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Developing Financial Inclusion Strategies through Technology and Policy to Improve Energy Access for Underserved Communities

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ABSTRACT

Access to affordable and reliable energy remains a significant challenge for underserved communities, particularly in developing regions. Financial constraints, lack of investment, and inadequate policy frameworks hinder the widespread adoption of modern energy solutions. This paper explores the role of financial inclusion strategies, driven by technology and policy interventions, in improving energy access for marginalized populations. By integrating digital financial services, decentralized energy systems, and innovative policy measures, this study proposes a comprehensive framework to bridge the energy gap. The proposed framework focuses on leveraging financial technology (FinTech), mobile banking, and blockchain-based microfinancing to enhance accessibility to clean energy solutions. Digital payment platforms and mobile-based credit scoring models facilitate microloans for renewable energy adoption, empowering low-income households and small enterprises. Blockchain technology ensures transparency, security, and accountability in financial transactions, reducing the risks of fraud and inefficiencies in energy financing. Policy interventions play a crucial role in fostering financial inclusion and energy accessibility. Targeted subsidies, regulatory reforms, and public-private partnerships are essential for creating an enabling environment. Governments and financial institutions must collaborate to design policies that incentivize investment in decentralized energy projects, such as mini-grids and off-grid solar solutions. Additionally, carbon credit markets and green bonds can provide sustainable financing mechanisms for long-term energy development. A case study analysis highlights successful implementations of technology-driven financial inclusion models in regions with limited energy access. Results demonstrate that integrating

mobile financial services and decentralized energy solutions leads to increased energy affordability, economic empowerment, and improved quality of life. The findings underscore the need for a multi-stakeholder approach, combining technological innovation, policy support, and community engagement to drive sustainable energy inclusion. This study contributes to the discourse on financial inclusion and energy sustainability by proposing a data-driven and policy-oriented approach. Future research should explore the scalability of digital financial services in emerging markets and the long-term impact of financial inclusion strategies on energy equity.

Keywords: Financial Inclusion, Energy Access, Underserved Communities, FinTech, Blockchain, Microfinance, Renewable Energy, Policy Interventions, Digital Payment Systems, Sustainable Development.

INTRODUCTION

Access to reliable and affordable energy remains a significant challenge for underserved communities across the globe, particularly in low-income and rural areas where infrastructure is lacking or inadequate. These communities often face persistent barriers such as high upfront connection costs, limited financing options, and a lack of supportive policy frameworks, all of which contribute to energy poverty and hinder social and economic development (Ozobu, et al., 2025). Despite global efforts to promote sustainable energy access, millions of people still live without electricity or rely on inefficient and hazardous energy sources for their daily needs.

Financial inclusion—defined as the availability and accessibility of affordable financial services to all individuals and businesses—is a critical enabler in the effort to expand energy access. Without access to credit, savings mechanisms, insurance, and payment systems, underserved populations are often unable to afford clean energy technologies or participate in emerging energy markets (Ajayi, et al., 2024, Ofodile, et al., 2024, Oyedokun, Ewim & Oyeyemi, 2024). Financial exclusion deepens the divide between urban and rural areas and exacerbates social inequities, making it essential to address financial barriers as part of any sustainable energy access strategy.

Technology and policy together offer powerful tools to bridge the gap between energy services and the financially excluded. Innovations such as mobile banking, pay-as-you-go (PAYG) energy systems, blockchain-based financing, and digital microloans have begun to redefine how energy services can be delivered and financed (Odio, et al., 2025). At the same time, targeted policy interventions—such as subsidies, public-private partnerships, and regulatory reforms—can create enabling environments that support inclusive energy financing models. By integrating technology and policy, stakeholders can develop scalable, context-specific solutions that not only expand energy access but also promote economic empowerment and resilience in underserved regions (Atta, et al., 2021, Ofodile, et al., 2020, Sobowale, et al., 2021).

This study aims to explore the intersection of financial inclusion, technological innovation, and policy development in the context of energy access. It investigates how these components can work together to create inclusive, sustainable energy solutions that address the unique needs of marginalized

communities. The paper examines current challenges, evaluates existing initiatives, and proposes a framework for leveraging digital finance and policy tools to enhance energy access outcomes (Okeke, et al., 2023, Oluwafunmike, et al., 2023).

The structure of the paper begins with a detailed analysis of energy access barriers in underserved communities, followed by a review of financial inclusion principles and their relevance to the energy sector. It then explores the roles of technology and policy in mitigating energy and financial inequalities, presents case studies and best practices, and finally, offers recommendations for designing integrated strategies that can be implemented at scale to improve energy access and financial resilience (Fredson, et al., 2025).

Methodology

This study adopts a Systematic Literature Review (SLR) methodology to explore and synthesize the evolving landscape of financial inclusion strategies and frameworks. The SLR approach was chosen due to its rigorous and replicable process, allowing for the comprehensive identification, evaluation, and integration of existing research evidence. A structured research question was developed to guide the review process: "What are the key elements, strategies, and outcomes associated with financial inclusion frameworks globally, and how can they inform an effective model?"

An extensive search was conducted across multiple databases including Scopus, Web of Science, ScienceDirect, JSTOR, Google Scholar, and EBSCOhost. The search strategy incorporated keywords and Boolean operators such as "financial inclusion" AND "strategy" OR "framework" OR "policy" OR "model" AND "access to finance" OR "unbanked" OR "financial services." To ensure the relevance of literature, the inclusion criteria were defined to select peer-reviewed journal articles, conference proceedings, working papers, and institutional reports published in English between 2013 and 2023. Studies outside this range or lacking relevance to financial inclusion strategy development were excluded.

The screening process began with the removal of duplicate records, followed by a review of titles and abstracts to assess relevance. Studies that met the criteria were subjected to a full-text review to ensure alignment with the research objectives. The final sample consisted of 84 publications that addressed the core dimensions of financial inclusion strategies.

Data from the selected studies were extracted systematically using a standardized template that captured key themes, conceptual frameworks, policy recommendations, research methods, and geographic focus. The extracted data were then synthesized using a thematic analysis approach to identify recurring patterns, conceptual clusters, and knowledge gaps in the literature.

The findings were analyzed to reveal common components of financial inclusion frameworks, including digital financial services, regulatory environments, socio-economic enablers, public-private partnerships, and financial literacy initiatives. The synthesis also highlighted differences in regional approaches, levels of financial infrastructure, and population segments targeted.

The results were integrated into a conceptual model that proposes a layered Financial Inclusion Strategy Framework. This model incorporates foundational enablers, implementation mechanisms, and impact assessment metrics. The final framework is designed to serve as a guide for policymakers, development practitioners, and financial institutions aiming to enhance inclusive financial systems.

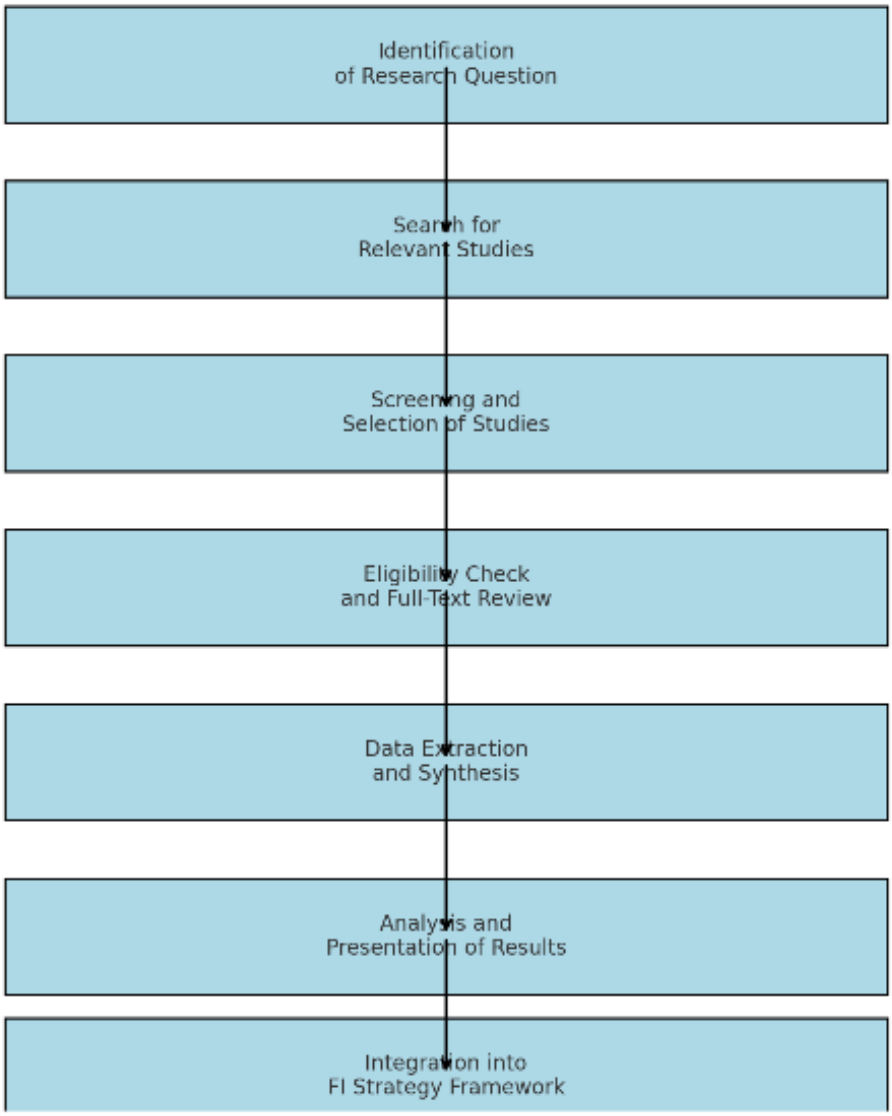

Figure 1: PRISMA Flow chart of the study methodology

Barriers to Energy Access in Underserved Communities

Energy access remains a critical development issue in many underserved communities around the world. Despite growing awareness and efforts to expand electricity coverage, millions of people—particularly in rural and low-income urban areas—continue to live without reliable, affordable, or sustainable energy services (Ajiva, Ejike & Abhulimen, 2024, Ogunbiyi-Badaru, et al., 2024). These communities face a complex web of interrelated barriers that hinder the development and adoption of energy infrastructure, technologies, and services (Ozobu, et al., 2025). Financial constraints, lack of investment, policy shortcomings, and socioeconomic challenges all contribute to the persistent energy access gap, necessitating a multidimensional approach to overcome them (Akhigbe, et al., 2023, Okeke, et al., 2023).

Financial constraints and affordability issues are among the most immediate and visible obstacles to energy access in underserved communities. For many households, the upfront cost of connecting to the national grid, installing solar systems, or purchasing clean cooking technologies is prohibitively high (Atta, et al., 2024, Olorunyomi,et al., 2024, Paul, et al.,

2024). Even when energy systems are available, ongoing costs such as electricity tariffs, fuel, maintenance, and service fees can place an unsustainable burden on low-income families (**Ogunnowo, et al., 2025**). With limited income and competing priorities like food, healthcare, and education, energy services are often deprioritized (Akintobi, Okeke & Ajani, 2022, Oham & Ejike, 2022). The situation is further worsened by the informal nature of employment in these communities, where incomes are not only low but also irregular and unpredictable, making it difficult for residents to commit to long-term payments or financing plans for energy products.

Another significant barrier is the lack of access to credit and investment for energy infrastructure development. Underserved communities often exist in areas that are deemed high-risk or low-return by traditional financial institutions. As a result, banks and investors are reluctant to provide loans or equity financing for energy projects in these regions, especially when those projects involve small-scale, decentralized systems like mini-grids or solar home systems (Ajiga, et al., 2024, Ogunnowo, et al., 2024, Uchendu, Omomo & Esiri, 2024). Even when financing is theoretically available, stringent requirements such as collateral, formal identification, and stable income disqualify many residents and local entrepreneurs from accessing funds (Oyenuga, Sam-Bulya & Attah, 2025). This credit gap not only limits consumer access to energy products but also stifles the growth of energy startups and local service providers who could otherwise deliver innovative solutions tailored to community needs.

The physical and economic challenges associated with grid expansion and decentralized energy systems also present formidable obstacles. Extending the national grid to remote or sparsely populated areas is often logistically complex and financially unviable. The terrain may be difficult, the distances vast, and the population density too low to justify the capital expenditure (Ayorinde, et al., 2024, Oke, et al., 2024, Paul, Ogugua & Eyo-Udo, 2024). In these cases, decentralized energy solutions—such as off-grid solar systems, mini-grids, or bioenergy technologies—are often more appropriate. However, these systems are not without cost. The initial setup, procurement of equipment, technical expertise for installation and maintenance, and the need for community-level energy management all add to the financial burden (Ogunsola, et al., 2025). Without adequate subsidies, financing options, or supportive policy frameworks, the deployment of these decentralized systems remains limited, despite their potential to deliver rapid and flexible energy access in hard-to-reach areas. (Alabi, et al., 2024, Okeke, et al., 2024, Oyenuga, Sam-Bulya & Attah, 2024)

Compounding these challenges are significant policy and regulatory gaps in energy financing, particularly in regions where governance structures are weak or fragmented. In many countries, energy policies do not adequately address the financial needs of low-income or rural populations (Oluokun, et al., 2025). Subsidies are often poorly targeted or fail to reach the most vulnerable groups, while public financing mechanisms may prioritize large-scale infrastructure projects over decentralized or community-based energy solutions. Furthermore, the lack of clear guidelines for integrating private sector participation in energy financing discourages investment and innovation (Adewoyin, Adediwin & Audu, 2025). Regulatory barriers such as restrictive licensing, inconsistent tariff policies, or cumbersome approval processes can also delay or derail energy projects that seek to serve underserved communities. Without a coherent policy and regulatory environment, efforts to scale up inclusive energy financing models face significant uncertainty and inefficiency (Okoro, Ikemba & Uzor, 2008, Olufemi-Phillips, et al., 2020). Agwu, 2021, presented in figure 2, Financial inclusion, technology and rural development model .

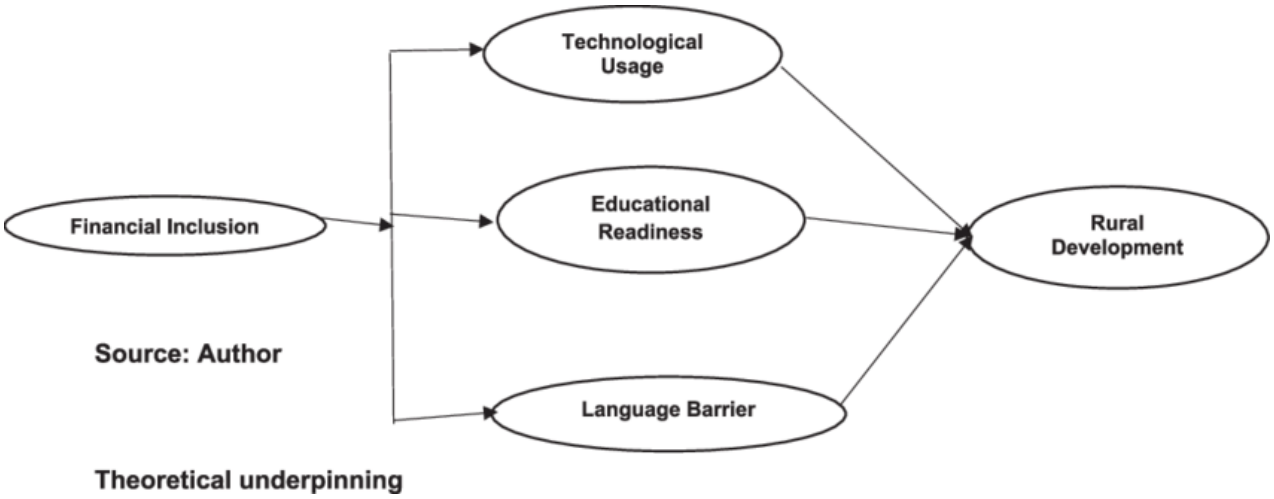

Figure 2: Financial inclusion, technology and rural development model (Agwu, 2021).

Socioeconomic challenges and digital illiteracy further reinforce the cycle of energy poverty in underserved areas. Many communities face broader development issues such as low education levels, high unemployment, poor health outcomes, and limited access to basic services. These conditions weaken household resilience and reduce the ability to invest in energy services (Attah, Ogunsola & Garba, 2023, Ogundeji,et al., 2023, Okeke, et al., 2023). In addition, a lack of awareness about the benefits of modern energy systems can lead to skepticism or resistance to adoption. Behavioral factors, such as the preference for traditional fuels or mistrust of new technologies, can also slow the uptake of cleaner energy alternatives.

Digital illiteracy presents another layer of complexity, especially as modern energy financing and service delivery models increasingly rely on digital platforms. Mobile-based payment systems, remote monitoring technologies, digital credit scoring, and online customer engagement tools have become critical components of last-mile energy solutions (Ajayi & Udeh, 2024, Oham & Ejike, 2024, Paul & Iyelolu, 2024). However, in many underserved communities, especially those with older populations or limited educational attainment, the ability to use these digital tools is constrained. People may not own mobile devices, lack internet access, or be unfamiliar with mobile money and other financial applications (Adewoyin, et al., 2025). As a result, even when digital solutions are technically available, their usage remains low, limiting their potential to democratize access to energy and financial services.

The intersection of these barriers creates a vicious cycle where poverty, exclusion, and limited access to services reinforce each other. Financial constraints prevent households and businesses from accessing energy; without energy, opportunities for education, income generation, and health improvement are limited; and without economic advancement, communities remain trapped in a state of underdevelopment (Agu, et al., 2024, Ogunnowo, et al., 2024, Sobowale, et al., 2024). Breaking this cycle requires a strategic and coordinated effort that combines financial inclusion, technology, and policy to create enabling environments for sustainable energy access (Oluokun, et al., 2025).

Efforts must be made to design inclusive financing mechanisms that account for the unique economic realities of underserved communities. These might include microloans, pay-as-you-go models, or savings groups that enable households to spread the cost of energy investments over time. At the same time, there is a need for increased public and private investment in decentralized energy infrastructure, supported by risk mitigation tools and blended

finance approaches that make projects more attractive to investors (Augoye, Muyiwa-Ajayi & Sobowale, 2024, Oyedokun, Ewim & Oyeyemi, 2024). Support framework for financial inclusion commitments and strategies: priorities, mechanisms presented by Pearce & Ortega, 2012, is shown in figure 3.

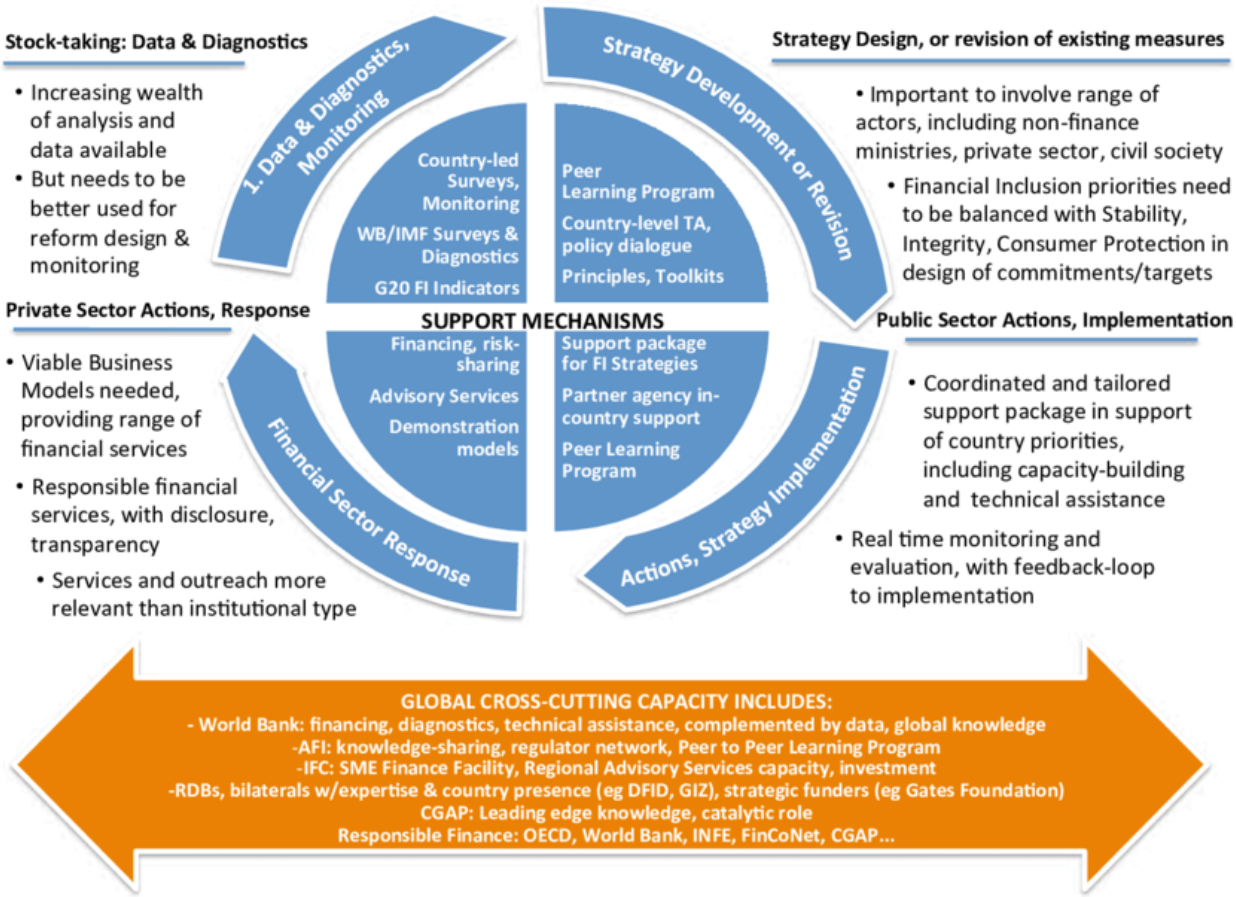

Figure 3: Support framework for financial inclusion commitments and strategies: priorities, mechanisms (Pearce & Ortega, 2012).

Policy reform is also essential. Governments should develop targeted energy access strategies that prioritize vulnerable populations and create incentives for private sector participation. Clear regulatory frameworks, standardized procedures, and transparent subsidy allocation can enhance the efficiency and effectiveness of energy programs. Capacity building and community engagement should also be prioritized to address knowledge gaps and build trust in new technologies and financial services (Atta, et al., 2024, Okoli, et al., 2024, Paul, Ogugua & Eyo-Udo, 2024).

Finally, addressing digital illiteracy must become a core component of energy and financial inclusion strategies. Digital literacy programs, user-friendly platforms, and the integration of local intermediaries or agents can help bridge the gap and ensure that technological innovations truly reach and benefit the communities most in need (Adikwu, et al., 2025).

In conclusion, the barriers to energy access in underserved communities are deeply intertwined with financial, infrastructural, policy, and social challenges. Understanding and addressing these barriers is a critical first step toward developing inclusive strategies that leverage technology and policy to improve energy access (Akintobi, Okeke & Ajani, 2023, Okeke, et al., 2023, Sam Bulya, et al., 2023). Without deliberate, coordinated, and inclusive action, underserved communities will continue to be left behind in the global energy transition,

perpetuating cycles of poverty and inequality (Oluokun, et al., 2025).

Theoretical and Technological Foundations

The development of financial inclusion strategies aimed at improving energy access for underserved communities draws upon a robust foundation of theoretical frameworks and technological innovations. Financial inclusion, in the context of energy access, refers to the ability of individuals and households—particularly those in low-income and remote areas—to access affordable and appropriate financial services that enable them to invest in and benefit from modern energy solutions (Okeke, et al., 2022, Oluwafunmike, et al., 2022). Without financial inclusion, the transition from traditional, inefficient energy sources to clean, reliable, and sustainable systems becomes unattainable for millions of people (Oyenuga, et al., 2025). Theoretical models of inclusive finance emphasize the importance of access, usage, and quality of financial services as key pillars for empowering marginalized populations and reducing energy poverty. Product ecosystem as presented by Damodaran, 2013, is shown in figure 4.

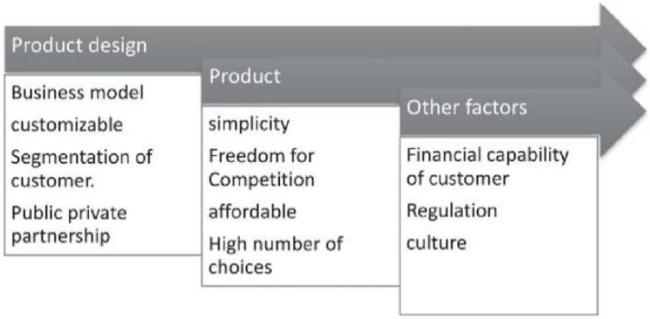

Figure 4: Product ecosystem (Damodaran, 2013).

At its core, financial inclusion in energy access is built on the recognition that energy services are not merely technical commodities, but essential enablers of economic participation and human development. The ability to access and utilize electricity or clean cooking fuel depends not only on physical infrastructure but also on the capacity of end-users to afford and sustain those services over time (Aigbedion, Ayorinde & Adebisi, 2025). This introduces the need for financial tools that cater to irregular incomes, low collateral availability, and limited financial literacy. Theoretical approaches, such as the capability approach, further support this view by highlighting the role of financial empowerment in expanding individual freedoms and improving quality of life (Ajiga, et al., 2024, Okon, Odionu & Bristol-Alagbariya, 2024, Urefe, et al., 2024). In this context, inclusive finance becomes a prerequisite for inclusive energy, and any effort to enhance energy access must be underpinned by mechanisms that address affordability, creditworthiness, and economic resilience.

Technology has become a transformative force in operationalizing financial inclusion for energy access. Financial technology, or FinTech, plays a central role by offering innovative solutions that overcome the traditional barriers to financial services in underserved communities (Oyegbade, et al., 2022, Popo-Olaniyan, et al., 2022). FinTech leverages mobile connectivity, digital platforms, data analytics, and automation to deliver financial products and services in cost-effective, user-friendly formats. These innovations are particularly impactful in regions where physical banking infrastructure is scarce or non-existent (Ajayi & Udeh, 2024, Ogunnowo, et al., 2024, Uchendu, Omomo & Esiri, 2024). By using technology to bridge geographical and institutional gaps, FinTech creates opportunities for individuals to save, borrow, insure, and pay for energy services through accessible and customized channels.

Digital banking, microfinance, and mobile money solutions are three interrelated FinTech pillars that have significantly advanced financial inclusion in energy-related sectors. Digital banking allows users to perform financial transactions via mobile applications or web interfaces, eliminating the need to travel to physical bank branches (Akhigbe, 2025). This is crucial for rural populations that may live hours away from the nearest financial institution. Through digital

accounts, users can store value, receive payments, and manage their finances conveniently and securely (Aminu, et al., 2024, Okorie, et al., 2024, Paul, Ogugua & Eyo-Udo, 2024).

Microfinance institutions (MFIs) have long been recognized for their role in providing small-scale loans to individuals who lack access to formal banking services. In the context of energy access, MFIs have evolved to offer tailored loan products for purchasing solar home systems, clean cookstoves, and other off-grid technologies (Ajayi, et al., 2024, Olawale, et al., 2024, Sam Bulya, et al., 2024). Some MFIs collaborate directly with energy service companies (ESCOs) to finance the deployment of energy assets, creating integrated models that combine product delivery with financial support (Ayorinde, et al., 2024, Oham & Ejike, 2024, Uchendu, Omomo & Esiri, 2024). These models are designed to accommodate the financial realities of low-income households, offering flexible repayment schedules, low-interest rates, and minimal collateral requirements.

Mobile money solutions represent one of the most impactful financial innovations in recent years. By enabling users to send, receive, and store money using mobile phones, mobile money platforms have opened financial pathways for millions of previously unbanked individuals (Apeh, et al., 2024, Olufemi-Phillips, et al., 2024, Udeh, et al., 2024). This technology is particularly powerful in supporting pay-as-you-go (PAYG) energy models, where customers make incremental payments for energy services, typically through their mobile wallets (Awoyemi, et al., 2023, Onukwulu, et al., 2023, Sam Bulya, et al., 2023). PAYG systems have become popular in Sub-Saharan Africa and South Asia, where they allow users to access solar lighting, phone charging, and small appliances without incurring prohibitive upfront costs. The integration of mobile money with energy services creates a seamless experience that enhances convenience, affordability, and reliability, while also generating digital transaction histories that can be used to assess creditworthiness over time (Akhigbe, et al., 2025).

Another promising technological foundation is blockchain technology, which offers secure, transparent, and tamper-proof systems for managing energy financing. In regions where trust in financial institutions is low or where records are fragmented, blockchain provides an immutable ledger that ensures accountability across all stakeholders (Al-Amin, et al., 2024, Onita & Ochulor, 2024, Soremekun, et al., 2024). Smart contracts—automated agreements coded into a blockchain—can be used to facilitate energy-related transactions, such as disbursing microloans for solar installations or releasing subsidies once pre-defined conditions are met (Attah, Ogunsola & Garba, 2023, Okeke, et al., 2023). This reduces the need for intermediaries, lowers transaction costs, and ensures that funds are used for their intended purposes.

Blockchain can also support community-based energy financing models, where groups of users pool resources to invest in shared energy infrastructure like mini-grids. By maintaining transparent records of contributions, usage, and payments, blockchain platforms enable decentralized governance and equitable access to benefits (Ajiga, et al., 2024, Oluokun, et al., 2024, Paul, Ogugua & Eyo-Udo, 2024). Moreover, tokenization—representing energy units or financial assets as digital tokens—can further streamline energy trading and create new financial instruments that support renewable energy investments at the grassroots level (Augoye, et al., 2025). Though still emerging, these applications hold significant potential for increasing the scalability and trustworthiness of energy financing mechanisms in underserved areas.

Equally important in the technological foundation of financial inclusion for energy access is the rise of decentralized energy systems. These systems—comprising solar home systems, mini-grids, and other off-grid solutions—represent a departure from centralized grid infrastructure and are uniquely suited

to the needs of remote or marginalized communities (Atta, et al., 2024, Olaleye, et al., 2024, Shittu, et al., 2024). One of the key advantages of decentralized systems is their modularity, which allows users to start with small installations and scale up based on their needs and financial capacity (Ajiva, Ejike & Abhulimen, 2024, Omowole, et al., 2024, Uchendu, Omomo & Esiri, 2024). This aligns well with inclusive financing models that emphasize incremental payments, microloans, and pay-per-use mechanisms.

Decentralized systems also benefit from reduced transmission losses, faster deployment times, and lower dependency on large-scale public investment. Technological advancements in energy storage, smart meters, and remote monitoring have further enhanced the performance and reliability of decentralized solutions (Ajiga, et al., 2024, Olawale, et al., 2024, Toromade, et al., 2024). For end-users, this means increased accessibility to electricity and reduced reliance on polluting and expensive energy sources like kerosene, charcoal, or diesel generators (Atta, et al., 2024, Okon, Odionu & Bristol-Alagbariya, 2024). When combined with digital financing tools, decentralized energy systems become even more affordable and manageable, empowering communities to take control of their energy needs and invest in sustainable livelihoods.

In conclusion, the theoretical and technological foundations of developing financial inclusion strategies to improve energy access are deeply interconnected. Financial inclusion theory emphasizes the role of affordable, accessible, and appropriate financial services in overcoming poverty and promoting development (Okeke, et al., 2022, Onukwulu, et al., 2022). Technological innovations—particularly those driven by FinTech—provide the means to operationalize these principles, making energy services more attainable for underserved communities (Awoyemi, et al., 2025). Digital banking, microfinance, mobile money, blockchain, and decentralized energy systems all contribute to an ecosystem that supports inclusive, scalable, and sustainable energy access. Future progress will depend on the continued integration of these technologies with supportive policies, robust infrastructure, and community engagement to ensure that the benefits of the energy transition reach those who need them the most (Ojebode & Onekutu, 2021, Okpeh & Ochefu, 2010, Sobowale, et al., 2021).

Strategic Framework for Financial Inclusion in Energy Access

Developing a strategic framework for financial inclusion in energy access involves integrating multiple components that align technological innovation with inclusive economic and policy systems (Apeh, et al., 2024, Omowole, et al., 2024, Sam Bulya, et al., 2024). As energy poverty continues to affect millions in underserved communities, particularly in rural and low-income regions, the ability to access and sustain clean, reliable energy services depends significantly on the availability of appropriate financial tools and supportive institutional frameworks (Daramola, et al., 2025). The proposed strategic framework includes five interconnected components: FinTech and digital financial services, blockchain-based energy financing, microfinance and alternative funding mechanisms, policy interventions, and community engagement with capacity building. Together, these elements offer a holistic approach to dismantling barriers to energy access while promoting financial empowerment and sustainability (Akintobi, Okeke & Ajani, 2022, Okeke, et al., 2022).

FinTech and digital financial services are central to the framework, offering scalable, cost-effective solutions to bridge the gap between financial exclusion and energy access. Mobile banking and digital payment platforms have revolutionized the way individuals manage their finances in regions where traditional banks are either absent or inaccessible. By enabling secure, low-cost

transactions, these platforms allow users to make incremental payments for energy services through pay-as-you-go (PAYG) models (Ajayi, 2024, Oham & Ejike, 2024, Oyedokun, et al., 2024). Customers can purchase solar lighting, charge phones, or access mini-grid power using mobile wallets, without needing upfront capital. This flexibility is particularly crucial for households with irregular incomes, providing them with a manageable and user-friendly way to afford modern energy technologies (Akinsooto, Ogundipe & Ikemba, 2024, Oriekhoe, et al., 2024).

In parallel, artificial intelligence (AI)-driven credit scoring models enhance the reach and impact of microloan offerings for energy-related purchases. Traditional credit assessments often exclude individuals in informal employment or without a formal banking history. AI models can analyze alternative data sources—such as mobile phone usage patterns, payment histories, and social network interactions—to evaluate creditworthiness more accurately and inclusively (Attah, Ogunsola & Garba, 2022, Ogunnowo, et al., 2022). These data-driven insights enable lenders to offer small, unsecured loans to people who would otherwise be denied access to credit, thus expanding the customer base for energy service providers and supporting financial resilience among the underserved.

The second component of the strategic framework involves blockchain-based energy financing, which brings transparency, security, and efficiency to energy investments and transactions. Blockchain, a distributed ledger technology, allows all stakeholders in the energy value chain—consumers, producers, financiers, and regulators—to track and verify transactions in real time (Ajiga, et al., 2024, Okorie, et al., 2024, Uchendu, Omomo & Esiri, 2024). One promising application is the use of smart contracts for peer-to-peer (P2P) energy trading. In this model, individuals who generate surplus renewable energy (e.g., through solar panels) can sell excess power directly to neighbors using automated contracts stored on a blockchain platform (Digitemie, et al., 2025). These smart contracts execute transactions only when predetermined conditions are met, ensuring trust, accuracy, and fairness without the need for intermediaries.

Blockchain also enhances transparency and security in larger energy investments, particularly those involving public funds, development finance, or impact investors. Every financial transaction, from the disbursement of grants to the repayment of loans, can be recorded on the blockchain, creating an immutable audit trail. This not only reduces the risk of fraud and corruption but also builds investor confidence, enabling greater capital flows into clean energy projects in high-need areas (Okeke, et al., 2023, Onukwulu, et al., 2023, Oteri, et al., 2023). Additionally, blockchain can facilitate tokenized investments, allowing individuals or institutions to invest in fractional shares of renewable energy projects, further democratizing access to sustainable finance.

The third component of the framework centers on microfinance and alternative funding mechanisms that cater specifically to the unique needs of low-income populations and emerging markets. Community-based microfinancing has proven to be an effective model for deploying energy solutions in areas where formal banking is limited (Ajayi & Udeh, 2024, Okeke, et al., 2024, Paul, et al., 2024). Through savings groups, cooperatives, or rotating credit associations, communities can pool resources to invest in shared solar home systems or mini-grid installations (Ajiva, Ejike & Abhulimen, 2024, Oluwafunmike, et al., 2024). These local structures foster trust, accountability, and collective ownership, increasing the likelihood of project success and long-term sustainability.

Complementing grassroots financial efforts are global and national mechanisms such as green bonds and carbon credit markets. Green bonds are debt

instruments issued to finance environmentally friendly projects, including renewable energy infrastructure. By tapping into institutional investment pools, green bonds can channel significant resources toward clean energy development in underserved regions (Ayanponle, et al., 2024, Oluokun, et al., 2024, Umana, Garba & Audu, 2024). Similarly, carbon credit markets offer a way for energy projects that reduce emissions—such as solar mini-grids replacing diesel generators—to earn revenue by selling carbon offsets. These financial flows provide new revenue streams for sustainable energy initiatives and can help subsidize the cost of access for low-income users (Oyedokun, 2019, Oyegbade, et al., 2021, Sulaiman, Ikemba & Abdullahi, 2006).

Effective financial strategies must also be grounded in robust policy interventions and regulatory frameworks, which form the fourth component of the strategic framework. Government incentives and subsidies play a vital role in making renewable energy projects financially viable and socially equitable (Ajayi, et al., 2021, Olutimehin, et al., 2021). These can include tax breaks for solar equipment, performance-based grants for mini-grid developers, or subsidies for low-income households to cover connection costs (Egbuhuzor, et al., 2025). Importantly, such incentives must be designed to target the most vulnerable populations and should be disbursed transparently to avoid market distortion.

Public-private partnerships (PPPs) are another strategic tool for scaling energy access. By combining public sector support with private sector efficiency and innovation, PPPs can mobilize investment for energy infrastructure development in underserved areas. Governments can de-risk investments by providing guarantees, co-financing arrangements, or facilitating access to land and permits (Atta, et al., 2024, Okon, Odionu & Bristol-Alagbariya, 2024). Meanwhile, the private sector brings technological expertise, business models, and operational capacity to deploy and maintain energy systems at scale. Regulatory clarity and consistent enforcement are essential to support these partnerships, ensuring that energy providers can operate in a predictable environment while protecting consumer rights (Arinze, et al., 2024, Olufemi-Phillips, et al., 2024).

The final and perhaps most critical component of the framework is community engagement and capacity building. Financial inclusion and energy access cannot be achieved without investing in people's knowledge, confidence, and agency. Financial literacy programs are essential to help low-income households understand and use digital financial tools, manage budgets, and make informed decisions about energy investments (Aminu, et al., 2024, Onita & Ochulor, 2024). These programs should be delivered in local languages, tailored to the socio-economic context, and supported by community-based facilitators or trusted local organizations.

Additionally, localized strategies for technology adoption ensure that energy solutions are not only technically appropriate but also culturally and economically acceptable. Community involvement in the planning, implementation, and monitoring of energy projects increases ownership and accountability (Atta, et al., 2024, Olaleye, et al., 2024, Temedie-Asogwa, et al., 2024). Training programs for local technicians, entrepreneurs, and service providers can also create employment opportunities and strengthen the local energy ecosystem. When communities are equipped with the knowledge and tools to maintain and expand their energy systems, the likelihood of long-term sustainability increases significantly Ajiga, Ayanponle & Okatta, 2022, Okeke, et al., 2022).

In sum, the strategic framework for financial inclusion in energy access integrates technological innovation, financial creativity, policy support, and community engagement to address the multifaceted barriers faced by underserved populations (Amafah, et al., 2023, Onita, et al., 2023, Udeh, et al., 2023). Each

component reinforces the others, creating a comprehensive system that enables low-income communities to access, afford, and sustain modern energy services (Ewim, et al., 2025). As the global push for universal energy access accelerates in line with the Sustainable Development Goals, frameworks like this offer a practical and inclusive roadmap for delivering transformative impact. For practitioners, policymakers, and investors alike, adopting such a strategy means not only lighting homes but also unlocking economic opportunities, improving health outcomes, and empowering communities to shape their own development futures (Akintobi, Okeke & Ajani, 2023, Ogunnowo, et al., 2023).

Case Studies and Best Practices

Across the globe, the intersection of financial inclusion, technology, and energy policy has produced several innovative and effective models for improving energy access in underserved communities. These models demonstrate that when appropriate financial strategies are combined with enabling technologies and supportive policy environments, it is possible to overcome the structural and economic barriers that have long prevented marginalized populations from accessing modern energy services (Ayorinde, et al., 2024, Omowole, et al., 2024, Urefe, Odonkor & Agu, 2024). A closer look at case studies from Africa, Asia, and Latin America offers valuable insights and best practices that can inform future initiatives and guide stakeholders aiming to bridge the energy access gap.

In Africa and Asia, FinTech-driven energy access projects have emerged as game changers, particularly in rural areas where traditional banking and grid infrastructure are limited or non-existent. One of the most widely cited examples is M-KOPA in East Africa. M-KOPA leverages mobile money and pay-as-you-go (PAYG) technology to provide off-grid solar solutions to low-income households in Kenya, Uganda, and Tanzania. Customers make small, daily payments via mobile platforms like M-Pesa, enabling them to gradually pay off the cost of a solar home system (Ayorinde, et al., 2024, Omowole, et al., 2024, Urefe, Odonkor & Agu, 2024). This model removes the upfront cost barrier and aligns with the cash flow patterns of low-income users who earn and spend money daily. M-KOPA's integration of digital credit scoring allows the company to extend additional services and products—such as smartphones and solar-powered appliances—based on a customer's repayment history, fostering a deeper level of financial inclusion.

Another exemplary project is India's Simpa Networks, which offers similar solar-as-a-service models in rural areas of the country. Simpa's innovation lies in its "Progressive Purchase" system, where customers make a down payment for a solar energy system and then prepay for energy in small increments using mobile payments (Ajiva, Ejike & Abhulimen, 2024, Orieno, et al., 2024). Each payment contributes toward ownership of the system, turning energy consumers into asset owners. This creates a sense of empowerment and long-term investment, while also building financial discipline and creditworthiness among users (Ewim, et al., 2025). Both M-KOPA and Simpa illustrate how FinTech can enable flexible, customer-centric financing mechanisms that are scalable, sustainable, and responsive to the needs of underserved communities.

In Bangladesh, Grameen Shakti has combined microfinance with clean energy deployment by offering loans for solar home systems, biogas plants, and improved cookstoves. As a subsidiary of the Grameen Bank, which pioneered microcredit, Grameen Shakti employs a highly localized approach, using trained technicians and community workers to install and maintain systems while also providing financing through its extensive rural network (Al Zoubi, et al., 2022, Okeke, et al., 2022, Sobowale, et al., 2022). The model has proven effective in addressing both energy poverty and financial

exclusion simultaneously, reaching millions of households and contributing to Bangladesh's broader success in expanding rural electrification.

While FinTech and community finance initiatives have led the way in Africa and Asia, Latin America has made significant progress through policy-driven energy inclusion initiatives. In countries like Brazil, Mexico, and Peru, governments have taken active roles in designing and implementing programs that expand energy access through targeted subsidies, infrastructure investment, and regulatory reforms (Ajayi & Udeh, 2024, Okeke, et al., 2024, Oyedokun, Ewim & Oyeyemi, 2024).

Brazil's "Luz para Todos" (Light for All) program, launched in 2003, is one of the most ambitious rural electrification efforts in the world. Backed by substantial government funding and executed in partnership with private utilities, the program extended electricity to over 16 million people in rural and remote areas (Atta, et al., 2024, Oluokun, et al., 2024, Sam Bulya, et al., 2024). The initiative provided subsidies to reduce connection costs for low-income households and prioritized marginalized communities, including indigenous populations and quilombolas (descendants of Afro-Brazilian slaves). Through strong political commitment, clear regulatory frameworks, and coordinated action between federal, state, and municipal levels, "Luz para Todos" demonstrated the effectiveness of policy as a driver of inclusive energy access (Ajiga, et al., 2024, Olorunyomi,et al., 2024, Shittu, et al., 2024).

Mexico's efforts through the Comisión Federal de Electricidad (CFE) have similarly prioritized rural and off-grid electrification. In addition to grid expansion, Mexico has invested in solar photovoltaic (PV) systems for isolated communities, supported by international financing and government subsidies. The establishment of clear tariff structures and a legal framework for energy access helped create a more predictable and attractive environment for private sector participation (Anjorin, et al., 2024, Onita & Ochulor, 2024, Usman, et al., 2024). These policy interventions, aligned with social equity goals, have improved energy coverage while also reinforcing the role of public institutions in facilitating inclusive development.

Peru offers a slightly different approach with its Rural Electrification Program, which combines policy and financial mechanisms to expand access. By establishing the Rural Electrification Fund and enabling concessional financing for decentralized energy providers, the Peruvian government has supported the growth of private and community-led mini-grids (Okeke, et al., 2022, Otokiti, et al., 2022). This model not only increased energy access but also encouraged innovation in energy service delivery. The use of performance-based incentives and technical assistance helped ensure that service providers remained accountable and efficient (Ayanponle, et al., 2024, Oriekhoe, et al., 2024).

A comparative analysis of decentralized energy financing models across these regions highlights the diversity of strategies and the importance of tailoring approaches to local contexts. In Africa and Asia, PAYG solar systems and microfinance-driven energy solutions have gained traction due to the high cost of grid extension, the presence of mobile money infrastructure, and the entrepreneurial dynamics of the off-grid energy sector (Ewim, et al., 2025). These models emphasize flexibility, customer ownership, and digital innovation, making them particularly suitable for areas with poor infrastructure but high mobile penetration.

In contrast, Latin America has leveraged stronger institutional frameworks and public financing capacity to implement large-scale electrification through centralized and decentralized approaches. The policy emphasis has been on ensuring equitable access through subsidies, legal rights to energy, and integration of energy access into national development plans (Okeke, et al., 2023, Onukwulu, et al., 2023, Oteri, et al., 2023). While FinTech has a

growing presence in Latin America, especially in countries like Colombia and Chile, the dominant models have focused more on government-led coordination and regulatory clarity.

One important takeaway from these comparisons is the value of hybrid models that combine elements of FinTech, microfinance, and policy. For example, Nigeria's Rural Electrification Agency (REA) has supported mini-grid development through a mix of capital subsidies, performance-based grants, and support for digital payment systems (Eyo-Udo, et al., 2025). The Nigeria Electrification Project, financed by the World Bank and the African Development Bank, blends public funding with private investment to build sustainable business models for off-grid power (Akinsooto, Ogundipe & Ikemba, 2024, Oteri, et al., 2024, Udeh, et al., 2024). By integrating mobile money platforms and data-driven consumer insights, the project aligns with global best practices while addressing the specific challenges of energy access in Nigeria's diverse and underserved regions (Ajiga, et al., 2024, Okorie, et al., 2024, Sam Bulya, et al., 2024).

Another emerging best practice is the use of blockchain and digital platforms to increase transparency and reduce costs in energy financing. Companies such as Power Ledger in Australia and Sun Exchange in South Africa have introduced blockchain-based platforms that facilitate peer-to-peer energy trading and crowd-investment in solar projects (Attah, Ogunsola & Garba, 2023, Okeke, et al., 2023). These platforms enable broader participation in the clean energy economy, particularly for individuals and communities that traditionally lack access to formal investment channels (Okeke, et al., 2022, Ozobu, et al., 2022, Popo-Olaniyan, et al., 2022).

In summary, the case studies from Africa, Asia, and Latin America show that financial inclusion strategies for energy access can take many forms, each shaped by local economic, technological, and policy conditions. Successful initiatives share common traits: they are inclusive, adaptable, community-focused, and supported by appropriate financing tools and enabling environments (Ajiva, Ejike & Abhulimen, 2024, Oyedokun, et al., 2024). The integration of digital technologies such as mobile banking, AI, and blockchain with targeted policy interventions creates powerful synergies that can accelerate energy access for the world's most vulnerable populations. Going forward, the replication and scaling of these best practices will depend on continued collaboration among governments, private sector players, civil society organizations, and the communities themselves (Ajayi, et al., 2024, Olawale, et al., 2024, Sam Bulya, et al., 2024). Through such partnerships, it is possible to realize the vision of universal, equitable, and sustainable energy access as a cornerstone of inclusive development (Eyo-Udo, et al., 2025).

Discussion and Implications

Developing financial inclusion strategies through technology and policy to improve energy access for underserved communities holds immense transformative potential, both economically and socially. Access to reliable, clean, and affordable energy is a foundational enabler of development, yet it remains elusive for hundreds of millions of people around the world (Alabi, et al., 2024, Omowole, et al., 2024). By addressing the financial barriers that prevent low-income and remote populations from adopting modern energy solutions, this approach not only promotes energy equity but also stimulates broader economic activity and resilience. The discussion surrounding these strategies reveals a complex interplay of opportunities, technological innovations, policy interventions, and challenges that must be addressed to realize inclusive and sustainable energy access at scale (Ariyibi, et al., 2024, Olaleye, et al., 2024, Soremekun, et al., 2024).

Improved energy access, facilitated through financial inclusion, yields significant financial and economic benefits for individuals, households, and

communities. At the household level, access to energy reduces dependence on expensive and inefficient traditional fuels such as kerosene, charcoal, or diesel, which often consume a disproportionate share of income and pose health and safety risks (Ajayi & Udeh, 2024, Oluokun, et al., 2024, Usiagu, et al., 2024). When households can switch to solar home systems, clean cookstoves, or mini-grid electricity, they typically experience lower energy expenditures over time and benefit from enhanced convenience, safety, and quality of life. In addition, energy access unlocks productivity, allowing small businesses to operate for longer hours, adopt machinery, and offer new services. Women, in particular, benefit economically from improved energy services, as they gain time, safety, and opportunities to participate in income-generating activities (Atta, et al., 2024, Okeke, et al., 2024, Oyenuga, Sam-Bulya & Attah, 2024).

On a broader scale, communities that gain access to energy through inclusive financing mechanisms often witness a positive ripple effect on local economies. Electrified schools, health centers, and markets become more functional and efficient, contributing to better educational outcomes, improved healthcare, and thriving trade (Okeke, et al., 2022, Olorunyomi,et al., 2022, Popo-Olaniyan, et al., 2022). As local energy markets develop, they attract entrepreneurs, create jobs, and stimulate investment in complementary sectors such as agriculture, retail, and telecommunications (Eyo-Udo, et al., 2025). When these developments are underpinned by financial inclusion—through tools like mobile payments, microloans, and digital wallets—economic empowerment becomes more durable and widespread, reducing poverty and fostering inclusive growth (Atta, et al., 2024, Olufemi-Phillips, et al., 2024).

Technology plays a pivotal role in reducing the financial barriers that have historically excluded underserved populations from the energy economy. Mobile money platforms, for example, allow customers to make small, frequent payments for energy services, aligning with their irregular income patterns. Pay-as-you-go (PAYG) systems offer flexible and scalable access to solar and other off-grid technologies, eliminating the need for large upfront investments (Okeke, et al., 2023, Orikpete, Ikemba & Ewim, 2023, Sam Bulya, et al., 2023). FinTech innovations such as AI-driven credit scoring enable lenders to assess the creditworthiness of users with no formal financial history, thereby expanding access to microloans and installment financing. These technologies not only bridge the gap between energy providers and low-income consumers but also help build digital transaction histories that can support future financial inclusion.

Blockchain technology further enhances transparency, trust, and efficiency in energy financing. By creating immutable records and enabling smart contracts, blockchain platforms facilitate secure and automated transactions between stakeholders, reducing the need for costly intermediaries and minimizing fraud. This is particularly useful in contexts where institutional trust is low or where public funds must be closely monitored (Famoti, et al., 2025). The use of digital platforms also allows for remote monitoring and data collection, enabling energy service providers to optimize performance, detect malfunctions, and better understand customer behavior. These capabilities contribute to the long-term viability of energy projects and ensure that financial inclusion efforts are aligned with service quality and customer satisfaction (Arinze, et al., 2024, Onita & Ochulor, 2024).

To scale financial inclusion strategies for energy access, robust and adaptive policy frameworks are essential. Governments must recognize energy access and financial inclusion as interconnected development goals and design policies that support integrated approaches. First, regulatory environments

should encourage innovation by providing space for FinTech companies, energy startups, and community-based organizations to experiment with new models without excessive bureaucratic hurdles (Akhigbe, et al., 2021, Otokiti, et al., 2021). At the same time, consumer protection regulations must ensure that these models remain fair, transparent, and responsive to user needs.

Governments can also offer targeted subsidies and incentives to de-risk investments in underserved regions. These may include performance-based grants for energy providers, tax exemptions for clean energy equipment, or direct subsidies for low-income consumers. Importantly, such support must be transparent and well-targeted to avoid distorting markets or excluding the most vulnerable. In parallel, public investment in digital infrastructure—such as mobile networks, internet connectivity, and identification systems—can lay the groundwork for the effective delivery of digital financial services (Anjorin, et al., 2024, Omowole, et al., 2024, Udeh, et al., 2024).

Policy alignment between energy, finance, and technology ministries is also critical. Coordinated planning ensures that energy access programs are designed with appropriate financing mechanisms and that financial regulations accommodate the specific needs of energy users (Ajayi, et al., 2022, Okeke, et al., 2022). Public-private partnerships (PPPs) offer a promising pathway to scale, allowing governments to leverage the expertise and capital of private sector actors while providing oversight and strategic direction (Eyo-Udo, et al., 2025). Successful PPPs require clear roles, performance metrics, and accountability frameworks to balance innovation with public interest.

Despite the promise of these strategies, implementation faces a number of challenges and potential risks. One major challenge is the digital divide. Many underserved communities still lack access to mobile phones, internet connectivity, or digital literacy, which limits their ability to benefit from mobile-based financial and energy services. Addressing this requires complementary investments in digital inclusion, such as training programs, affordable device distribution, and support for community agents who can facilitate access and usage (Ajiga, et al., 2024, Oriekhoe, et al., 2024, Usiagu, et al., 2024).

Another challenge is affordability, even with inclusive financial tools. While PAYG models reduce upfront costs, the long-term costs of these systems may still be high relative to household incomes. There is a risk that users may default on payments or become locked out of essential services. Financial models must therefore be designed with affordability and flexibility in mind, offering grace periods, tiered pricing, or emergency subsidies when needed (Alabi, et al., 2024, Okeke, et al., 2024, Sam Bulya, et al., 2024).

Additionally, the success of financial inclusion strategies depends on the strength of the ecosystem in which they operate. Weak institutions, policy inconsistency, or corruption can undermine the credibility of programs and deter private investment. In countries with fragile governance, the deployment of technology-based solutions must be accompanied by efforts to build institutional capacity, ensure transparency, and engage local stakeholders in decision-making processes (Anyanwu, et al., 2024, Onukwulu, et al., 2024).

Another risk lies in over-reliance on technology without adequate safeguards. For instance, AI-driven credit scoring models, if poorly designed, can reinforce biases and exclude deserving individuals. Blockchain platforms, while secure, require careful regulation to prevent misuse and ensure consumer privacy. Policymakers and practitioners must ensure that technology serves as an enabler rather than a barrier, maintaining a human-centered approach that prioritizes inclusion, fairness, and accessibility (Atta, et al., 2024, Omowole, et al., 2024, Udeh, et al., 2024).

In conclusion, developing financial inclusion strategies through technology and policy to improve energy access presents a powerful opportunity to address some of the most pressing challenges facing underserved communities. The benefits extend far beyond electricity, touching every aspect of socioeconomic development—from income generation to education and health (Okeke, et al., 2023, Onyeke, et al., 2023, Sobowale, et al., 2023). Technology reduces financial barriers and expands service delivery, while policy frameworks provide the structure and support needed to scale solutions sustainably (Ezechi, et al., 2025). However, successful implementation requires a comprehensive approach that addresses digital literacy, affordability, institutional capacity, and consumer protection. As stakeholders navigate these complexities, the ultimate goal remains clear: to ensure that no community is left in the dark and that everyone, regardless of income or geography, has the opportunity to participate in and benefit from the clean energy transition.

Future Research Directions

As the global community continues its pursuit of universal energy access and inclusive economic development, the intersection of financial inclusion, technology, and policy will remain a dynamic and evolving research frontier. While existing initiatives have demonstrated substantial promise in improving energy access through digital financial services, blockchain innovations, and progressive policy interventions, numerous questions remain unanswered—particularly regarding the long-term implications, scalability, and institutional readiness in diverse socio-economic and political contexts (Famoti, et al., 2025). Future research must therefore delve deeper into evaluating outcomes, identifying best-fit models, and guiding adaptive strategies that are responsive to the complexities of underserved communities (Akhigbe, et al., 2022, Oluwafunmike, et al., 2022). The future research directions of developing financial inclusion strategies through technology and policy to improve energy access are broad, multi-disciplinary, and essential for sustaining momentum in the global clean energy transition.

One of the most pressing areas for future inquiry is the long-term impact assessment of digital financial services on energy sustainability. While mobile banking, pay-as-you-go (PAYG) systems, and microloans have enabled millions of people to access clean energy technologies, the long-term viability of these financing models requires more comprehensive study. Research should explore whether households and businesses that initially benefit from digital financial tools are able to maintain and upgrade their energy systems over time, or whether they face recurring affordability challenges that hinder sustained energy usage (Ajayi & Udeh, 2024, Olufemi-Phillips, et al., 2024, Sobowale, Augoye & Muyiwa-Ajayi, 2024). Longitudinal studies can track the durability of access, changes in consumption patterns, and behavioral responses to digital financial products over several years. Furthermore, the environmental sustainability of energy solutions financed through digital services—such as the lifecycle impact of distributed solar systems or the carbon offset potential of clean cookstoves—should be systematically assessed to ensure that inclusion and sustainability go hand in hand.

It is also essential to examine the economic resilience of users within these financial ecosystems. Do users of PAYG energy systems build credit histories that translate into access to broader financial services such as education loans, business capital, or health insurance? Does energy access financed through digital tools lead to improved income, savings, and investments at the household and community levels? Understanding these ripple effects would provide a fuller picture of how financial inclusion strategies contribute not just to energy access but to inclusive development more broadly (Ajiga, et al., 2024,

Oluokun, et al., 2024, Paul, et al., 2024). This requires interdisciplinary collaboration between economists, technologists, energy specialists, and development practitioners to collect, analyze, and interpret robust datasets over time and across diverse geographies.

Another crucial area for future research is the scalability of blockchain and artificial intelligence (AI) in energy financing, particularly in low-resource and high-risk environments. Blockchain has been touted for its potential to provide transparent, secure, and decentralized energy transaction systems, while AI offers advanced capabilities in risk profiling, fraud detection, and demand forecasting (Akinsooto, Ogundipe & Ikemba, 2024, Osundare & Ige, 2024). However, their adoption remains limited due to technical, economic, and institutional barriers. Research should focus on testing and refining scalable models that apply these technologies in the energy contexts of underserved communities, especially in Sub-Saharan Africa, South Asia, and parts of Latin America where energy poverty remains high.

For blockchain, questions of infrastructure, energy consumption, interoperability, and user accessibility are critical. Future studies should evaluate the real-world performance of blockchain-based smart contracts in energy service delivery and payment verification. How do these systems perform under limited connectivity, low literacy, and variable regulatory conditions? Are blockchain-based energy markets effective in improving transparency and reducing corruption in energy subsidies and investments? Additionally, research must investigate the economic models underlying tokenized energy systems and decentralized finance (DeFi) for clean energy (Apeh, et al., 2024, Okeke, et al., 2024, Oyeyemi, et al., 2024). Can micro-investors effectively participate in solar mini-grid projects through token ownership? What risks do they face, and how can those risks be mitigated through smart regulation and platform design?

AI's scalability in energy financing raises another set of critical questions. Although AI algorithms can significantly enhance credit scoring, customer targeting, and energy usage forecasting, they require high-quality data and consistent feedback loops to function optimally. Many underserved communities operate outside of formal data ecosystems, with fragmented or incomplete financial, demographic, and energy usage records (Atta, et al., 2024, Olawale, et al., 2024, Sam Bulya, et al., 2024). Future research should investigate ways to build ethical, inclusive, and context-sensitive AI systems that leverage alternative data sources—such as mobile phone usage, utility records, or social network interactions—without reinforcing biases or compromising user privacy. Moreover, AI models must be transparent and explainable, especially when used for decisions that affect financial eligibility or energy service continuity (Famoti, et al., 2025). Research into the governance of AI in inclusive energy financing—covering algorithmic accountability, community participation, and fairness—will be crucial for ensuring that AI serves as a tool for empowerment rather than exclusion.

The policy environment must also evolve to keep pace with these technological developments, and this necessitates research into how policy frameworks and regulatory institutions can adapt effectively in emerging markets. Most existing energy access and financial inclusion policies were designed in an era of centralized utilities and brick-and-mortar banking. They often fail to accommodate the decentralized, digital, and cross-sectoral nature of today's clean energy financing models (Oyeniyi, et al., 2021, Paul, et al., 2021, Tula, et al., 2004). Future research should focus on understanding how governments can create agile, responsive policy frameworks that enable innovation while ensuring equity, consumer protection, and systemic stability.

This includes evaluating existing regulatory sandboxes—controlled environments where new

financial and energy technologies are tested—and their effectiveness in facilitating innovation without compromising public interest. What governance models are most effective for regulating digital finance in energy? How can regulators ensure that consumer rights are upheld in PAYG contracts, blockchain transactions, or AI-based loan decisions (Okeke, et al., 2022, Oyegbade, et al., 2022)? What kind of institutional capacity building is needed to equip regulators and policymakers with the technical knowledge to engage with complex digital systems? Comparative studies across different national contexts can help identify which combinations of policies, incentives, and institutional arrangements are most conducive to fostering inclusive and sustainable energy finance ecosystems (Kokogho, et al., 2025).

Moreover, future research must address the political economy of financial inclusion and energy access. As technologies and policies are introduced, they often disrupt existing power dynamics and economic interests. Incumbent utilities, fossil fuel suppliers, or entrenched financial institutions may resist inclusive models that threaten their market positions. Research into how political incentives, stakeholder coalitions, and community mobilization shape the adoption and diffusion of inclusive strategies is essential for informing the design of more effective interventions (Alabi, et al., 2024, Olaleye, et al., 2024, Sam Bulya, et al., 2024).

Lastly, there is a need for participatory and community-led research that centers the voices and experiences of those most affected by energy poverty and financial exclusion. Many existing studies rely heavily on top-down methodologies that overlook local knowledge, preferences, and constraints (Akhigbe, et al., 2023, Onukwulu, et al., 2023). Engaging communities as co-researchers—not just subjects—can lead to more nuanced insights and more sustainable outcomes. This includes incorporating gender perspectives, as women are disproportionately affected by energy poverty and often excluded from financial decision-making (Aigbedion, Ayorinde & Adebisi, 2025).

In conclusion, the future research directions of developing financial inclusion strategies through technology and policy to improve energy access for underserved communities must be both ambitious and grounded. Long-term impact assessment will be critical to understanding how digital financial tools affect the sustainability and inclusiveness of energy systems. The scalability of blockchain and AI must be examined through a practical lens, identifying the conditions under which these technologies can be deployed effectively and equitably (Ajayi, et al., 2023, Oriekhoe, et al., 2023, Oteri, et al., 2023). Finally, policy evolution and regulatory adaptation will require continuous learning, experimentation, and collaboration between government, private sector, civil society, and academia (Kokogho, et al., 2025). Only through rigorous, interdisciplinary, and community-oriented research can we build the knowledge base needed to scale inclusive energy access and achieve the dual goals of financial empowerment and energy justice.

Conclusion

The development of financial inclusion strategies through technology and policy to improve energy access for underserved communities represents a transformative approach to addressing one of the most persistent development challenges of our time. This study has highlighted how financial constraints, lack of access to credit, high infrastructure costs, regulatory gaps, and socioeconomic limitations have historically excluded millions from modern energy services. By integrating digital financial services, blockchain technologies, microfinance mechanisms, and supportive policy frameworks, it becomes possible to bridge this gap and foster inclusive energy economies that empower marginalized populations.

Key findings show that mobile banking, pay-as-you-go systems, AI-driven credit scoring, and blockchain-

based financing models are instrumental in lowering entry barriers for low-income households and small enterprises. These technologies offer flexible, scalable, and data-driven solutions that align with the financial behavior and needs of underserved users. Policy interventions, particularly those involving subsidies, public-private partnerships, and regulatory innovation, have also been critical in creating enabling environments for inclusive energy financing. Case studies from Africa, Asia, and Latin America demonstrate that when financial tools and energy systems are designed with local contexts in mind, they can catalyze widespread access to clean, reliable, and affordable energy.

This work contributes meaningfully to the broader discourse on financial inclusion and energy accessibility by illustrating the deep interconnections between economic empowerment, technological advancement, and sustainable energy development. It underscores the importance of moving beyond siloed approaches and embracing integrated models that combine finance, policy, and technology to drive equitable progress. Furthermore, it emphasizes that energy access should not be viewed merely as a technical or infrastructural issue, but as a fundamental component of inclusive development and social justice.

To ensure that these strategies are effectively implemented and scaled, several recommendations are put forward. Policymakers should prioritize cross-sectoral collaboration and regulatory reforms that support innovation while safeguarding consumer rights. Investment in digital infrastructure, financial literacy, and decentralized energy systems must be matched by transparent and equitable subsidy mechanisms. Financial institutions should develop inclusive products that leverage alternative data for credit assessments and expand their reach through mobile and agent-based channels. Energy stakeholders, including utilities and off-grid providers, must continue to adapt their business models to serve low-income customers sustainably, building partnerships with FinTech firms and community organizations.

Ultimately, achieving universal energy access through financial inclusion is not only a technological or policy challenge—it is a moral imperative. By aligning our financial systems and energy policies with the needs of the underserved, we can unlock economic potential, improve quality of life, and accelerate the transition to a just and sustainable energy future for all.

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