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Green Energy Entrepreneurship: Emerging Business Models for Decentralized Renewable Power in Developing Economies

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ABSTRACT: Decentralized renewable energy (DRE) systems are becoming a vital part of solving energy access issues and fostering sustainable development in developing countries. In this discussion, we explore how different legislative, economic, and entrepreneurial frameworks can help expand the reach of DRE technologies. We place particular emphasis on the importance of public-private partnerships, innovative business models, and targeted investment strategies that cater to local markets. Despite these hurdles, tremendous opportunities are waiting to be tapped. Creative financing options, community-driven energy projects, and investments focused on climate solutions can all play a crucial role. The transition to renewable energy not only has the potential to create jobs and bolster economic resilience but also to empower youth and communities through skill development and entrepreneurial ventures. Educational institutions and collaborative stakeholder efforts need to step in and help bridge the skills gap, driving inclusive growth. Ultimately, we conclude that a comprehensive and integrated approach, one that combines supportive legislation, financial innovation, and grassroots involvement, is essential for unlocking the full potential of decentralised renewable energy systems. By pursuing these initiatives, we can move toward a just and equitable energy transition that contributes to climate resilience and sustainable development, particularly in the Global South. Significance: Empowering communities through decentralized renewable energy fosters climate resilience, economic growth, job creation, and equitable access in developing regions.

Keywords: Decentralized Renewable Energy, Sustainable Development, Energy Access, Public-Private Partnerships, Climate Resilience.

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INTRODUCTION

Green energy entrepreneurship, primarily focused on decentralized renewable power, is becoming a vital player in the quest for sustainable and inclusive energy solutions, particularly in developing countries. These regions often grapple with persistent issues like unreliable energy access, environmental degradation, and the need for economic growth. In this landscape, decentralized renewable energy (DRE) systems are emerging as promising alternatives to traditional fossil-fuel-based infrastructures, allowing communities to tap into local renewable resources like solar, wind, and biomass. This shift is not just about improving energy access; it is also fostering innovation, driving economic empowerment, and promoting environmental stewardship at the grassroots level [1]. Entrepreneurs in the renewable energy sector are reshaping the narrative by developing innovative business models tailored to the specific socio-economic and infrastructural realities of

developing nations. These models are crafted to overcome the typical hurdles posed by high initial investments and limited grid connectivity, while also promoting equitable participation and long-term sustainability. Consequently, green energy entrepreneurship is increasingly recognized as a crucial driver of inclusive growth, supporting both national and global efforts aimed at climate change mitigation and sustainable development. Among the notable emerging business models are community-based initiatives, digital platforms, and novel financing mechanisms. Community solar programs, for instance, showcase collaborative ownership structures that enable individuals—especially those who may lack financial resources or suitable rooftops—to invest collectively in and benefit from renewable energy systems [2]. This approach ensures that the advantages of renewable energy extend beyond affluent segments of society, fostering a more equitable distribution of benefits across wider populations. Simultaneously, the digital revolution is continually reshaping the decentralized energy landscape through innovative mechanisms like peer-to-peer (P2P) energy trading. These platforms utilize blockchain and innovative grid technologies, allowing consumers to buy and sell surplus energy directly. This not only heightens efficiency and transparency but also bolsters local energy resilience. The shift towards prosumer engagement, where individuals both produce and consume energy, marks a democratization of energy markets, aligning with broader trends in digital innovation. Innovative financing options are equally vital in broadening access to decentralized renewable energy. Financial structures like solar leases, pay-as-you-go (PAYG) systems, and power purchase agreements (PPAs) help mitigate the burden of upfront capital investments, making clean energy technologies more accessible for low- and middle-income households and small enterprises. By aligning payment schedules with users' ability to pay, these models enhance both affordability and scalability [3]. Despite their vast potential, decentralized renewable energy systems and their associated business models face significant challenges. High initial costs, limited financing access, and underdeveloped regulatory frameworks can hinder widespread adoption. Often, policies and incentives are still tilted toward centralized power generation, leaving DRE initiatives without adequate institutional backing.

Furthermore, the shortage of skilled labor and insufficient infrastructure, such as robust transmission networks and storage systems, adds to the obstacles faced in effectively deploying and maintaining renewable technologies. Another pressing challenge lies in the lack of consumer awareness and trust in new business models and technologies. Many potential users may be unfamiliar with decentralized systems or may exhibit skepticism due to past failures or misinformation. Therefore, building trust through transparency, community engagement, and capacity-building initiatives becomes essential for long-term success [4]. Overcoming these challenges requires coordinated efforts across public, private, and civil society sectors. Governments must implement supportive policies and regulatory frameworks that foster innovation while protecting consumer interests. Investment in education and workforce development is crucial for creating a skilled labor force capable of designing, installing, and maintaining renewable systems. Additionally, international collaboration and knowledge sharing can facilitate the replication of successful models across different regions, amplifying their impact [5]. The growing focus on decentralized renewable energy reflects a broader global commitment to tackling climate change, achieving energy justice, and reducing reliance on fossil fuels. In this transformative journey, green energy entrepreneurship is at the forefront, enabling solutions that align economic development with environmental sustainability and social inclusion. These emerging business models in decentralized renewable energy are not only changing how energy is produced and consumed; they are also creating new pathways for inclusive growth in developing economies. These models highlight the importance of innovation and community engagement in shaping a sustainable future.

Types of Business Models

The renewable energy sector, particularly within the context of decentralized systems in developing economies, encompasses a spectrum of business models designed to address diverse challenges related to energy access, affordability, and sustainability (Table 1). These models can be broadly categorized into three types: **traditional,** innovative, hybrid, and Community-Based business models. Each model reflects varying degrees of technological integration, market orientation, and stakeholder involvement, catering to specific socioeconomic and infrastructural conditions.

Table 1: Types of Business Models in Decentralized Renewable Energy Systems

Business Model Type	Key Characteristics	Examples & References
Traditional Models	Centralized generation, large-scale infrastructure, high capital investment, utility-driven.	Government or private utility grids; fossil-fuel or centralized solar/wind plants [6].
Innovative Models	Technology-enabled, user-centric, pay-as-you-go, peer-to-peer trading, Energy-as-a-Service (EaaS).	PAYG solar (e.g., M-KOPA in Kenya), P2P blockchain platforms [7].
Hybrid Models	Combines traditional utilities with community or private innovation, flexible financing integration.	Public-private solar microgrids with mobile banking in South Asia [8].
Community-Based Models	Local ownership and participation, cooperative models, skill-building and economic empowerment.	Community solar in rural Tanzania; energy cooperatives in Europe [9. 10].

Traditional Business Models

Traditional business models in the energy sector usually revolve around a centralized system where energy is generated in large plants and distributed through national grids, often managed by government or private utility companies. This setup relies on significant infrastructure like fossil-fuel power plants and tends to generate revenue through fixed prices or regulated tariffs. While this model has been the foundation of energy systems in many places, it comes with some downsides—it is capital-intensive, slow to adapt to new changes, and often struggles to reach rural or underserved communities (Figure 1) [11]. When it comes to renewable energy, traditional approaches typically involve utilities or third-party companies owning solar or wind installations. However, this often demands a significant upfront investment and navigates through a maze of regulations. While these traditional models have their strengths, they can also be quite limiting in today's rapidly evolving energy landscape.

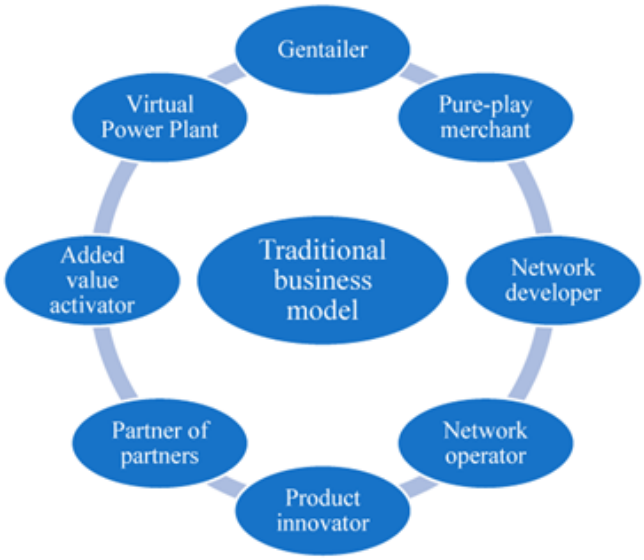

Figure 1: Business Models in the Energy Sector (Courtesy images from Sułek *et al* [6].

Innovative Business Models

In the renewable energy field, new and creative business models are emerging that use cutting-edge technology and focus on consumers' needs. These approaches aim to make clean energy more accessible and affordable, especially in developing countries. They are designed to break away from the constraints of traditional energy systems by being more flexible and inclusive. One

of the exciting models is the pay-as-you-go (PAYG) system, which allows people—especially in rural areas without reliable electricity—to get solar energy solutions, like solar home systems, without having to pay a large sum upfront. Instead, they can pay gradually based on how much energy they use. Another innovative option is peer-to-peer (P2P) energy trading [12]. This system enables individuals to buy and sell energy directly to one another through digital platforms and blockchain technology. This reduces the need for big, centralized companies and gives people more control over their energy sources. Then there is the energy-as-a-service (EaaS) model, which changes the game by allowing customers to subscribe to energy services rather than owning the infrastructure themselves [13]. This means they can enjoy consistent costs and lower risks associated with technology. These modern approaches are not just one-size-fits-all; they can be customized to fit the unique needs of local communities. They help spark entrepreneurship, attract investments at the local level, and promote community ownership of clean energy initiatives, ultimately contributing to a more sustainable and resilient future.

Hybrid Business Models

Hybrid models bring together traditional and innovative approaches to create flexible and tailored solutions. For example, a utility company might team up with a local community or a private company to set up distributed solar panels, all while providing financing options through mobile banking. This kind of collaboration combines the strength of centralized management with the adaptability of local initiatives, ensuring that large systems are reliable while also embracing the creativity and responsiveness of grassroots solutions. These hybrid strategies are especially beneficial in transitional economies, where some areas may have limited access to the grid [14]. They help connect existing infrastructure with new decentralized technologies, paving the way for a more integrated energy future.

Community-Based Models

Community-based renewable energy models are all about bringing people together to create a sustainable future. They focus on collective ownership and benefit-sharing, making sure that everyone in the community has a stake in the energy systems that serve them. A great example of this is community solar programs, which allow multiple people to access energy from a shared solar array. This means even those who live in rented homes or shaded areas can enjoy clean energy without needing their solar panels [15]. These models have several essential elements that make them effective. They encourage co-investment, so the benefits of renewable energy are shared more equitably. By pooling resources, communities can lower installation and maintenance costs, making renewable energy more affordable, especially for those in low-income households. Plus, when residents get involved, it leads to more community engagement, skill development, and job opportunities. Moreover, community involvement helps raise awareness about environmental issues and responsible energy use, fostering a culture of sustainability. Energy cooperatives take this a step further by operating democratically, ensuring that the members themselves make decisions. Profits from these initiatives are often reinvested back into the community, supporting local development [16]. Ultimately, these community-based approaches to energy not only meet specific needs but also build ownership and trust among residents, paving the way for a more sustainable and clean future of energy.

Enabling Innovations in Decentralized Renewable Energy Models

The potential for decentralized renewable energy systems in developing countries is becoming more promising thanks to various innovative solutions that help overcome financial, technological, and infrastructure challenges. One of the most exciting developments is the introduction of new financing options, like solar leasing and power purchase agreements (PPAs) [17]. These options make it easier for people to access renewable energy without having to pay a significant upfront cost. With a solar lease, customers pay a regular monthly fee to use a solar system, while PPAs allow them to pay for the electricity they use at a set rate over time. This not only makes renewable energy more affordable but also provides predictable pricing and often includes maintenance, making it more convenient for users. In addition to these financial tools, the rise of digital technology and peer-to-peer (P2P) energy trading is transforming how energy is shared and utilized. Platforms powered by blockchain technology now enable consumers to trade electricity directly with each other, cutting out traditional utility companies [18]. This shift gives people more control, leads to more transparent pricing, and

builds trust in energy markets. Another significant breakthrough is the integration of energy storage and grid services into these decentralized systems. Technologies like battery storage allow us to save excess energy produced during peak times, ensuring that there is a steady supply even when generation is low or demand is high. These storage solutions, along with improved connections to the grid, greatly enhance the efficiency and reliability of renewable energy systems. Together, these innovations, financial, digital, and technological, create a strong foundation for sustainable and inclusive business models that can help bring clean energy to underserved areas.

Key Technologies in Green Energy Entrepreneurship

Solar Energy Technologies

Solar energy technologies are at the heart of green energy entrepreneurship, and two main types play important roles: solar photovoltaic (PV) systems and solar thermal systems. PV systems are great because they convert sunlight directly into electricity, making them ideal for rooftops and small solar farms. On the other hand, solar thermal systems capture solar energy to generate heat, which is helpful for homes, businesses, and even industrial settings. These technologies are perfect for decentralized energy generation, meaning they can bring power production closer to where it is used [19]. This not only helps reduce energy losses during transmission but also makes it easier to set them up in both urban and rural areas. However, solar energy systems do have their challenges. Their effectiveness depends on the availability of sunlight, which means energy generation can be inconsistent. To address this, regular maintenance is necessary, along with integrating storage solutions to ensure a reliable energy supply when the sun is not shining.

Wind Energy Technologies

Onshore wind energy is becoming increasingly crucial for green energy entrepreneurs because it produces electricity with very few emissions during operation. One of the great things about wind turbines is that they can be installed on agricultural land, making it possible for farmers to use the same land for both farming and energy production. This dual-use approach helps to reduce visual disruption and land-use conflicts. In areas where the wind blows consistently, these turbines can generate a significant amount of clean energy efficiently, all while avoiding the carbon emissions that come from fossil fuels [20]. However, some challenges come with wind energy too. For instance, some people in nearby communities might worry about noise from the turbines or how they might impact the beauty of the local landscape. Also, wind turbines can pose risks to local wildlife, especially birds and bats. To address these concerns, it is crucial to choose the right locations for turbines and to use innovative, wildlife-friendly designs that help protect the environment.

Decentralized Wind Systems

Increasingly, rural and semi-urban areas are turning to decentralized wind energy solutions, especially those using small to medium-sized turbines, to create their sustainable power. These wind systems are a game changer for rural electrification, helping communities become more energy-independent and bolstering their local economies by cutting down on their dependence on large, centralized power grids [21]. They work particularly well in areas that have steady wind resources. Plus, they can seamlessly fit into hybrid renewable energy setups that mix wind with solar power or storage solutions. This means communities can enjoy a more reliable and steady energy supply that truly meets their unique needs.

Micro-Hydro Systems

Micro-hydro systems are a fantastic and eco-friendly way to generate electricity by tapping into the natural energy of flowing water or small dams. They are instrumental in hilly and river-rich areas, making a real difference in countries like China, India, and the Philippines, where they help bring electricity to rural communities. When these systems are well-maintained, they can provide a reliable and steady source of energy with minimal negative impact on the environment. However, they are not without their challenges [22]. They can disrupt local aquatic ecosystems and wildlife movements, and they might contribute to increased evaporation from still water sources. To make sure these systems are sustainable, it is crucial to conduct thorough seasonal flow analyses and ecological planning. This careful approach helps to balance the need for energy with the importance of protecting our natural surroundings.

Legislative, Economic, and Strategic Considerations

To unlock the full potential of decentralized renewable energy (DRE) technologies, particularly in

developing countries, it is crucial to establish supportive laws and economic policies. Thoughtfully designed policies can stimulate partnerships between public and private sectors, paving the way for innovative business models that seamlessly integrate renewable energy into local markets. A great example is Bangladesh, where decentralized solar projects have been implemented successfully, resulting in over 6 million solar home systems installed and a marked improvement in energy access for rural communities [23]. For investors looking to venture into the renewable energy sector, it is essential to carefully consider factors like how scalable the technologies are, what the specific needs of the market are, and the reliability of the management teams behind them. Investing in technologies with proven business models while also diversifying through promising renewable energy startups can not only deliver financial returns but also contribute to sustainable development in the long run. However, the shift to DRE is not without its challenges and opportunities. Many developing economies grapple with infrastructure issues, financing difficulties, and uncertain regulations [24]. However, these same hurdles can foster innovation, driven by an urgent need to tackle climate change and resource depletion. This growing demand for clean, inclusive, and locally adapted energy solutions presents an opportunity for innovative solutions. Successfully navigating this dynamic landscape calls for collective efforts from governments, investors, entrepreneurs, and communities alike. Together, we can build energy systems that are resilient, fair, and sustainable for everyone.

Challenges in Decentralized Renewable Energy Deployment

The shift toward decentralized renewable energy (DRE) systems is an exciting prospect for a sustainable future, but it comes with its own set of hurdles. One of the biggest challenges is the steep initial costs, which can be a significant turn-off for businesses and governments looking to invest in these eco-friendly solutions. This financial barrier is made worse by a lack of clear policies, cumbersome permitting processes, and uncertainty in regulations, making investors hesitant and slowing down the adoption of DRE technology [25]. Another pressing issue is the skills gap in the workforce. If we fail to implement tailored training programs and integrate vocational education into schools, we will lack the skilled professionals needed to tackle the technical aspects of DRE systems. Educational institutions have a key role to play in ensuring that people are well-equipped with the knowledge and skills needed for this growing field. Furthermore, we must consider how the planning and construction of renewable energy infrastructure can impact local ecosystems and communities (Table 2) [26]. The extraction of resources like metals and sand, which are vital for many renewable technologies, often happens in ways that are harmful to the environment. If we do not manage these projects carefully, we may end up jeopardizing the very environmental goals we aim to achieve. To overcome these challenges, we need a comprehensive strategy that includes reforming policies, investing in education and training, and developing infrastructure that is mindful of ecological concerns. It is all about finding solutions that benefit not just our energy needs but also the health of our planet and local communities.

Table 2: Enabling Innovations for Decentralized Renewable Energy Deployment

Innovation Type	Description	Impact & Application	References
Solar Leasing & PPAs	Financial models allowing users to pay periodically for solar energy services.	Reduces upfront cost, increases adoption in low-income households.	Barbose *et al.* [27].
Peer-to-Peer (P2P) Trading	Blockchain-based platforms for direct energy exchange among prosumers.	Enhances market transparency, democratizes energy access.	Howell *et al.* [7, 28].
Battery Storage & Grid Services	Energy storage solutions integrated with renewable generation.	Ensures reliability during intermittent supply, supports microgrid stability.	Worku *et al.* [29].

Digital Monitoring & IoT Tools	Real-time system analytics for performance and usage tracking.	Improves operational efficiency, enables predictive maintenance.	Wolniak *et al.* [30].

Opportunities in Decentralized Renewable Energy Systems

Despite the hurdles we face, decentralized renewable energy (DRE) systems present exciting opportunities that can truly promote sustainable development. Creative financing options, like public-private partnerships and community-based funding models, are changing the game for renewable energy projects, making them more affordable and accessible to everyone. When solid policies and regulations back these initiatives, they become attractive to investors concerned about climate change, as they offer a sense of security and lower financial risks [31]. Moreover, the rise of the DRE sector plays a crucial role in generating jobs and boosting local economies, especially in developing countries. Investing in renewable technologies not only drives economic progress but also helps build a workforce equipped with the skills needed for the energy transition. Another vital opportunity lies in empowering young people and encouraging community involvement. Young individuals—whether they are students, entrepreneurs, or early-career professionals—have a unique ability to spark innovation, lead awareness efforts, and make meaningful contributions to clean energy projects [32]. By fostering collaboration between local communities and businesses, we can enhance public understanding of sustainability and highlight the long-term benefits of careers in renewable energy. Together, these opportunities showcase the transformative potential of DRE systems in creating energy futures that are inclusive, sustainable, and resilient for all.

Studies and Community Impact of Decentralized Renewable Energy

Across the globe, both emerging and developed countries offer fascinating examples of how green energy entrepreneurship can take different forms, presenting unique challenges and exciting opportunities. Nations like Vietnam, Sri Lanka, Indonesia, South Africa, Tanzania, Egypt, Brazil, and Turkey showcase a variety of ways that local conditions influence the adoption of renewable energy [33]. Take Kilolo District in Tanzania, for instance. A closer look at this area reveals a complex scene of green entrepreneurship. While a good portion of entrepreneurs—about 37.5%—are involved in organic farming and 25% are tapping into renewable energy sources, many still face significant hurdles. Common challenges include limited access to financing, poor infrastructure, a lack of technical expertise, and regulatory obstacles. Interestingly, over 60% of the entrepreneurs mentioned they lack technical training, and half reported dealing with regulatory issues. However, there is a silver lining: the research indicates ample growth potential if there is improved support in financing, infrastructure, and skill development [34]. On the other hand, the United Kingdom has established itself in the renewable energy landscape. Boasting advanced technologies and a supportive political environment, the UK has made impressive strides. However, it still needs to focus on refining regulatory frameworks and addressing infrastructure challenges to keep green enterprises thriving. Lessons from the UK's experience could prove invaluable for emerging economies looking to boost their renewable energy investments. In Latin America, countries like Brazil, Argentina, and Mexico are witnessing remarkable growth in wind energy, enjoying an average annual increase of 13%. This success can be attributed to plentiful wind resources, falling technology costs, and helpful government policies [35]. To maintain this momentum, though, it is crucial to strengthen the grid infrastructure and ensure stable policies that will continue to attract private investment. These case studies emphasize the need for tailored solutions that resonate with the specific challenges each region faces while nurturing the growth of green entrepreneurship. They illustrate how renewable energy can seamlessly blend into local economies, promoting sustainability while also fueling economic development. At the community level, decentralized renewable energy (DRE) systems have the power to create meaningful positive change, especially in developing regions. DRE initiatives can spark local economic growth through job creation, innovation, and shared ownership opportunities, allowing communities to gain firsthand benefits from clean energy projects [36]. By generating energy locally, these systems lower transmission costs, boost energy efficiency, and often result in broader economic benefits especially when paired with affordable financing and energy-efficient housing

projects (Figure 2). To put things in perspective, recent reports indicate that the renewable energy sector provides jobs for nearly 12 million people worldwide, and DRE systems are particularly effective at promoting inclusivity, offering fair job access, and contributing to poverty reduction in neglected areas. The environmental and health benefits are hard to ignore as well. By cutting down on fossil fuel use, DRE systems help reduce air pollution, leading to lower healthcare costs and better public health—especially in lower-income communities that suffer the brunt of pollution's impact. DRE projects can enhance community engagement and skill-building opportunities [37]. When local stakeholders are involved in the planning and execution of these initiatives, it cultivates a sense of ownership and responsibility. Programs that provide training and apprenticeships are also vital, helping to close skill gaps and prepare residents for jobs in the renewable energy industry. Despite these promising developments, challenges still linger. Many communities grapple with financial limitations, inadequate infrastructure, and regulatory roadblocks that complicate their involvement in green entrepreneurship. A one-size-fits-all electrification strategy may miss the mark when it comes to addressing the unique needs of different communities, which can hinder efforts to achieve energy equity. To fully harness the social, economic, and environmental benefits of decentralized renewable energy systems, it is crucial to tackle these challenges and ensure that these systems can succeed and remain inclusive in the long run.

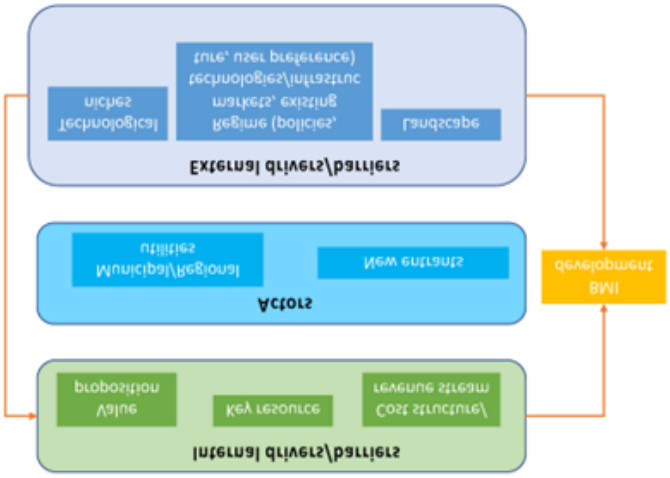

Figure 2: Analytical framework (Courtesy images from Howell *et al.* [7]

DISCUSSION

The urgent need for sustainable, inclusive, and equitable energy access in developing economies has brought decentralized renewable energy (DRE) systems to the forefront of energy transitions. As traditional, centralized fossil-fuel-based grids struggle to meet the increasing demands of widely dispersed populations, innovative green energy entrepreneurship is emerging as a transformative solution [38]. This shift is not merely about the adoption of new technologies; it also encompasses fresh business models, financing strategies, and governance mechanisms that drive the adoption of renewable energy technologies. Decentralized energy systems are designed to generate power close to where it is consumed. This approach minimizes transmission losses and encourages self-reliance, making these models particularly appealing in regions where extending the conventional power grid is either economically unfeasible or logistically challenging. For example, solar microgrids offer customized energy solutions to rural communities that are off the grid. Countries like Bangladesh and Kenya have successfully rolled out solar home systems and pay-as-you-go payment models, allowing rural populations to access electricity via affordable, user-friendly schemes . This success has spurred entrepreneurial ventures that combine mobile banking with real-time monitoring and customer support, creating sustainable ecosystems that revolve around renewable technologies. Biomass energy is another important avenue, particularly for rural and peri-urban areas. By harnessing agricultural waste or organic residues, biomass energy supports circular economies effectively turning waste into electricity, heat, or biofuels

[39]. An increasing number of green startups are investing in compact biomass gasifiers and improved cookstoves. These technologies not only have the potential to reduce indoor air pollution greatly but also offer businesses opportunities in equipment manufacturing, distribution, and ongoing maintenance. Meanwhile, hydropower, specifically through micro and mini-hydro plants, promises significant benefits in mountainous or riverine areas. While such projects can be capital-intensive, they provide stable and long-term energy solutions with minimal environmental impact when managed appropriately. These initiatives can thrive where communities come together to form cooperatives that manage operations and the flow of revenue. For decentralized renewable energy (DRE) initiatives to truly thrive and reach their full potential, having supportive policy and regulatory frameworks is crucial [40]. Imagine a world where cutting-edge energy solutions can flourish rather than struggle to find their footing; this is possible only with the right legislation in place.

Governments play a pivotal role in crafting regulations that not only promote innovation and attract investment but also stimulate competition—all while ensuring that social and environmental safeguards remain at the forefront. In developing countries, for example, policies that foster public-private partnerships (PPPs) and define clear procedures for licensing, grid interconnection, and quality control can significantly lower market entry barriers. By doing so, they can attract both homegrown and international investors, paving the way for a more vibrant energy economy. Take Bangladesh, for instance. It stands out as an inspiring success story in the realm of renewable energy. The country has rolled out over six million solar home systems, mostly through innovative PPPs and initiatives funded by donors like the Infrastructure Development Company Limited (IDCOL) [41]. This effective approach combines concessional financing with technical assistance, creating a robust supply chain that resonates with consumers' needs and builds their confidence in adopting solar technology. By involving microfinance institutions and empowering local entrepreneurs, the implementation has become more decentralized, rooting these business models deeply within community structures. From the investor's viewpoint, the DRE market presents both its challenges and a wealth of opportunities. Unlike traditional energy infrastructures that often rely on a one-size-fits-all approach, decentralized models require localized expertise and the flexibility to adapt. Successful investment strategies in the green energy space focus on scalability, replicability, and good governance. Investors are tasked with identifying technologies that not only prove to be technically sound but also enjoy the backing of skilled management teams and effective strategies for engaging with the communities they serve. A diversified investment portfolio can be a game-changer here . By including early-stage renewable energy startups that specialise in modular technologies or rely on subscription-based revenue models, investors can achieve promising returns while also championing climate resilience [42, 43]. Additionally, international development banks, impact investors, and green venture capitalists are stepping in to mitigate investment risks. They do this through blended finance mechanisms, performance guarantees, and results-based financing, providing the much-needed support to help nurture these innovative ventures. Ultimately, it is about more than just numbers and bottom lines; it is about creating a sustainable future that benefits everyone. Moving towards decentralized renewable energy not only empowers communities but also lights the way for a greener planet, where energy is accessible and affordable for all. Every policy, every investment, and every partnership can make a difference because together, we can build a brighter, cleaner future for generations to come [44, 45]. Despite the encouraging outlook, deploying DRE in developing economies is not without its hurdles. Technical and financial barriers remain among the most pressing challenges. The high upfront costs associated with renewable energy infrastructure, like solar panels, inverters, and batteries, often hinder adoption, particularly in low-income regions. Compounding this issue is the lack of robust policy environments, inconsistent regulatory enforcement, and ambiguous grid interconnection standards, all of which can deter potential private investors and developers. Looking ahead, these challenges require innovative solutions and a collaborative approach among stakeholders to ensure that the promise of decentralized renewable energy becomes a reality for all.

The importance of youth in green entrepreneurship is significant and cannot be overlooked. Young people today, armed with digital skills and a strong passion for sustainability, are at the forefront of grassroots energy movements. Initiatives that focus on training

young entrepreneurs in renewable energy technologies and business development not only foster innovation but also promote inclusive growth [46, 47]. When young people are actively involved in awareness campaigns and community-based energy cooperatives, it builds trust within communities, encourages behavior change, and enhances the social acceptance of renewable initiatives. Community engagement is crucial in amplifying these benefits. Projects that emphasize community ownership and promote participation in decision-making processes are more likely to succeed and sustain over time. By empowering local populations to co-create solutions, we ensure that the technologies implemented are relevant and welcomed by the end-users [28]. This approach is critical in multicultural and multilingual regions, where solutions designed from a centralized perspective might not resonate or work effectively. Green energy entrepreneurship, supported by decentralized renewable technologies, presents a comprehensive pathway toward development that is both inclusive and resilient to climate change. In developing economies, where access to energy remains a pressing issue, decentralized renewable energy (DRE) models offer scalable and context-specific solutions that align with global sustainability goals [48, 49]. However, unlocking this potential necessitates a determined effort from policymakers, investors, educators, and communities. To move forward, it is essential to align legislative reforms with grassroots innovation, incorporate DRE into education and workforce development programs, and explore creative financing methods to tackle capital challenges. Most importantly, a people-centered approach—where we prioritize local needs, capacities, and aspirations will be key in ensuring that the transition to renewable energy is fair, equitable, and lasting.

CONCLUSION

Decentralized renewable energy (DRE) systems offer an exciting opportunity for developing economies to achieve not just energy security but also to fuel economic growth and promote environmental sustainability. There are still challenges to overcome, such as financial limitations, gaps in technical skills, and hurdles in regulations that can pose significant obstacles. This will not only help to create a just and resilient energy transition but will also empower communities and drive sustainable development. Ultimately, the journey towards a greener energy future can benefit everyone, and the effort to harness these technologies is well worth it.

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