communities face increasing threats from environmental degradation and digital exclusion (Akbar, 2017).

This study aims to develop an integrative strategy combining blockchain, green sukuk, and coastal community empowerment to create a replicable model for sustainable blue economy development. It highlights the potential for inclusive finance, transparent project management, and community-driven conservation while identifying challenges such as limited digital infrastructure and regulatory frameworks. The transdisciplinary approach, blending technology, Islamic finance, and community sociology, distinguishes this research. Its findings aim to inform policymakers, technology developers, and academics, contributing to global development agendas like SDG 14 and SDG 13. By addressing digital and financial

exclusion, this model seeks to ensure coastal communities are active participants in the digital and economic transformations shaping the future.

## **2. Literature Review**

### **2.1. Blockchain in Strengthening Transparency and Efficiency of Islamic Social Finance**

Blockchain technology has great potential to improve Islamic social financial governance through greater transparency, efficiency, and security. As a distributed ledger technology, blockchain enables permanent, immutable, and auditable transaction recording in real time. These characteristics are very relevant in the context of managing Islamic social financial funds, such as zakat, *infaq*, *shodaqoh*, and waqf, which require high accountability and trustworthy management. The use of blockchain can guarantee that the funds distributed actually reach the beneficiaries, and each stage can be tracked transparently.

According to Dimiyati et al. (2023), the implementation of blockchain-based smart sukuk can accelerate the process of issuing and distributing funds, while reducing the administrative and bureaucratic burdens that have been obstacles. This is a great opportunity for empowering MSMEs, especially in remote areas that have difficulty accessing conventional financing. Smart sukuk allows investors to participate directly in socially valuable projects through a safe, efficient, and manipulation-free system. Furthermore, blockchain creates a more trusted financial ecosystem by building strong relationships between fund issuers, managers, and beneficiaries. Aminin (2024) emphasized that this technology can be a catalyst for the transformation of the Islamic financial system towards a more inclusive and socially responsible direction, as it ensures that social funds are managed efficiently, fairly, and on target.

### **2.2. The Relevance of Blockchain and Green Sukuk in the Context of Coastal Communities**

Coastal communities often face structural challenges that hinder sustainable development, such as limited access to formal financial services, low digital connectivity, and minimal participation in the development decision-making process. In facing these challenges, the integration of blockchain technology and green sukuk offers an innovative solution that is relevant and has a real impact (Yanagihara & Fujihara, 2021). Blockchain, as a secure and transparent digital recording technology, allows tracking of the flow of funds and resources in real time, thereby preventing budget leakage and increasing accountability in the implementation of development projects. A study by Pranita et al. (2023) on the implementation of blockchain in the Seribu Islands area shows that this technology can strengthen coordination between the government, private sector, and local communities, especially in developing a sustainable blue economy.

In addition, green sukuk as a sharia-based financing instrument offers an ethical financial approach that is in line with the principles of *maqasid syariah*, especially in protecting the environment and social welfare. Funds from green sukuk can be allocated for strategic projects in coastal areas, such as marine ecosystem restoration, waste management, mangrove conservation, and environmentally friendly infrastructure development. According to Samintang (2024), the combination of blockchain and green sukuk not only strengthens data-based supervision but also opens up space for local community participation in development, creating a system that is inclusive, equitable, and oriented towards long-term sustainability.

### **2.3. Strategic Integration to Achieve Sustainable and Inclusive Finance**

The integration of blockchain technology and green sukuk instruments has a broad strategic dimension in encouraging sustainable development, especially in

coastal areas. This approach not only plays a role in empowering the local economy but also creates a more inclusive, transparent, and ethical financial system. According to Thaker et al. (2022), the combination of digital technology and Islamic financial principles can expand access to financing for communities that were previously marginalized from the formal financial system, such as vulnerable coastal communities. Furthermore, this integration is in line with the achievement of the Sustainable Development Goals (SDGs), especially SDG 13 (Climate Action) and SDG 14 (Marine Ecosystems), by supporting environmental conservation projects, climate change adaptation, and sustainable management of marine resources.

Green sukuk serves as a source of ethical financing for environmental projects, while blockchain ensures transparency and accountability in the use of funds. This combination bridges the digital and financial divide that has been a major obstacle to coastal development (Djati et al., 2024). In addition, this approach strengthens the independence of local communities by encouraging active involvement in the planning, implementation, and supervision of projects based on their regional potential in a participatory manner. Blockchain-green sukuk integration a form of systemic innovation that not only responds to structural challenges but also encourages a transformation of coastal development that is fair, resilient, and oriented towards sustainable community empowerment.

### 3. Research Method

This study uses a qualitative study approach based on literature and conceptual analysis. The purpose of this approach is to build a systematic framework for thinking about the integration between blockchain technology and green sukuk in supporting the empowerment of coastal communities within the framework of a sustainable blue economy. The data sources in this study come from secondary data, namely scientific publications, policy reports, indexed journal articles, blockchain technology whitepapers, green sukuk development documents, and data from international organizations such as UNDP, World Bank, and IFSB (Islamic Financial Services Board). The literature reviewed covers the last 10 years, with a priority on the last 5 years to ensure the relevance and recency of the issues. In this study, data search and selection were carried out through digital databases such as Scopus, Google Scholar, Springer, and ScienceDirect. Inclusion criteria included documents relevant to the keywords: blockchain in public finance, green sukuk, blue economy, digital empowerment, and coastal community development. After the data was collected, a content analysis was conducted to identify key themes related to the characteristics of blockchain technology and its potential in financial transparency and efficiency, the structure and mechanism of green sukuk in an environmental context, and the role of financial innovation in community-based community empowerment. This study also utilizes a conceptual model approach, namely compiling a workflow diagram of the integration between the blockchain system and the issuance of green sukuk, as well as the mechanism for distributing funds to coastal community projects. The model prototype is compiled using system visualization software (such as draw.io or Lucidchart) to facilitate the representation of interactions between actors and technology. Conceptual accuracy and validity are tested through cross-referencing with documented frameworks and case studies. Thus, the selection of credible and comparative references ensures that the developed model has a strong empirical basis.

### 4. Results

Mas et al.'s (2024) conceptual analysis shows that the integration of blockchain and green sukuk significantly strengthens the sustainable blue economy across economic, social, and environmental dimensions, enabling transparent and

participatory project management. Arwani and Priyadi (2024) explain that economically, blockchain enhances green sukuk issuance by using smart contracts to increase efficiency, transparency, and accountability, thereby reducing costs and fraud risks. Real-time and tamper-proof fund tracking reduces dependence on traditional financial institutions, allowing micro-investors to participate through digital platforms, thereby increasing financial inclusion in coastal communities (Isaini et al., 2024; Harahap et al., 2025). This supports projects such as ecotourism and sustainable fisheries, which strengthen local economies. However, as explained by Hamsiah et al. (2024) financial inclusion is still low in coastal areas, with access to formal financial services ranging from 38% to 45% in areas such as East Nusa Tenggara and South Sulawesi, compared to the national average of 76.19%.

Socially, blockchain fosters an accountable ecosystem where smart contracts and transparency dashboards empower coastal communities to actively monitor projects, transforming them into governance participants. This reduces information asymmetry and builds trust through verifiable funding processes, fostering collaboration among communities, governments, and investors (Nasywa & Lahuri, 2025). Digital literacy, however, is a barrier, with only 57% of coastal educators using digital tools and 55% accessing online resources.

Environmentally, blockchain and green sukuk enhance conservation through evidence-based monitoring. Sensor technology and blockchain enable the recording of verified data such as restored mangroves or protected coral reefs ensuring accurate tracking of impacts (Novrizal et al., 2024). Wiraguna & Purwanto (2024) real-time monitoring of coral reefs through blockchain prevents illegal activities such as destructive fishing, thereby increasing transparency. Suryanto (2024) state that Indonesia's blue economy growth relies on ICT investment and infrastructure, but uneven electricity and digital access in coastal areas hinder progress.

Indicators of success include improving community welfare through micro-funds, transparent fund tracking through blockchain explorers, and effective environmental monitoring to reduce fictitious reporting (Thaker et al., 2022). According to Batubara et al. (2024) despite issuing more than USD 3 billion in green sukuk since 2018, its direct impact on coastal communities is still limited. This model represents social innovation, combining technology and Islamic finance for inclusive and sustainable development in Indonesia (Anggraini, 2018).

**Table 1.** Financial Inclusion Statistics of Coastal Communities in Indonesia

<b>Coastal Region</b>	<b>Access Percentage</b>	<b>Common Barriers</b>	<b>Level of Participation</b>
South Sulawesi	45%	Distance to financial institutions, low financial literacy	Low
East Nusa Tenggara	38%	Limited infrastructure, low public trust	Low
West Kalimantan	42%	Reliance on cash transactions, limited outreach	Medium
West Papua	34%	Geographical isolation, lack of digital system integration	Low
Riau Islands	51%	Fair access but not yet inclusive for marginalized groups	Medium
National Average	76%	–	High in urban areas

Table 1 shows the level of access of coastal communities to formal financial services in several regions in Indonesia and the obstacles they face. The average financial access in coastal areas such as South Sulawesi, East Nusa Tenggara, West Kalimantan, West Papua, and the Riau Islands is still far below the national average of 76%. The main obstacles include geographical distance, lack of financial literacy, dependence on cash transactions, and limited digital infrastructure. As a result, the level of participation of coastal communities in Islamic financial products is also relatively low to moderate, far compared to urban areas which have high levels of participation. This table underlines the importance of increasing financial inclusion in coastal areas to support sustainable economic development.

**Table 2.** Digital Literacy Statistics in Coastal Areas

Aspect of Digital Literacy	Percentage of Educators	Additional Remarks
Operating basic digital devices	62%	Mostly limited to using smartphones and chat applications
Using devices for teaching	57%	Majority have not actively integrated technology into the curriculum
Accessing online educational resources	55%	Often hindered by internet access and device costs
Creating digital-based teaching materials	42%	Design and editing skills remain very limited
Attending online technology training	33%	Lack of local training and availability of trainers
Using digital financial platforms	40%	Mostly use e-wallets, not yet Islamic financial apps
Following social media for education	68%	Still rarely used as a tool for productivity or business improvement

Table 2 shows that most coastal communities are able to use basic digital devices (62%) and social media for education (68%), but are still low in terms of creating digital materials (42%) and online training (33%). The use of technology is still limited, especially in the context of learning and Islamic finance, due to limited internet access and training.

**Table 3.** Green Sukuk Issuance by the Indonesian Government

Year	Issuance Value (USD)	Main Funded Project Types	Type of Sukuk	Target Priority Areas
2018	1.25 billion	Renewable energy, eco-friendly transportation	Global Green Sukuk	National
2019	750 million	Water management, disaster mitigation	Green Retail Sukuk	Urban and vulnerable regions
2020	1 billion	Green infrastructure, sustainable development	Green Global Sukuk	Conservation and coastal areas
2021	1.25 billion	Energy transition and energy efficiency	International Green Sukuk	Java, Sumatra, Kalimantan
2022	1.5 billion	Climate adaptation, ecosystem restoration	Global Green Sukuk	Coastal and remote areas
Total	5.75 billion	Various sustainable development sectors	Various types	National

Table 3 shows that from 2018 to 2022, the Indonesian government has issued green sukuk worth a total of USD 5.75 billion. These funds are allocated for sustainable projects such as renewable energy, water management, green infrastructure, and ecosystem restoration. The types of sukuk used vary, both global and retail, with priority areas ranging from national to coastal and remote areas, reflecting a strategic focus on environmentally friendly development in various regions.

**Table 4.** Determinants of Indonesia's Blue Economy Growth

<b>Blue Economy Factor</b>	<b>Impact on Growth</b>	<b>Additional Explanation</b>
Investment in Information Communication Technology	Positive and significant	ICT facilitates marine resource tracking, coastal product e-commerce
Capture and Aquaculture Fisheries Production	Positive and significant	Main livelihood source in coastal areas, absorbs large labor force
Access to Ports and Marine Logistics	Positive	Enhances distribution of coastal products to national and international markets
Electricity and Energy Distribution	Negative (if uneven)	Areas without stable electricity struggle to develop productive enterprises
Maritime Vocational Education and Training	Positive	Improves human resources and efficiency in marine-based economic activities
Internet Connectivity in Coastal Areas	Very Positive	Key to blockchain systems, digital reporting, and e-learning development

Table 4 shows that Indonesia's blue economic growth is greatly influenced by factors such as ICT investment, fisheries production, and internet connectivity, all of which have positive and significant impacts. Meanwhile, unequal access to electricity has a negative impact because it hampers economic activity. Ports, vocational education, and digital infrastructure are important pillars for distribution, strengthening human resources, and the application of technologies such as blockchain in coastal areas.

## 5. Discussion

The integration of blockchain technology and green sukuk offers a transformative opportunity to empower coastal communities through an inclusive, transparent, and sustainable financial system. However, several significant challenges must be addressed, especially in developing countries with complex geographical and social dynamics in coastal regions (Tamim, 2016; Irfana et al., 2023). The first challenge is low digital literacy; many coastal residents, especially fishermen, lack a basic understanding of digital technologies, which hinders the adoption of blockchain-based systems (Riupassa & Pesik, 2022). The second challenge is limited digital infrastructure, including poor internet access and electricity in rural areas, which affects the real-time application of blockchain systems such as smart contracts (Hadi, 2018). World Bank data (2019) shows that only 36% of rural Indonesians have internet access, compared to 62% in urban areas. The third challenge lies in regulatory readiness; current Islamic finance regulations rarely explicitly address the use of blockchain in instruments such as green sukuk, creating legal uncertainty that could reduce investor interest and slow innovation (Hidayat, 2018; Dinata et al., 2024).

Despite these challenges, several strategic opportunities can be leveraged. Open-source blockchain technology allows for the development of cost-efficient systems tailored to local needs. The Indonesian government's support for the blue economy and green finance—including the issuance of green sukuk and policies for sustainable coastal management—provides a strong policy foundation (Nisak, 2023; Suprianto et al., 2024). In addition, the rising trend of impact-based investment is well aligned with the principles of green sukuk, and the transparency and real-time accountability of blockchain can enhance investor trust (Aminin, 2024; Kautsar et al., 2025). The analysis shows that the main strength of this integration lies in improving transparency and efficiency in the Sharia-based financing system. According to Mulyanto & Purbasari (2024), blockchain technology ensures secure, accountable, and publicly verifiable transaction recording, which aligns with the principles of green sukuk and enhances financial inclusion in coastal communities that have long been marginalized. However, weaknesses such as low digital literacy and limited infrastructure remain significant barriers to adoption. Opportunities remain through the adoption of more flexible technologies and strong government policy support (Alifa et al., 2024). The global trend in impact-based investment also provides incentives for investors to support socially and environmentally beneficial projects, further reinforced by the transparency offered by blockchain (Aminin, 2024). Nonetheless, serious threats remain, particularly the absence of clear and comprehensive regulations regarding blockchain use in green sukuk. Legal uncertainty, could undermine investor confidence and hinder innovation by Islamic financial institutions.

A collaborative model implementation strategy in developing countries should begin with a phased approach, starting in areas with relatively good infrastructure and social readiness. This allows for ongoing technical and social evaluation, enabling continuous adjustments before wider scaling. It also helps build local capacity and ensures that systems evolve to meet community needs effectively (Sofianto, 2020; Handoko et al., 2023). Collaboration among stakeholders is key—governments act as policy facilitators, NGOs bridge technology and community needs, Islamic fintech institutions provide infrastructure and design Sharia-compliant digital financial products, and coastal communities, as users and strategic partners, co-design systems tailored to their local economic and cultural contexts (Harlyandra & Kafaa, 2021; Iffada et al., 2024). Digital literacy is a fundamental pillar, which must be built through practical training using local languages—not only to improve technical skills but also to foster trust in digital financial systems. Meanwhile, adaptive and participatory regulatory frameworks are crucial to ensure

policies are responsive and supportive of innovation. Regulation-making should involve communities, the private sector, and academics to reflect local realities, avoid resistance, and support economic and social goals (Barahona & Davin, 2021). Through a collaborative strategy that involves phased implementation, simple digital prototypes, digital literacy programs, and adaptive policies, the blockchain-green sukuk model can be implemented practically, inclusively, and sustainably to empower coastal communities.

## 6. Conclusion

This study shows that the integration of blockchain technology and green sukuk has significant potential in supporting the empowerment of coastal communities and strengthening the foundation of a sustainable blue economy. The collaboration of the two creates a more transparent, efficient, and accountable financing system, with a smart contract-based reporting and funding mechanism that can be openly accessed by all stakeholders. From a social perspective, this approach changes the position of coastal communities from passive recipients to active actors in project governance, while from an environmental perspective, an evidence-based reporting system supported by sensors and blockchain increases the effectiveness of monitoring conservation projects.

However, a number of structural challenges such as low digital literacy, limited infrastructure, and the absence of supporting regulations need to be addressed through a gradual and collaborative approach. An inclusive, adaptive, and community-based implementation strategy is key to the success of this model in developing countries. The implications of this study are the need for progressive and participatory policy support, the development of simple technology prototypes, and massive digital literacy programs so that this integration can be applied widely and sustainably. As a future proposal, further research can be directed at implementation case studies in various coastal areas to test the effectiveness of the model and develop a more standardized approach.

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