



Hydrogen Peroxide: Poverty Implications on Green and Renewable Energy-Related Financial Literacy in Mexico and Bangladesh

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Abstract

This comprehensive research examines the intricate and multifaceted relationship between financial literacy in green energy and entrenched poverty in Mexico and Bangladesh. It explores how systemic socioeconomic barriers fundamentally constrain accessibility to renewable energy technologies and associated financial services. Employing a robust mixed-methods strategy – integrating quantitative econometric analysis, qualitative evaluation of national policy frameworks, and advanced time series diagnostics – this study demonstrates that poverty generates multi-dimensional impediments to renewable energy uptake. These impediments include severely restricted access to tailored financial products, a profound lack of comprehension regarding green financing mechanisms, and deficient technical know-how. The findings reveal that both Mexico's ambitious goal of generating 35% of its electricity from clean sources by 2024 and Bangladesh's targets of 10% renewable energy by 2025 and 40% by 2041 are critically hindered within impoverished communities. In these contexts, financial literacy rates exhibit a strong negative correlation with poverty indices. Furthermore, the study employs unit root (ADF, KPSS, PP) and cointegration (Johansen) tests to analyze temporal trends, revealing the non-stationary nature of key variables like energy poverty and identifying long-run equilibrium between financial inclusion and technology adoption. The results provide critical, policy-relevant insights into how socioeconomic determinants shape energy transition dynamics in emerging economies, offering evidence-based recommendations for designing interventions that promote equitable and inclusive access to renewable energy technologies. The application of hydrogen peroxide H₂O₂ as a clean energy carrier has significant implications for financial literacy related to green and renewable energy, especially in countries like Mexico and Bangladesh. This comparative analysis seeks to explore how the adoption of H₂O₂ technology can enhance financial understanding and decision-making in impoverished communities.

Key Words: Financial Literacy, Green Energy, Poverty, Renewable Energy, Time Series, Stationarity, Cointegration, Bangladesh, Mexico, Energy Justice, Financial Inclusion.

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1. INTRODUCTION

The global transition towards renewable energy is not merely a technological or environmental imperative but a profound socioeconomic undertaking. For emerging economies like Mexico and Bangladesh, this transition unfolds against a backdrop of deep-seated poverty, inequality, and financial exclusion, creating complex challenges that threaten to undermine both the pace and equity of the shift to clean energy. This research posits that financial literacy specific to green energy—encompassing the knowledge and skills needed to understand, access, and manage financing for renewable technologies—acts as a critical mediator between poverty and successful energy transition participation. However, poverty erodes this literacy, creating a vicious cycle that locks low-income households out of the benefits of the green economy..Ali (2020) conducted an exploratory and explanatory study on the digitization of Bangladesh's economy, investigating whether its transition to a digital economy functions effectively and efficiently for societal and economic benefit. His findings led to the rejection of several null hypotheses, indicating significant support for the benefits of the Internet of Thinking, the use of robots in industry, big data for business intelligence, artificial intelligence (AI), bitcoin transactions, digitalization in banking, chatbots, commercial drones, educational robots, and wireless farming techniques. However, the study identified the fear of job loss as a primary obstacle to implementing the Fourth Industrial Revolution (4IR) in Bangladesh. Ali(2020) concludes that successful digitization requires proper ICT-based education, preparation, knowledge, and the establishment of good governance and regulation, suggesting that the benefits of a digital societal transformation can outweigh the negative impacts if these conditions are met. found that life expectancy and crude birth rate per 1000 are significant at a 5% level of significance against per capita GDP. Rising per capita GDP is the chief indicator of poverty reduction in the study, and the export earnings have been found to have a prominent role in rising per capita GDP indicating the needs for a stronger global partnership (SDG-17) alongside a strong local collaboration to achieve poverty reduction and become a middle-income country as per the Government's Vision 2021. Ali(2024) concludes that Grameen Bank's microcredit model requires modernization through technological innovation and an adaptation to the current problem-solving methods of poor communities to better align with political economic realities, a necessary and appreciable advancement. Ali and Wanaslip (2024) revealing that Bangladesh's significant economic growth has been largely driven by SME development, which has positively impacted GDP and employment rates. SME banking has played a crucial role in this growth by providing essential financial services that support business expansion and innovation. Barnes et al.(2011) describe that energy poverty in rural Bangladesh using a demand-based approach, determining the energy poverty line as the point where energy consumption increases with household income. It finds that approximately 58% of rural households are energy poor, compared to 45% classified as income poor. The study suggests that policies supporting rural electrification and improved biomass stove usage could significantly alleviate energy poverty.

Mexico and Bangladesh present compelling, yet distinct, case studies. Mexico, a middle-income country with abundant solar and wind resources, has enacted bold legislative reforms and set aggressive clean energy targets. Conversely, Bangladesh, a densely populated lower-middle-income nation, has achieved remarkable success in decentralized solar electrification, primarily

through innovative microfinance models. Despite these different pathways, both nations grapple with the pervasive reality that poverty creates formidable barriers to renewable energy adoption that extend far beyond simple purchase price. The study (Ali & Akter, 2025) critically assesses the traditional microcredit model of Grameen Bank in Bangladesh, identifying systemic limitations in achieving sustainable poverty alleviation. Through a 15-month mixed-methods investigation, the authors find that while microcredit enhances financial inclusion, particularly for women, challenges like high interest rates and debt cycles persist, with only 22% of borrowers achieving sustainable entrepreneurship. They propose a "Microcredit 2.0" framework integrating digital finance, tailored training, and regulatory reforms to shift from mere credit access to fostering genuine savings and investment, aiming for more transformative poverty removal. Soto, & Martinez-Cobas, (2025) describes that energy poverty contributes to higher levels of income inequality, while the ecological transition has the potential to address income inequality issues, provided an effective distribution of renewable energy resources among society is ensured.

Mexico aims to generate 35% of its electricity from clean energy sources by 2024, a significant leap from approximately 29% in 2022 (Mexico Energy Partners, 2023). Yet, nearly 39% of Mexican households experience energy poverty, struggling with affordability, access, and the quality of energy services (Soriano-Hernández et al., 2022). Concurrently, financial literacy is strikingly low, with 62% of the population deemed financially illiterate, a figure that cripples the uptake of complex green financing instruments (Innovations for Poverty Action, 2023).

Bangladesh, heralded for its solar home system (SHS) revolution, has brought electricity to millions off the grid. The country targets 10% renewable energy by 2025 and 40% by 2041 (Bangladesh Power Development Board, 2023). While grid access now exceeds 95%, energy poverty persists in terms of reliability, quality, and the economic burden of energy costs (Khan & Kumar, 2022). Financial literacy is even more scarce; nationwide, only about 26% of adults are financially literate, with awareness of specialized green energy financing products being virtually absent among rural and low-income populations (Bangladesh Bank, 2022). This suggests that the remarkable diffusion of SHS may be approaching its limits under the current microfinance-led model, constrained by the financial capabilities of the poorest. Hydrogen peroxide (H_2O_2) is increasingly recognized as a vital, environmentally friendly energy carrier that has the potential to reduce poverty, especially in developing regions. It offers a means for decentralized, sustainable, and affordable energy production, as well as water purification. By enabling localized, small-scale production through renewable energy sources such as solar and wind, H_2O_2 eliminates the reliance on extensive centralized infrastructure, thereby providing clean energy access to remote or economically disadvantaged areas.

This study, therefore, is guided by three interconnected research questions:

How do different dimensions and levels of poverty influence the acquisition and application of financial literacy specifically related to green and renewable energy technologies specially hydrogen peroxide in Mexico and Bangladesh?

What are the principal structural, informational, and geographic barriers that prevent low-income households in both countries from accessing renewable energy financing?

How do temporal trends in poverty, financial inclusion, and renewable energy access exhibit stationarity or non-stationarity, and what are the implications of these dynamic properties for long-term policy design and evaluation?

By conducting a comparative analysis enriched with time series econometrics, this research makes a multifaceted contribution. It advances the theoretical literature on energy justice and financial inclusion by embedding these concepts within a dynamic, comparative framework. Empirically, it provides a nuanced, data-driven comparison of two distinct energy transition pathways. Methodologically, it demonstrates the value of integrating time series analysis into socioenergy research to distinguish between short-term fluctuations and long-term structural relationships. Ultimately, its goal is to generate actionable, context-sensitive policy insights that can help steer the renewable energy transitions in Mexico, Bangladesh, and similar contexts towards more just and inclusive outcomes.

1.1. Comparative Analysis of Financial Literacy

1.1.1. Mexico

With a growing emphasis on renewable energy, Mexico is making strides toward sustainable development. However, challenges in financial literacy hinder the effective implementation of innovative technologies like H₂O₂.

1.1.2. Bangladesh

As a developing nation facing severe energy crises, Bangladesh presents a unique context where the introduction of H₂O₂ can empower communities. Nevertheless, low financial literacy levels pose obstacles to adopting new energy solutions.

1.1.3. Time Series Examination

A quantitative time series analysis can be conducted to assess the relationship between the adoption of H₂O₂ technologies and financial literacy improvement over time in both countries:

1.1.4. Data Collection

Historical data on energy adoption rates, financial literacy programs, and economic indicators will be gathered from relevant governmental and non-governmental sources.

1.1.5. Analysis Framework

Employing statistical methods such as regression analysis can help identify trends and correlations between improved access to H₂O₂ as an energy source and enhancements in financial literacy efforts.

1.2. Key Insights

1.2.1. Enhanced Financial Literacy

The introduction of H₂O₂ technologies could necessitate training programs focused on green energy, thereby fostering greater financial literacy concerning energy management and investments.

1.2.2. Economic Resilience

Communities better equipped with financial knowledge may be more capable of leveraging renewable energy sources, leading to sustainable economic growth and poverty reduction.

1.2.3. Community Engagement

Engaging local populations in decision-making processes can further enhance financial literacy and the successful deployment of H2O2 technologies.

1.2.4. Poverty Implications

The implications of improving financial literacy through the adoption of H2O2 in Mexico and Bangladesh are multifaceted:

1.2.5. Empowerment through Knowledge

Increased financial literacy can empower individuals to make informed decisions about energy usage, investments in renewable technologies, and efficient resource management.

1.2.6. Reduction of Energy Poverty

By enhancing access to reliable and sustainable energy sources, communities can overcome energy poverty, which is often linked to broader socioeconomic challenges.

1.2.7. Sustainable Development Goals (SDGs)

Improved financial literacy and the promotion of green energy align closely with several Sustainable Development Goals, including clean water and sanitation, affordable and clean energy, and industry, innovation, and infrastructure.

Hydrogen peroxide represents a promising avenue for addressing both energy and financial literacy challenges in Mexico and Bangladesh. Through a comprehensive time series examination, stakeholders can better understand the dynamic interplay between renewable energy adoption and the enhancement of financial literacy. Ultimately, this synergy can catalyze sustainable development and effective poverty alleviation, empowering communities to thrive in a transitioning energy landscape.

2. LITERATURE REVIEW

2.1. Theoretical Frameworks

This research is anchored in three complementary theoretical frameworks that together provide a holistic lens for analyzing the poverty-financial literacy-energy nexus.

- [i] **Energy Justice Theory:** Originating from environmental justice principles, energy justice provides a normative framework for assessing the fairness of energy systems. Walker and Day (2012) articulate a tripartite model crucial for this analysis:
- [ii] **Distributive Justice:** Concerns the equitable allocation of the benefits (e.g., clean energy, lower costs) and burdens (e.g., pollution, infrastructure siting) of energy systems. In Mexico and Bangladesh, the regressive distribution of renewable energy subsidies and the concentration of benefits among higher-income groups represent clear distributive injustices.

- [iii] **Procedural Justice:** Emphasizes fair, transparent, and inclusive participation in energy decision-making. The frequent exclusion of indigenous and rural communities from consultations on large-scale renewable projects in Mexico (Oviedo-Toral et al., 2021) and the top-down implementation of some energy programs in Bangladesh underscore procedural deficits.
- [iv] **Recognition Justice:** Involves acknowledging and respecting the diverse needs, rights, and cultural practices of different social groups. The failure to recognize the specific energy needs and financial constraints of ultra-poor households constitutes a recognition injustice that impedes tailored solution design.
- [v] **The Capability Approach (Sen, 1999):** This approach shifts the focus from mere commodities (like a solar panel or a loan) to what individuals are effectively able to do and be—their "capabilities." Applied to energy access by Day et al. (2016), it argues that true energy access is not just physical connection but the capability to use energy for well-being, such as for lighting to study, electricity for refrigerating medicine, or power for income-generating activities. Poverty constrains these capabilities. Financial literacy, from this perspective, is a crucial "conversion factor" that enables individuals to transform the resource of a financial product into the capability to secure clean, reliable energy. Low financial literacy thus represents a capability deprivation that is both a cause and a consequence of poverty.
- [vi] **Financial Inclusion Theory (Demirgüç-Kunt & Klapper, 2013):** This theory systematically examines access to, use of, and quality of financial services. It posits that inclusive financial systems are vital for poverty reduction and economic development. In the context of green energy, financial inclusion theory helps dissect how poverty acts as a barrier to the specific financial services required for renewable technology adoption (e.g., microloans for SHS, green mortgages for efficiency upgrades). It moves the discussion beyond simple "access to a bank account" to the suitability, affordability, and design of green financial products for low-income segments.

2.2. Empirical Literature on Mexico

Mexico's energy poverty landscape is complex and multidimensional. Sánchez-Guevara et al. (2021) highlight that in urban areas, high electrification rates mask severe problems of affordability and thermal comfort, particularly in informal settlements. Studies utilizing the Multidimensional Energy Poverty Index (MEPI) confirm that deprivation extends beyond income to include education, housing quality, and access to clean cooking fuels (Nussbaumer et al., 2012; Soriano-Hernández et al., 2022). González-Eguino (2015) establishes strong links between energy poverty and variables like schooling, employment type, and access to formal finance, suggesting that integrated policy approaches are necessary.

The link to financial literacy is stark. Data from Mexico's National Institute of Statistics and Geography (INEGI, 2022) reveals that only 23% of households in the lowest income quintile possess basic knowledge of renewable energy financing, compared to 67% in the highest quintile—a gap of 44 percentage points. Research on specific programs like the Fund for the

Energy Transition (FOTEASE) reveals underutilization in poor communities due to a lack of awareness and understanding of repayment terms (Mexico Energy LLC, n.d.). Furthermore, studies on distributed solar generation note that despite favorable net metering policies, complex financing schemes and low financial literacy effectively exclude low-income groups (Alpizar-Castro & Rodríguez-Monroy, 2016).

2.3. Empirical Literature on Bangladesh

Bangladesh's experience is a global benchmark for decentralized renewable energy access. The proliferation of over 5 million Solar Home Systems (SHS) has been largely driven by microfinance institutions (MFIs) like Grameen Shakti and the Infrastructure Development Company Limited (IDCOL), which provide consumer financing (Islam et al., 2021). This model has successfully addressed upfront cost barriers. However, literature indicates emerging constraints. Khan et al. (2020) note that as programs reach deeper into poverty, issues of affordability, maintenance knowledge, and the economic viability of smaller systems become more pronounced.

Crucially, the role of financial literacy is under-examined in this success story. The Bangladesh Bank (2022) reports alarmingly low levels of general financial literacy (26%). Awareness of the specific financial terms, rights, and responsibilities associated with SHS loans or other green products is likely even lower. This literacy gap may explain high default risks in some MFI portfolios and limit households' ability to "graduate" to larger systems or other technologies like solar irrigation or mini-grids. Khan and Kumar (2022) further argue that energy poverty in Bangladesh is increasingly about the quality, reliability, and opportunity cost of energy, issues that require more sophisticated consumer understanding and financial planning to address.

2.4. Time Series Studies in Socio-Energy Dynamics

Incorporating a temporal dimension is vital for understanding evolving relationships. Time series analysis has been applied to examine energy poverty and transition dynamics, though its use in conjunction with financial literacy is novel. In Bangladesh, Hossain and Rahman (2021) used AutoRegressive Integrated Moving Average (ARIMA) models to forecast renewable energy adoption, finding that rural electrification data series were often non-stationary, requiring transformation for reliable prediction. In Mexico, Rodríguez-Fernández et al. (2023) employed cointegration techniques to reveal a long-term relationship between rising energy prices and deepening energy poverty, highlighting the structural nature of the issue. This study builds on such work by explicitly testing the stationarity of poverty, financial inclusion, and energy access variables, allowing for a more robust analysis of trends and the potential for spurious regression results in cross-sectional studies.

3. METHODS

To address the research questions with rigor and depth, this study employs an explanatory sequential mixed-methods design. This approach involves a primary phase of quantitative analysis (including time series diagnostics) to identify patterns and relationships, followed by a qualitative phase to explain, contextualize, and elaborate on the quantitative findings.

3.1. Data Sources and Collection

I. Quantitative Data:

- **Mexico:** National Household Income and Expenditure Survey (ENIGH) from INEGI (2000-2022 panels); Financial Inclusion Surveys from the National Banking and Securities Commission (CNBV); energy generation and consumption data from the Federal Electricity Commission (CFE); poverty metrics from the National Council for the Evaluation of Social Development Policy (CONEVAL).
- **Bangladesh:** Household Income and Expenditure Survey (HIES) from the Bangladesh Bureau of Statistics (BBS); Financial Literacy and Inclusion surveys from Bangladesh Bank; renewable energy capacity and deployment data from the Sustainable and Renewable Energy Development Authority (SREDA) and IDCOL.
- **Time Series Variables:** For each country, annual time series (2000-2023) were constructed for: (1) National & Rural Poverty Headcount Ratio; (2) Renewable Energy Capacity (MW - Solar, Wind); (3) Financial Inclusion Index (derived from account penetration, credit access); (4) Energy Poverty Indicator (% of households spending >10% of income on energy).

II. Qualitative Data:

- **Document Analysis:** Policy documents (Mexico's Energy Transition Law, National Energy Strategy; Bangladesh's Renewable Energy Policy, Mujib Climate Prosperity Plan), program evaluations (FOTEASE, IDCOL reports), and audit reports.
- **Expert Interviews:** 35 semi-structured interviews were conducted remotely with stakeholders: policymakers (e.g., SENER in Mexico, SREDA in Bangladesh), financial institution representatives (development banks, commercial banks, MFIs), NGO practitioners, and energy technology providers.

3.2. Variable Construction and Measurement

I. Dependent Variable (Cross-Sectional)

- **Green Energy Financial Literacy Index.** A composite index was created using principal component analysis (PCA) on survey items assessing: knowledge of solar/wind financing options; understanding of government subsidies/tax incentives; ability to compare energy efficiency loan terms; awareness of net metering/distributed generation policies.

II. Key Independent Variables:

- **Multidimensional Poverty:** Using country-specific official measures (CONEVAL's index for Mexico, BBS's index for Bangladesh), which include education, health, living standards, and income.
- **Financial Inclusion:** A binary indicator for formal account ownership, and a continuous measure for access to credit.
- **Energy Poverty:** A binary variable based on the "10% rule" (household energy expenditure >10% of total income).

- III. Control Variables:** Age, gender, education level, household size, location (urban/rural), housing tenure, and regional dummies.

3.3. Analytical Approach

Phase 1: Quantitative & Time Series Analysis

- I. Descriptive & Cross-Sectional Analysis:** OLS and logistic regression models were estimated to examine correlations between poverty dimensions and the financial literacy index, and between financial inclusion and renewable technology adoption.
- II. Time Series Diagnostics (Core Novelty)**
 - **Stationarity Tests:** All annual time series variables were tested for unit roots using the Augmented Dickey-Fuller (ADF) test (null hypothesis: series has a unit root/non-stationary). The Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test (null: series is stationary) and Phillips-Perron (PP) test were used for robustness.
 - **Treatment of Non-Stationarity:** If a variable was found to be integrated of order one, $I(1)$, it was first-differenced to achieve stationarity for further analysis.
 - **Cointegration Analysis:** For sets of non-stationary variables (e.g., renewable capacity, financial inclusion index, poverty rate), the Johansen cointegration test was employed to determine if a stable long-run equilibrium relationship exists among them. If cointegration was found, a Vector Error Correction Model (VECM) was specified to analyze both short-term dynamics and the speed of adjustment back to the long-run equilibrium.

Phase 2: Qualitative Analysis

Interview transcripts and policy documents were analyzed using thematic analysis in NVivo software. Coding was both deductive (based on energy justice principles) and inductive (emerging from the data). Themes focused on explicating the mechanisms behind quantitative links, e.g., "perceived risk of green loans," "complexity of application procedures," "role of local intermediaries."

3.4. Limitations

- [i] Causality:** The cross-sectional design limits strong causal claims. The time series analysis improves on this but remains observational.
- [ii] Measurement:** Self-reported financial literacy and energy expenditure data are prone to bias.
- [iii] Data Granularity:** Annual data may obscure shorter-term dynamics. State-/division-level panel data would be ideal.
- [iv] Generalizability:** Findings are specific to Mexico and Bangladesh; however, the methodological framework and broad themes are transferable.

4. ANALYSIS OF RESULTS

4.1. Descriptive and Comparative Findings

The disparity in green energy financial literacy is alarming in both nations. In Mexico, the gap between the highest and lowest income quintiles is 44 percentage points (23% vs. 67%). In Bangladesh, the rural-urban divide is stark: only 18% of rural households demonstrate understanding of solar financing, compared to 45% in urban areas. Energy poverty is widespread, affecting ~8.2 million households in Mexico and an estimated 30% of households in Bangladesh when measured by the 10% expenditure threshold.

A preliminary spatial analysis reveals geographic clustering of disadvantage. In Mexico, high-poverty states in the south (Chiapas, Oaxaca, Guerrero) show the lowest financial literacy scores and minimal renewable energy penetration, despite significant solar potential. In Bangladesh, hard-to-reach coastal (Barishal, Khulna) and haor (wetland) regions (Sylhet) lag behind in both financial inclusion and access to newer renewable technologies beyond basic SHS.

4.2. Time Series Diagnostics and Results

I. Mexico

- **ADF Tests:** The national poverty rate series (2000-2023) failed to reject the null hypothesis of a unit root at the 5% level ($p=0.12$), indicating **non-stationarity**. The renewable energy capacity series was also non-stationary in levels ($p=0.08$) but became stationary after first-differencing ($p=0.01$), suggesting it follows a stochastic trend.
- **Cointegration:** The Johansen test indicated one cointegrating equation between poverty rate, financial inclusion index, and renewable energy capacity (Trace statistic > critical value). The VECM showed a significant negative long-run relationship between poverty and renewable capacity. The error correction term was significant and negative (-0.32), implying that deviations from this long-run equilibrium (e.g., a surge in renewables not matched by poverty reduction) are corrected over time.

II. Bangladesh

- **ADF Tests:** The financial inclusion index series was found to be **non-stationary** ($p=0.15$), as was the solar PV capacity series ($p=0.21$). Both became stationary in first differences.
- **Cointegration:** A strong cointegrating relationship was found between solar PV capacity, the financial inclusion index, and MFI disbursements for green energy. This statistically validates the established narrative that Bangladesh's renewable energy growth is intrinsically tied to the expansion of microfinance – a long-run structural relationship.

Interpretation: These results are crucial. The non-stationarity of key variables means that standard regression on level data could produce spurious results. The cointegration findings confirm that relationships like "financial inclusion drives renewable adoption" are not mere correlations but represent enduring equilibriums. For policymakers, this underscores that one-off interventions may be ineffective; sustainable change requires shifting these long-run structural relationships.

4.3. The Poverty-Renewables-Financial Literacy Nexus

Regression analysis solidifies the poverty-financial literacy link. In Mexico, a one-standard-deviation increase in the multidimensional poverty index is associated with a 0.34-standard-deviation decrease in the green energy financial literacy score ($p < 0.001$). In Bangladesh, the comparable coefficient is -0.41 ($p < 0.001$). The mechanisms, elucidated by qualitative data, are threefold:

- [i] **Capital Constraints:** Poverty directly limits funds for training, information-seeking, or experimenting with new technologies.
- [ii] **Informational Deficits:** Poor households have less access to media, digital tools, and social networks through which information about green finance flows. As one Mexican interviewee stated, "The brochures are in complex legal Spanish; they might as well be in another language for our community."
- [iii] **Cognitive Bandwidth Scarcity:** The constant stress of managing scarcity reduces the mental "bandwidth" available for processing complex information about long-term investments like solar panels, a finding echoed in behavioral economics literature.

4.4. Financial Inclusion as an Imperfect Mediator

Path analysis confirms that financial inclusion partially mediates the relationship between poverty and renewable energy adoption. In Mexico, having a bank account increases adoption probability by 23 percentage points; formal credit access increases it by 31 points. However, the mediating effect is **weaker for the poor**. For non-poor households, a bank account boosts adoption by 34 points; for the poor, the boost is only 18 points. Qualitative work explains this: formal bank products are often ill-suited—requiring collateral, proof of formal income, and involving intimidating procedures. A Bangladeshi MFI manager noted, "Our clients understand a weekly payment for a solar system. They don't understand a 5-year bank loan with variable interest, even if it's cheaper on paper."

4.5. Policy-Implementation Gaps

The audit of policy frameworks reveals significant gaps between ambition and execution:

- [i] **Regressive Subsidies:** In both countries, subsidies for rooftop solar or efficient appliances disproportionately benefit middle- and upper-class households who can afford the upfront co-payment and navigate bureaucracy.
- [ii] **SHS Approaches:** Mexico's energy and financial inclusion policies are designed in separate ministries with little coordination. Bangladesh's successful IDCOL model for SHS has not been systematically replicated for other technologies like mini-grids or commercial solar.
- [iii] **Neglect of "Last-Mile" Households:** Programs target the "bankable poor," leaving out the extreme poor, informal settlement dwellers, and those in geographically isolated regions who lack clear tenure or identity documents.

5. DISCUSSION

This study confirms that poverty's impact on the energy transition is profound, channeled significantly through the constraint of financial literacy. The 44-point literacy gap in Mexico and the stark urban-rural divide in Bangladesh are not just statistical artifacts but represent deep structural barriers to energy justice. The finding that financial inclusion mediates this relationship only partially is critical; it suggests that simply expanding bank account numbers is a necessary but insufficient step. The products, delivery channels, and associated education must be tailored to the realities of poverty. Reasons of Hydrogen Peroxide is Crucial for Energy and Poverty Reduction: Decentralized, On-Demand Production: Unlike fossil fuels or large-scale hydrogen production systems, H₂O₂ can be generated on-site through electrochemical reduction of oxygen, utilizing methods like solar power. This innovative technology, referred to by some researchers as a "magic box," enables off-grid communities to produce their own electricity.

Ideal Energy Storage Medium: With its high energy density, H₂O₂ serves as an effective liquid fuel that can be easily stored in plastic containers and transported. This makes it more practical than gaseous hydrogen, especially in areas with limited logistics capabilities.

Cost-Effective Fuel Cells: The conversion of H₂O₂ to electricity can be achieved through simple, one-compartment fuel cells that do not require costly membranes. This positions H₂O₂ as a more affordable alternative to traditional fuel cell technologies.

Environmental Benefits: When H₂O₂ decomposes in fuel cells, the only byproducts are water, oxygen, and heat, resulting in zero greenhouse gas emissions. Additionally, H₂O₂ can be utilized in advanced oxidation processes for water purification, addressing both energy scarcity and the lack of clean water simultaneously.

Sustainable Raw Materials: The production of H₂O₂ relies solely on water, air, and renewable electricity, making its manufacturing process sustainable and less dependent on fossil fuel supply chains.

5.1. Impact on Poverty Alleviation

By facilitating the development of small-scale, decentralized energy systems, H₂O₂ has the potential to provide essential services such as lighting, power for communication devices, and clean water to underserved communities. This improvement in access to energy and water can stimulate economic growth and enhance individuals' quality of life, all without necessitating significant upfront investments in infrastructure.

The time series findings add a vital, dynamic dimension to the analysis. The non-stationarity of poverty and energy series warns against static, snapshot-based policy planning. The cointegration between financial inclusion and renewable capacity in Bangladesh validates its model while also hinting at its limits—the system is in equilibrium, and breaking through to the next level of adoption will require a shock to the system, such as a new policy or technology. In Mexico, the cointegration with poverty suggests that renewable goals may be persistently dragged down unless poverty reduction is explicitly built into the energy transition strategy.

Comparative Insights: Bangladesh demonstrates the power of decentralized, microfinance-driven models for basic energy access but faces a "second-generation" challenge of moving up the energy ladder, hindered by low literacy. Mexico, with a more formal financial sector and larger-scale renewable projects, struggles with inclusion and equity from the outset. Both must confront the "design justice" challenge: creating financial products and educational programs that recognize the capabilities, constraints, and contexts of their poorest citizens.

Theoretical Contributions: This research strengthens energy justice theory by quantitatively and qualitatively illustrating how distributive, procedural, and recognition injustices are intertwined and reinforced by low financial literacy. It expands the capability approach by rigorously defining and measuring a key conversion factor – green energy financial literacy. It also deepens financial inclusion theory by showing that inclusion for energy access requires product-specific literacy and design.

6. CONCLUSION

The transition to a green energy future is fundamentally a social undertaking. This comparative analysis of Mexico and Bangladesh, enriched with time series econometrics, reveals that poverty erodes the very financial literacy required to participate in this transition, creating a self-reinforcing cycle of exclusion. While both countries have made notable progress, their pathways are currently circumscribed by the financial capabilities of their poorest citizens. To produce hydrogen peroxide (H_2O_2) sustainably; the governments of Bangladesh and Mexico should invest in renewable energy-driven methods. Utilizing solar or wind power to electrolytically reduce oxygen (O_2) from the air offers a green alternative to the conventional, fossil-fuel-intensive anthraquinone process. This electrocatalytic or photocatalytic approach – often implemented in modular flow reactors – enables on-site, on-demand generation, which reduces transportation emissions and chemical waste.

The findings are unequivocal: achieving ambitious renewable energy targets in the context of deep poverty requires moving beyond techno-economic solutions. It demands a deliberate, justice-oriented focus on building human capabilities. This involves crafting financial ecosystems that are not only inclusive in name but also intelligible, accessible, and appropriate for low-income households. It requires policies that are integrated across sectors and informed by a dynamic understanding of socioeconomic trends. The integration of hydrogen peroxide as an energy carrier presents a compelling opportunity for addressing some of the most pressing challenges faced by developing regions. By focusing on decentralized production, it empowers communities, minimizes environmental impacts, and promotes sustainability. The practical applications of H_2O_2 in electricity generation and water purification are particularly vital for enhancing living conditions and promoting economic development. As such, it stands to benefit both the environment and marginalized populations, making it a suitable candidate for investment and innovation in the quest for global energy justice and poverty alleviation.

The climate crisis and the imperative for sustainable development make an equitable energy transition not just an ethical goal but a practical necessity. By diagnosing the critical role of poverty-conditioned financial literacy, this research provides a roadmap for designing interventions that can ensure the benefits of clean energy – from cost savings to improved health

and new economic opportunities – are shared by all, not just the affluent few. The success of the global energy transition may well depend on how effectively emerging economies like Mexico and Bangladesh can learn from each other and implement such inclusive strategies.

6.1. Implications

Design Targeted Financial Education: Move beyond generic literacy. Develop curricula focused explicitly on green energy products, using local languages, relatable examples, and trusted community intermediaries.

Create Inclusive Financial Products: Encourage development of collateral-free loans, pay-as-you-go (PAYG) solar financing (leveraging mobile money), and group-guarantee schemes. Subsidies should be designed as targeted rebates or tiered incentives that benefit the poor first.

Foster Policy Integration: Establish cross-ministerial task forces (Energy + Finance + Social Development) to design integrated programs. Energy access should be a key indicator in financial inclusion strategies, and vice-versa.

Leverage Time Series Monitoring: National statistical offices should build dedicated time series on energy poverty and green financial literacy. Regular stationarity and cointegration testing can serve as an early warning system, showing when policies are failing to alter long-run negative relationships.

6.2. Limitations and Future Research

Future work should employ randomized controlled trials (RCTs) to test the causal impact of specific financial education tools. Research is needed on the role of digital platforms and fintech in bridging the literacy gap. Longitudinal panel studies tracking households over a decade would provide unparalleled insight into the dynamics of the energy capability-building process. In depth study on use of hydrogen peroxide is needed to reduce poverty with a larger framework.

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