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Ar-Rahnu Energy Cooperative (AREC): A Community-Based Microfinance Model for Green Development in Indigenous Aceh

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Abstract

The tradition of gold dowries in Aceh has resulted in women owning significant amounts of gold, yet these assets often remain unproductive and are merely stored as passive savings. This study explores the *Gala or Ar-Rahnu* or *Jeulamee* tradition and proposes a community-based financing model that optimizes unproductive gold as capital for Energy Independent Villages in Aceh. The novelty of this research lies in introducing *Jeulamee* as an alternative financing mechanism for renewable energy. This approach has not been previously examined while designing a closed-loop ecosystem to ensure sustainable energy production at the community level. Employing a mixed methods approach, including Location Quotient, Dynamic Location Quotient, Shift Share, and Input-Output analysis, the study identifies strategic sectors for sustainable energy development and formulates the *Ar-Rahnu* Energy Cooperative concept. By integrating Islamic microfinance, indigenous cultural practices, and blockchain-based gold tokenization, this research contributes to the literature on green financing while offering practical implications for women's economic empowerment, improved access to clean energy, and the advancement of inclusive and sustainable energy transitions in indigenous communities.

Keywords:

Ar-Rahnu microfinance, blockchain for renewable energy, community-based energy financing, gold tokenization, indigenous sustainable development

1. Introduction

Indonesia has demonstrated a strong commitment to the transition toward clean energy and sustainable development, as outlined in the 2020–2024 National Medium-Term Development Plan. The government set a target to reduce greenhouse gas emissions by 27.3% below the Business as Usual scenario by 2024, in alignment with its Nationally Determined Contributions under the Paris Agreement. Indonesia aims for a primary energy mix in which renewable energy accounts for 23% by 2025, increasing to 31% by 2030. As part of this national effort, Aceh Province holds significant strategic potential to support the clean energy transition. The region is endowed with abundant renewable energy resources such as solar, hydro, geothermal, and biomass energy, alongside a sustainable agricultural base and opportunities for more efficient natural resource management (Pemerintah Provinsi Aceh, 2022).

Aceh's renewable energy potential is evidenced by its substantial capacity across various sectors. The province possesses an estimated 3,380.6 MW of micro to small hydropower potential, 1,138 MW of wind power potential at 50 meters altitude, and 933.4 MW of biomass energy potential, with the ability to generate up to 767.2 GWh of electricity (IESR, 2023). These figures place Aceh among the top provinces in Indonesia in terms of renewable energy capacity and highlight Aceh's potential to become a regional leader in clean energy transition (Pemerintah Provinsi Aceh, 2022). When effectively utilized, this potential could not only meet local energy demands independently but also stimulate economic growth rooted in sustainable resources and reduce dependence on fossil fuels. Furthermore, it aligns with global commitments to reducing carbon emissions and enhancing community energy resilience, particularly in rural and underserved areas (IEA, 2020).

In line with the commitment to clean energy transition and the optimization of renewable energy potential, Aceh Province has developed the Energy Self-Sufficient Village model, exemplified by the community of Nosar village in Central Aceh District. This village serves as a practical example of locally based renewable energy implementation through the One Flow Multi-Purpose approach, a concept in which a single water source is sustainably used for multiple purposes. Here, water resources are utilized not only for domestic needs but also for electricity generation, meeting over 60% of the local community's energy needs. A key initiative in realizing energy self-sufficiency in this village is the construction of a Mini Hydro Power Plant, developed through collaboration between Syiah Kuala University and the local community. This project has not only reduced residents' reliance on fossil fuels but also strengthened the village's capacity to manage its natural resources independently and sustainably. This initiative exemplifies how a clean energy transition can be materialized through the integration of technology, local potential, and community empowerment (Pemerintah Provinsi Aceh, 2022).

Despite these achievements, Mini Hydro Power Plant projects in Aceh, including the one in Nosar, have not yet significantly improved living standards or ensured long-term energy independence. A major barrier is the fragmented and unsustainable nature of financing, often disconnected from broader community-based economic initiatives (Sagajoka, 2023). Without strategies for economic sustainability and community engagement, such infrastructure projects risk limited and short-lived impacts. Yet, alternative financing options exist, including corporate social responsibility (CSR) funds, international grants, and mechanisms rooted in indigenous knowledge systems (Sagajoka, 2023).

One form of local wisdom with considerable potential as an alternative financing source in Aceh is the *Jeulamee* tradition. *Jeulamee* refers to the obligatory gold dowry presented by the groom to the bride, an integral component of traditional Acehnese wedding ceremonies. The gold is measured in a local unit called *mayam*, typically equivalent to 3.3 grams, although in some areas, like West Aceh, it is considered 3 grams per *mayam*. The value of *Jeulamee* varies by region and social status. In Pidie, for instance, the gold dowry ranges from 50 to 70 *mayam*, while other sources mention 30 to 50 *mayam*. This tradition results in married Acehnese women possessing substantial gold holdings, usually stored as family savings and a symbol of honor, but rarely utilized productively.

Inclusive financial mechanisms can unlock the latent value of gold from Aceh's *Jeulamee* tradition through the *Ar-Rahnu* system, enabling individuals, particularly women, to access short-term credit while retaining asset ownership (Azman Ong et al, 2024; Yahya et.al., 2025). While previous studies have shown *Ar-Rahnu*'s role in promoting financial inclusion and supporting women's participation in microenterprises (Hilaluddin & Abdullah, 2024), its application has largely been confined to conventional financial contexts. With rising gold prices, growing focus on environmental sustainability, and advances in blockchain technology, there is an opportunity to convert gold assets, including *Jeulamee* gold, into digital instruments (Hussen & Ibrahim, 2018). The concept of Energy-Backed Digital Tokens (EBDT) links the value of collateralized gold to blockchain-based tokens, offering a transparent and inclusive financing platform for community-based renewable energy projects, such as the Energy Self-Sufficient Village initiative in Aceh (Kouhizadeh et al., 2021; World Bank, 2022).

Although previous studies have explored *Ar-Rahnu*'s impact on financial access (Yahya et.al., 2025) and blockchain tokenization in sustainable infrastructure finance (Kouhizadeh et al., 2021), no research has integrated these approaches into a unified, community-based financing model. This study addresses that gap by proposing the *Ar-Rahnu* Energy Cooperative (AREC), which combines Islamic gold pawning, digital assets, and cooperative principles to mobilize community capital for sustainable energy (Zain et al, 2024). The model incorporates regional economic analysis, using Location Quotient, Dynamic LQ, Shift Share, and Input-Output methods to identify productive sectors aligned with local potential. This research advances inclusive green finance and provides a strategic framework to support Indonesia's energy goals and global commitments to Sustainable Development Goal (SDG) 7 and SDG 13 (UNDP, 2022), while also contributing to interconnected targets such as gender equality (SDG 5) and decent work and economic growth (SDG 8) through a holistic SDGs nexus approach.

2. Methods and Materials

Our study adopts a mixed-methods approach, combining qualitative and quantitative methods to obtain a comprehensive understanding of the financing model for Energy Self-Sufficient Villages based on local wisdom in Aceh. On the qualitative side, a critical literature review method is employed to explore and analyze renewable energy financing models that integrate the *Gala* (*Ar-Rahnu*) tradition with a closed-loop financing approach, as well as the development of gold tokenization as an innovative funding instrument. The literature review focuses on existing studies related to Islamic gold pawning (*Ar-Rahnu*), community-based energy financing models, and the application of blockchain technology in sustainable financial ecosystems.

The quantitative approach is used to identify regional leading commodities that are relevant to the integration of financing strategies and local economic development within the closed-loop framework. The quantitative methods applied include Location Quotient (LQ) to identify the economic base sectors in Aceh; Dynamic Location Quotient (DLQ) to assess changes in sectoral advantage over time; Shift Share Analysis to evaluate the contribution of sectoral growth to regional economic performance; and Input-Output (I-O) analysis to understand inter-sectoral linkages and potential multiplier effects of Energy Self-Sufficient Village financing interventions. These four methods are widely recognized in regional economics as complementary tools to identify leading sectors and measure their dynamic role in economic development. The analysis is based on Gross Regional Domestic Product (GRDP) data for the period 2019–2024.

These quantitative tools are not intended to merely list leading commodities but to ensure that the financing model, AREC, is grounded in sectors with strong local economic relevance. Identifying sectors with comparative and competitive advantages allows the cooperative to align its financing structure with value chains that are both viable and strategic for sustainable rural development. This integration supports the development of productive business units that can absorb financing from *Ar-Rahnu* schemes and operate using renewable energy.

LQ is an analytical method used to measure the concentration of a specific economic sector in a particular region compared to the national level. The LQ formula is shown in Equation 1. E_i is the output of sector i in the region, E_t is the total output of all sectors in the region, E_i national is the output of sector i at the national level, and E_t national is the total national output. An LQ value > 1 indicates that the sector is a basic (export-oriented) sector with a regional competitive advantage. Conversely, an LQ < 1 implies that the sector is more dependent on external supply and lacks local competitiveness.

$$LQ = \frac{(\frac{E_i}{E_t})_{region}}{(\frac{E_i}{E_t})_{national}} \quad (1)$$

DLQ is an extension of the LQ that measures how the competitiveness of a sector changes over time. The DLQ formula is expressed in Equation 2. $E_i(t)$ is the output of sector i in the region at time t+n, $E_i(t+n)$ is the total regional output at time t+n; $E_i(t+n)$, and n; $E_t(t+n)$ national refers to the national-level figures for the same sector and period. A DLQ > 1 signifies that the sector is gaining in competitiveness and has the potential to evolve into a future economic base. A DLQ < 1 reflects a decline in competitive advantage over time.

$$DLQ = \frac{\left(\frac{E_i(t+n)}{E_t(t)}\right)_{region}}{\left(\frac{E_i(t+n)}{E_t(t)}\right)_{national}} \quad (2)$$

Shift Share Analysis is used to evaluate the growth performance of a regional sector in comparison to national trends. The total change in sectoral employment or output (ΔE\Delta EΔE) is decomposed into three components as in Equation 3. NG measures National Growth Effect; IM assesses Industrial Mix Effect; dan RS captures the Regional Shift Effect. A positive RS indicates that a sector is growing faster locally than nationally, suggesting a regional competitive advantage. A negative RS reflects slower regional growth and possible structural challenges.

$$\Delta E = NG + IM + RS \quad (3)$$

The quantitative analysis in this study utilizes data from several key sources, including national Gross Domestic Product and GRDP of Aceh Province by industrial sector (2010 series), as well as the Indonesian Input-Output (IO) table (domestic transactions at producer prices, covering 52 industrial sectors) for the period from 2018 to 2023. These datasets were obtained from official sources, primarily the Indonesian Central Statistics Agency (BPS, 2025), and serve as the empirical foundation for identifying priority sectors and assessing the potential for integrated rural economic development in alignment with community-based energy projects.

Although a province-specific IO table for Aceh would offer greater accuracy, such a dataset is not publicly available. Therefore, the national IO table is used as a standard proxy to estimate inter-sectoral linkages. This approach remains valid and widely applied in regional economic analysis across Indonesia, especially when provincial IO tables are unavailable. The use of the national IO table helps capture the relative importance and connectivity of sectors relevant to designing a sustainable financing ecosystem for energy self-sufficiency in rural Aceh.

3. Results and Discussions

3.1 Global Benchmarks in Gold-Based Financing: From Pawn Systems to Tokenization

Various countries have utilized gold within microfinance and cooperative systems to expand access to financing, indirectly supporting green development objectives. Malaysia stands out through the *Ar-Rahnu* scheme, a Sharia-compliant gold pawning system (Mohd Thas Thaker et al, 2021). Institutions such as Co-opbank Pertama and Bank Rakyat offer microloans secured by gold jewelry, up to approximately 80% of the gold's value, without interest, making it accessible to low-income communities (Yahya et.al., 2025). Since its introduction in the 1990s as an alternative to conventional pawnshops, *Ar-Rahnu* has expanded significantly. This scheme enhances socioeconomic well-being, particularly by empowering women micro-entrepreneurs through rapid access to liquidity (Yahya et.al., 2025).

Meanwhile, India has developed one of the largest and most established gold loan industries in the world. Non-banking financial institutions such as Muthoot Finance provide large-scale lending to micro and small enterprises using gold as collateral, with gold loan assets under management exceeding ₹1 lakh crore (approximately USD 12 billion) as of early 2025 (Bandhva, 2025). According to the Reserve Bank of India (RBI), gold-backed lending grew by over 30% within several months in 2024,

significantly outpacing other forms of credit constrained by strict unsecured lending regulations (Nayak, 2025). In the 2025 fiscal year, gold loans in India doubled and became the fastest-growing segment in retail credit, surpassing home and auto loans (Bandhav, 2025).

This phenomenon underscores gold's emerging role as a key catalyst in micro and retail finance, enabling households and small enterprises to access capital swiftly, potentially for productive uses, including environmentally friendly initiatives (Hisham et al, 2013). This potential becomes increasingly relevant when aligned with advancements in digital finance, particularly asset tokenization. A growing body of academic research highlights the promising role of tokenized assets as innovative financial instruments for renewable energy projects. Naderi and Tian (2022) emphasized that tokenizing green assets via blockchain technology can bridge funding gaps in clean energy initiatives by enhancing transparency, security, and investor accessibility. Similarly, Bohr et al. (2024) demonstrate, through bibliometric analysis and expert interviews, that tokenization facilitates fractional ownership of renewable energy projects, enabling retail investors to participate in funding previously limited to institutional players. Berntsen and Leippold (2022) further reinforced this perspective with quantitative analysis, showing that tokenization can reduce financing costs for renewable energy projects by improving liquidity and enabling the creation of secondary markets for traditionally illiquid investments.

Although specific research on gold tokenization for green projects remains limited, emerging policy directions in several countries, including Indonesia, are beginning to recognize the potential of tokenizing real assets such as gold as a transparent, efficient, and inclusive mechanism for green financing. Building on these insights, this study proposes the AREC model, a financing scheme that integrates the *Gala (Ar-Rahnu*) tradition with a closed-loop financing approach and the development of gold tokenization to support Energy-Independent Village projects in Aceh. This model is envisioned as an alternative financing strategy grounded in local wisdom, technological innovation, and sustainability principles.

3.2 Empowering Women and Renewable Energy through Ar-Rahnu

The AREC in Figure 1 is a proposed community-based financing model that integrates the traditional Islamic pawn system (*Ar-Rahnu*) with modern digital innovation and closed-loop principles to support the development of renewable energy projects in rural areas, particularly in Aceh. This model leverages culturally embedded gold assets, such as those from the *Jeulamee* marriage tradition, as collateral through syariah-compliant gold pawning, enabling community members, especially women, to access financing without losing ownership of their gold (Efrinaldi et al, 2022). The funds generated from this system are collectively managed and allocated for the development of local renewable energy infrastructure, such as micro-hydro or solar power plants. AREC also introduces tokenization of gold assets using blockchain technology, converting pawned gold into EBDT that represents fractional ownership and value contribution in energy projects. These tokens enhance transparency, traceability, and inclusivity by allowing even small contributors to become stakeholders in energy development. By combining traditional financial practices, cooperative governance, and digital innovation, AREC aims to create a sustainable, inclusive, and locally grounded financing ecosystem that supports energy independence and economic empowerment at the village level.

AREC is envisioned as a women-centered community financing ecosystem that facilitates access to productive credit through the syariah-based pawning of gold, particularly gold received as *Jeulamee* in Acehnese marriage traditions. Through this mechanism, women can utilize dormant gold assets as collateral to obtain microcredit without relinquishing ownership, thereby transforming cultural wealth into productive capital. Once financing is secured, community members, especially women, can engage in entrepreneurial activities developed within the business units operated by AREC. These business lines will be carefully selected based on regional economic potential, as determined through LQ, DLQ, Shift Share Analysis, and Input-Output analysis, which will be presented in the subsequent sections.

Importantly, these businesses will operate using renewable energy sources, ensuring that economic activities are aligned with sustainability goals. The energy infrastructure may be supported through various channels, including academic grants, government aid, and innovative financing mechanisms such as CSR funding, international partnerships, and green grants. The products or services generated through these enterprises will be distributed to pre-identified off-takers, with whom formal Memoranda of Understanding has been established. This creates certainty in the downstream market and strengthens the value chain. Should the business operations generate profit, a percentage of earnings will be reinvested into the expansion or upgrading of renewable energy infrastructure. This reinvestment model ensures that the initiative is not only economically beneficial for the community but also sustainable in terms of energy self-sufficiency, ultimately reinforcing both local resilience and inclusive green development.

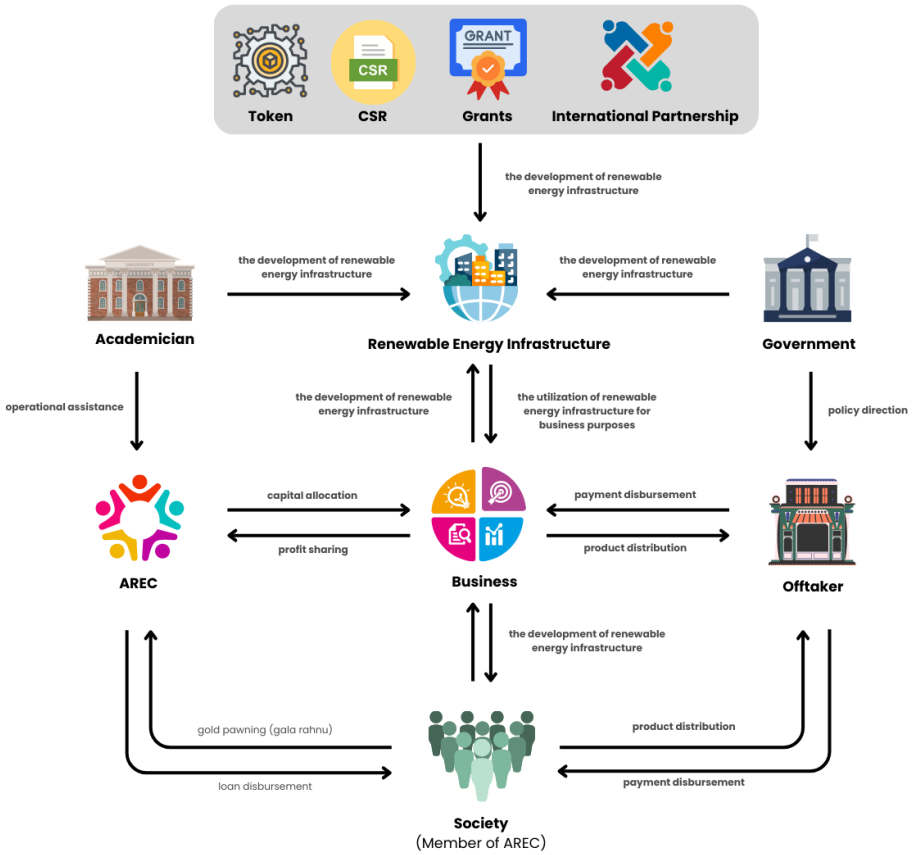

Figure 1. Closed-loop financing concept within the AREC ecosystem.

3.3 Strategic Sector Identification and Commodity Selection for AREC's Closed-Loop Financing Model

The integrated assessment of Aceh's economy, using LQ, DLQ, Shift-Share, and Input-Output analysis, underscores the structural importance and competitiveness of several subsectors. As shown in Table 1, the DLQ results indicate that eight subsectors are classified as base sectors (DLQ > 1), while two remain non-based. Similarly, the LQ results in Table 2 show that seven subsectors function as basic sectors, with the remainder identified as non-basic. The Shift-Share analysis in Table 3 reveals a mixed dynamic: two subsectors are competitive and growing, five are competitive but declining, two are non-competitive yet growing, and one is both non-competitive and declining. Complementing these findings, the Input-Output results in Table 4 identify four subsectors as developing, four as lagging, one as a potential sector, and one as non-competitive and declining. Taken together, these results highlight that Aceh's economy is supported by a diverse mix of base and strategically linked sectors, each contributing in different ways to regional resilience and sustainable growth.

The analysis results show that the food and beverage industry and the electricity sector emerge as base sectors in the regional economy. This indicates that these sectors contribute more significantly to regional economic output compared to the national average, and they hold strategic importance in driving local development. Furthermore, both sectors exhibit strong forward and backward linkages with other industries, suggesting that their growth can stimulate activity across multiple sectors in the local value chain.

Table 1. Result of DLQ.

Subsector	DLQ	Description
Food Crops	0.98	Non-Prospective
Horticultural Crops	1.01	Prospective
Plantation Crops	1.02	Prospective
Livestock Farming	1.00	Prospective
Agricultural and Hunting Services	1.01	Prospective
Forestry and Logging	0.98	Non-Prospective
Fisheries	1.01	Prospective
Oil, Gas, and Geothermal Mining	1.02	Prospective
Coal and Lignite Mining	1.01	Prospective
Metal Ore Mining	0.96	Non-Prospective

Table 2. Result of LQ.

Subsector	LQ	Description
Food Crops	1.67	Basic Sector
Horticultural Crops	2.82	Basic Sector
Plantation Crops	2.31	Basic Sector
Livestock Farming	2.67	Basic Sector
Agricultural and Hunting Services	5.88	Basic Sector
Forestry and Logging	1.98	Basic Sector
Fisheries	2.05	Basic Sector
Oil, Gas, and Geothermal Mining	1.57	Basic Sector
Coal and Lignite Mining	0.83	Non-Basic Sector
Metal Ore Mining	0.37	Non-Basic Sector

Table 3. Result of Shift-Share

Subsector	PP	PW	Quadrant	Description
Food Crops	-14.08	-18	4	Non-Competitive but Growing
Horticultural Crops	-3.549	12.547	2	Competitive but Declining
Plantation Crops	-3.87	20.012	2	Competitive but Declining
Livestock Farming	-2.169	1.532	2	Competitive but Declining
Agricultural and Hunting Services	-6.33	8.472	2	Competitive but Declining
Forestry and Logging	-10.9	-15.89	4	Non-Competitive but Growing
Fisheries	2.83	11.651	1	Competitive and Growing
Oil, Gas, and Geothermal Mining	-26.21	8.056	2	Competitive but Declining
Coal and Lignite Mining	7.562	7.838	1	Competitive and Growing
Metal Ore Mining	76.794	-10.21	3	Non-Competitive and Declining

More specifically, coffee has been identified as a leading commodity within the food and beverage sector, with recorded export values reaching USD 97,336,905. This underscores coffee's economic potential as a key anchor product in the proposed closed-loop financing model within the AREC ecosystem. Through this model, financial resources mobilized via gold pawning (*Ar-Rahnu*) could be directed toward strengthening coffee-based enterprises, which in turn would benefit from renewable energy supplied by the cooperative. The integration of a high-value commodity like coffee into AREC's

financing and energy model enhances both its economic sustainability and its capacity to generate inclusive, community-based development.

Table 4. Result of Input-Output Analysis

Subsector	BL	FL	Quadrant	Description
Food Crops	0.839	1.088	3	Developing Sector
Horticultural Crops	0.832	0.801	4	Lagging Sector
Plantation Crops	0.902	1.406	3	Developing Sector
Livestock Farming	0.933	1.023	3	Developing Sector
Agricultural and Hunting Services	0.825	0.772	4	Lagging Sector
Forestry and Logging	0.815	1.086	3	Developing Sector
Fisheries	0.833	0.891	4	Lagging Sector
Oil, Gas, and Geothermal Mining	0.976	1.331	3	Developing Sector
Coal and Lignite Mining	1.033	0.867	2	Potential Sector
Metal Ore Mining	0.93	0.707	4	Lagging Sector

3.4 Tokenizing Gold for Green Finance

EBDT is a proposed digital financial instrument within the AREC ecosystem that represents the value of gold pawned through the syariah-compliant *Ar-Rahnu* system. The concept of EBDT is designed to tokenize the collateralized gold into blockchain-based digital tokens, creating a transparent, traceable, and fractional form of value that can be used to finance renewable energy projects at the community level. In this system, when a member of the cooperative pawns their gold (such as *Jeulamee*) through AREC, the gold is not only stored as collateral but also converted into EBDT, each token representing a specific value backed by the underlying gold.

These tokens serve multiple purposes. They act as a capital pooling mechanism. EBDTs are aggregated to form a communal funding pool used to develop renewable energy infrastructure, such as micro-hydro or solar power systems. They are also ownership representation. EBDTs can reflect fractional ownership or claim over the energy infrastructure or revenue generated, depending on the governance model. The tokens support accountability and transparency. Since EBDTs are issued and tracked through blockchain technology, all transactions and fund flows are immutable and verifiable by stakeholders. The tokens are also tradable (optional). In future implementations, EBDTs may be made tradable within a closed ecosystem, enabling community members to exchange tokens for goods, services, or energy credits.

4. Conclusions

The findings of our study highlight the potential of the AREC as an inclusive, culturally grounded financing model for accelerating clean energy development in rural Aceh. By integrating *Jeulamee*-based gold pawning with syariah-compliant finance, community cooperatives, and EBDT. AREC mobilizes dormant household wealth into productive capital. This capital is then reinvested into renewable energy-powered enterprises, selected based on regional economic strengths identified through LQ, DLQ, Shift Share, and Input-Output analyses. In bridging local traditions with financial and digital innovation, the model contributes to ongoing efforts in inclusive green finance and decentralized energy transition, which have not been addressed in prior studies. The model not only empowers women as key economic actors but also creates a transparent and self-sustaining ecosystem aligned with Indonesia's net-zero emission goals and the SDGs. In doing so, AREC offers a replicable blueprint for decentralized green financing that links indigenous traditions with modern financial innovation. Although the AREC model was developed within the specific socio-cultural and economic context of Aceh, its core principles, such as the use of cultural assets, Islamic microfinance, and blockchain technology for green investment, are applicable to rural and indigenous communities in other parts of the world. This approach provides a transferable framework that can address similar challenges in promoting inclusive and sustainable energy financing at the global level.

To ensure effective implementation and scalability, several strategic actions are recommended. First, a clear legal and institutional framework is needed to support *Ar-Rahnu* cooperatives and ensure compliance with syariah and digital asset regulations. Second, targeted community mobilization and gender-inclusive policies must be prioritized, recognizing women's ownership of gold assets. Third, pilot projects should be launched in high-potential villages to validate the model. Fourth, partnerships with fintech and blockchain developers are essential to establish secure and transparent EBDT systems. Fifth, sectoral prioritization based on quantitative economic analysis should guide investment in enterprises such as coffee and food processing. Sixth, formalize off taker agreements to secure downstream market access. Seventh, create a reinvestment mechanism from business profits into renewable infrastructure. Finally, robust monitoring and evaluation tools are needed to assess impact and support the scaling of AREC across other rural regions in Indonesia.

In addition, the success of the AREC model also depends on improving financial literacy and education within the target communities. Women and other cooperative members must develop the ability to understand financial principles, manage assets, and use digital financial tools to ensure that the model remains inclusive and sustainable. At the same time, institutional strengthening is required through cooperative governance training, regulatory alignment, and transparent operational mechanisms to support the long-term viability and resilience of the financing ecosystem.

While our study presents a comprehensive conceptual framework, it is primarily exploratory in nature and relies on secondary data. Future research should focus on empirical validation through field-level implementation, particularly pilot testing in selected villages, and assess the social, financial, and environmental impacts of the model. Additionally, further refinement is needed to address regulatory and technological challenges in gold tokenization and shariah-compliant digital asset integration.

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