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Renewable energy transitions and gender justice: Women's empowerment through solar mini-grids in rural Nigeria

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Abstract

This paper explores how renewable energy transitions can promote gender justice, especially women empowerment by relying on solar mini-grids in rural Nigeria. The current energy systems comprising heavily of diesel generators and biomass are expensive, unstable, and unsustainable to the environment overly burdening the low-income households and women. In comparison, solar mini-grids are more inclusive as well as cleaner sources of power and are in line with some global development objectives, including SDG 5 (gender equality) and SDG 7 (affordable and clean energy). The study points to some of the major social advantages such as; time poverty should be reduced, women should have more chances to be entrepreneurs, and family and community decision-making need to be more inclusive. It further looks at the barriers that have been persistent like affordability, established gender norms, and poor policy frameworks. Using the example of rural electrification projects in Nigeria, and other similar examples in Kenya and Tanzania, the paper illustrates how decentralized solar systems could help uplift the livelihood of women. But their ultimate success will be a matter of conducive policies, financial inclusion policies and special investments on women technical and leadership skills. The paper finds that although solar mini-grids have massive potential, long-term gender-sensitive interventions are essential in making sure that mini-grids not only promote energy access but also social justice in rural Nigeria.

Keywords: Renewable Energy Transitions; Solar Mini-Grids; Women's Empowerment; Gender Justice; Rural Nigeria

1. Introduction

Nigeria still depends a lot on fossil fuels and its national electricity supply is very unreliable. In rural areas, many people live without steady electricity. Because of this, they often use expensive and harmful sources of energy like diesel generators and firewood (Balogun, 2024). This dependence slows down development and harms the environment (Mukhtar et al., 2021).

To solve this, Nigeria has made renewable energy a major focus. Solar mini-grids are now becoming popular because they can provide electricity directly to communities without relying on the weak national grid. Studies show that solar mini-grids in Kenya and Nigeria have helped people by lowering energy costs and supporting small businesses (Carabajal et al., 2024). In southwest Nigeria, off-grid solar systems have created new jobs, improved local economies, and made life better for many (Babalola et al., 2022). Other researchers argue that renewable energy can make energy systems fairer and more sustainable (Ponnambalam and Lampooning, 2025).

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Renewable energy also creates more jobs. Tagliapietra et al. In 2020 found that it improves employment in Nigeria, and Ezebuihe et al. (2024) showed that it helps women in rural areas find off-farm work. These studies prove that renewable energy especially solar mini-grids can transform rural Nigeria's economy.

However, the benefits are not the same for everyone. Women are still more affected by energy poverty because they spend much of their time gathering fuel, cooking, and doing energy-related household chores. This limits their time for education, paid work, and leadership (Cicowiez et al., 2022). Tandrayen-Ragoobur (2024) explains that this energy poverty deepens gender inequality and keeps women excluded from economic and political opportunities across Africa. Solar mini-grids can help change this level of poverty. According to Segura-Rodríguez et al. (2025), these systems reduce women's household workload and give them more time to start businesses or take leadership roles. Khalifa (n.d.) suggests that renewable energy projects should be designed to promote gender equality, not just provide electricity.

Still, there are challenges. Janghorban et al. (2024) found that many female-headed households cannot afford renewable energy systems, which limits their participation. On the positive side, Sievert (2024) discovered that access to clean, reliable energy can even reduce domestic violence, showing that renewable energy improves family life too. In South Africa, Longe (2021) noted that cultural and gender beliefs affect how people accept clean energy—an important lesson for Nigeria.

Overall, renewable energy change is not just about technology—it is also about people and society. Focusing on gender equality ensures that women are not only recipients but also active leaders in Nigeria's solar mini-grid projects. This study therefore examines how solar mini-grids can help empower women in rural Nigeria and support fair, lasting development.

2. Conceptual and Theoretical Framework

2.1. Defining Gender Justice

Gender justice has come to be viewed as a multi-dimensional phenomenon, which is not only concerned with the goal of legal or formal equality. It questions the reproduction of hierarchies by structural arrangements, cultural practices, and institutional systems to the disadvantage of women and other marginalized people. Gender justice, in its essence, focuses on equality of opportunities, access, and results and responds to historical and social inequalities that determine the experiences that women live (Medupin, 2020). In development research, this viewpoint shifts the discussion towards the tokenistic inclusion to a transformative agenda that re-orders power in the household, community, and institutions (Finlay et al., 2024).

It is not just the issue of the eradication of blatant discrimination, but also the reconsideration of deep-rooted social standards according to which the subordination of women is acceptable. The evaluation of interventions must not only focus on the inclusion in the groups, but also on whether the inclusion of women reflects into real power of decision making and benefits that are equal (Chant and Sweetman, 2012). The participative nature of women will always be symbolic, and not transformative without the structural roots of inequality being challenged (Asiimwe, 2024). The other aspect of gender justice is the acknowledgment of care economies and the burden that women bear concerning unpaid labor. It is especially applicable in energy situations in which time-consuming activities, including fuel gathering, food cooking, and water boiling, constitute most of the daily activities of women (Bauhardt and Harcourt, 2018). The cycles of exclusion and vulnerability are strengthened by unequal access to modern energy as a perpetrator (Odo et al., 2021).

In the African case, the urgency of gender justice is especially high because there are still certain gender disparities in education, labor, and political representation. These inequalities are aggravated by energy poverty constraining the productive activity of women, as well as strengthen their marginality in making decisions (Tandrayen-Ragoobur, 2024). Wrongly constructed policies can fail to recognize the gendered distributional effects of energy access and therefore increase inequalities between men and women (Mperejekumana et al., 2024). In Nigeria, gender justice discourse is closely related to rural development and survival strategies of households. The rural women have unequal distribution of domestic energy pressure that results not only in labor-demanding but also in health-labor risks to the rural women because of indoor air pollution (Emordi, 2015). These gender labour divisions restrain the role of women in rural economies, as the unpaid caring duties use time and energy that were utilized in education or in enterprise (Okoli, 2024). The lack of access to energy also makes women vulnerable in rural families and does not allow them to join the leadership of their community (Jaho, 2024).

Gender justice is also being defined as an expanding of women substantive liberties and breaking of institutional obstacles across the world. It involves not just access but empowering women to acquire the capacity to lead lives that

they will have a cause to appreciate (Finlay et al., 2024). This here refers to the assessment of non-centralized systems, such as the solar mini-grids, not only based on their technical performance but also by the impact these systems have on changing the opportunities of agency and empowerment of women (Mperejekumana et al., 2024). Combined, these views highlight the fact that gender justice in the energy industry is not simply about access to equal access to electricity or renewable technologies. It is regarding the need to ensure that the gendered confines that abate the empowerment and agency of women are chosen to pieces. Incorporating gender-responsive strategies into the energy planning and governance, the renewable energy transitions can shift beyond bridging the gaps in infrastructure, to actively correct past inequities. In this way, gender justice will serve as a guide to diagnosing a gap between men and women and act as an outline on how to make energy transitions foster inclusive and transformative development in rural Nigeria.

2.2. Energy Transitions and Empowerment Theories

Energy transition is not a simple technical change of fossil fuels to renewable ones, energy transition is a complex socio-technical process that redefines economic, political, and social relationships. These shifts in rural African settings have far-reaching consequences to the empowerment of women since energy access has a strong connection to livelihoods, health, education, and agency in household and community settings. Sovacool (2021) points out that low-carbon transitions will leave both winners and losers and therefore the necessity to assess their distributional consequences and justice. The knowledge on energy transition with the help of empowerment theories can enable scholars and policymakers to value the multidimensional nature of energy intervention beyond infrastructural provision (Gupta and Prodani, 2022).

Empowerment is a multidimensional construct that involves the availability of resources, agency and the power to deliver the desired results. Cornwall (2016) emphasizes that empowerment should focus on taking beyond the superficial level of inclusion to make sure that there is an actual change that allows women to influence their life. Empowerment in energy sector implies that women should not only be able to receive the services of energy, but also take an active part in the decision-making process regarding energy technologies, governance, and resource distribution. Perrett (n.d.) shows that access to clean energy empowers the lives of women in urban areas, including the small-scale businesses, and Jaho (2024) directly associates energy poverty with barriers to girls in education. The availability of the modern and clean energy systems would decrease the household duties of women including time spent on fuel gathering, cooking, and heating water and enhance the time available to them to get an education, earn income, and participate in government affairs.

The capabilities approach offers a somewhat helpful prism through which energy transition empowerment potential can be considered. According to Robeyns (2017), empowerment is achieved when people possess the substantive freedom to live the life they cherish. By introducing new economic opportunities through decentralized energy systems, such as solar mini-grids, empowering women in Nigeria through rural energy infrastructure can improve health conditions (cleaner energy consumption) and enable women to have more time to study and be involved in community activities. Ahlborg and Hammar (2014) demonstrate that decentralized systems are capable of breaking the infrastructural barriers of rural Africa, though, in most cases, the benefits of their implementation depend on cultural and institutional factors to reach women. In the same vein, Stojanovski, Thurber, and Wolak (2017) disclose that even the most useful solar home systems cannot be transformed into real sources of empowerment without becoming a part of broader socio-economic systems.

Feminist empowerment theories also provide a useful addition to this insight, by highlighting that empowerment is personal and social and needs to discuss structural obstacles and social conventions that limit the agency of women. MacGregor (2017) underlines that interactions between gender and the environment are extremely influenced by systemic inequalities, i.e. energy transitions are not necessarily empowering unless the needs of women are central. Energy interventions also have a risk of recreating inequalities that already exist in case they do not break gendered hierarchies (Listo, 2018). Men usually dominate decision-making in the rural societies regarding the management of the energy resources, despite the fact that women may be the main users of these resources. This is indicative of how global energy justice structures have been criticized by Cowell (2016) who points to the idea that the three aspects of distributive, procedural, and recognition justice should be all factored into energy planning.

A promising direction of operationalizing energy transitions through the use of empowerment is decentralized renewable energy systems that can be solar mini-grid. Bhattacharyya and Palit (2014) demonstrate that locally managed mini-grids have the potential of transforming the rural livelihoods by increasing productive possibilities. Contrasting centralized grids, these systems provide the community with the opportunity to co-manage energy resources and enable the community to have an inclusive participation and shared decision-making. The participation of women in the planning, operation, and maintenance of these systems may contribute to their increased presence in

the leadership activities in their communities, encourage entrepreneurship, and create alternative sources of income. Similarly, it is suggested by Africa UUP (n.d.), which argues that women empowerment by utilizing renewable energy empowers them with resilience against climate change and enhances the achievement of sustainable development. However, there still are major obstacles. Women are mostly unable to enjoy the full benefits of renewable energy technologies due to affordability issues, cultural beliefs, inadequate training in technology. Blok and Bots (n.d.) will keep us conscious that the trends of energy consumption in the world are also influencing the priorities of countries which at times may overlook the needs of local women. Intervention by influential men in the proprietorship of energy resources and the overall decision-making process within the home environment regardless of energy infrastructure can restrict the positive empowerment gains. This underscores the need to incorporate energy transitions with wider social policies, capacity building programs and gender-sensitive development programs.

In Nigeria, the application of the empowerment theory in energy transitions is especially important because of significant rural energy shortages in the country as well as the gender-based inequalities. Tandrayen-Ragoobur (2024) demonstrates the disproportionate impacts of energy poverty on the well-being of African women, and Medupin (2020) stresses that such programs as Women in Environmental Sciences (WiES) can become the factors that can shift the energy justice and women towards leadership. Through solar mini-grids, women could be inspired to engage in constructive and community projects that would help in economic growth, better welfare of the family and social change. Developing energy projects by using the empowerment lens will make sure that the interventions do not simply give access to electricity but also make women more capable, break the social norms, and make the development process more inclusive and sustainable.

Finally, the combination of the empowerment theories with the energy transition models allows having an overall picture of aiming to design renewable energy initiatives in a way that will affect more people. The theories, which focus on agency, capabilities, and structural change, inform the policymakers and practitioners to ensure that the energy transitions are not merely substituting the fuel sources, but also producing gender justice, rural development, and social long-term equity. When well considered, however, solar mini-grids are not only a technological intervention, but also a tool of change in the lives of rural Nigerian women.

3. Renewable Energy and Rural Development in Nigeria

3.1. The Role of Solar Mini-Grids

Solar-powered mini-grids have emerged as one of the most promising options for tackling the issues in terms of rural electrification across sub-Saharan Africa. These systems can be adopted toward fulfilling community energy needs (Suberu et al., 2013) because, contrary to the extension of centralized (and often economically unfeasible) grids to sparsely populated rural areas, mini-grids are decentralized, modular, and scalable. The flexibility of solar mini-grids allows them to be immediately resourced and then extended further as rural economies grow (Amiliana and Suliswanto, 2025).

Low energy expenditures of households on power from solar mini-grids will permit productive uses of electricity also for microenterprises, for instance schools and health care facilities. Studies have indicated that mini-grids demonstrate evidence of positive growth in rural enterprises by providing electricity to milling machines, irrigation pumps, welding workshops, and cold storage systems, all meant to improve local value chains and employment opportunities (Carabajal et al., 2024). Such systems have provided South Africans with alternative options to income-generating activities that include women in rural areas, such as food processing and retailing on a smaller scale (Winther et al., 2018).

Mini-grids provide the significant co-benefits of social and environmental cost-effectiveness against economic productivity. Access to reliable electricity improves education in the countryside through longer study hours for pupils by lighting up their homes, thereby supporting digital learning initiatives (Yadoo and Cruickshank, 2010). Public health benefits accrue as households shift from kerosene lamps and firewood stoves and continue to use only clean electricity, further reducing indoor air pollution-prevalent illness concerning a poor dry environment (Bazilian and Pielke, 2013). The enhanced safety, due to well-lit streets and homes, adds to the improvement of the well-being of the community at large by reducing ccidents and vulnerabilities based on gender differences in rural settlements (Walking along the lines of power, 2014).

Hybrid solar mini-grids, the ones with batteries, and intermittently with backup generators engineer stable and reliable power well-suited to the consumption pattern of rural countries. Demand-side management tools, like smart meters and load limiters, optimize efficiency, allow backup, and facilitate transparent billing, thus cementing consumer trust and willingness to pay (Bhattacharyya, 2015). Hybrid renewable energy systems have recently extended debate to focus

on innovations in combining solar, wind, and storage solutions to build resilience and efficiency in rural electrification programs (Natividad and Benalcazar, 2023).

Long-term benefits relate to lessons from pilot projects both in Nigeria and across Africa: community participation and local ownership which are vital for sustainability. Payment compliance and sustainability usually compare favorably with projects where community members have a voice in the decisions, management, and maintenance thereof as against externally driven models (Yadoo and Cruickshank, 2010). In a similar vein, the deployment of mini-grids would be beneficial to align with broader rural development programs-especially agricultural extension services and women's empowerment initiatives-beyond lighting to socio-economic transformation (Carabajal et al., 2024). Thus, mini-solar grids constitute not just a technical intervention, but rather a reformative rural development strategy. Affordably linking access to clean energy by the poor with poverty alleviation, gender empowerment, and environmental sustainability give them, at the same time, the position of being the bedrock for inclusive energy transitions in Nigeria's rural landscape (Suberu et al., 2013).

3.2. Policy and Institutional Landscape

Rural electrification deployment with renewable energy sources in Nigeria, particularly exemplified by solar mini-grids, thrives well within the context of an enabling policy and institutional environment. Over past twenty years, some modification of the Nigerian policy context has occurred, with systematic influences targeting energy diversification and access from various frameworks, including the Renewable Energy Master Plan (REMP) and the National Renewable Energy and Energy Efficiency Policy (NREEEP) (Ajia, 2025). Such policies view off-grid electrification as one of the critical pathways to truly universal energy access given the deep costs and complexity of extending national grid supply to rural and remote areas (Energy Sector Management Assistance Programme, 2017).

Essentially, the Rural Electrification Agency (REA) oversees efforts toward rural electrification in Nigeria, the effectiveness of which is greatly enhanced by the development partners on the Nigeria Electrification Project (NEP) that are engendering pathways for the development of mini-grids through grants and performance-based subsidies to developers (Sesan et al., 2024). Such institutions are indicative of the government recognizing that scaling up renewables in rural areas can only be accomplished with the involvement of the private sector complemented with an appropriate regulatory framework (Toyin et al., 2023).

However, regulatory and institutional obstacles somehow impede the progressive evolution of the energy sector in Nigeria. Ineffective enforcement of policies, overlapping mandates in relation to the energy-related ministry and agencies, and bottlenecks in bureaucracy greatly undermine proper enforcement of project guidelines regarding energy deployment. To illustrate, policies may support mini-grid installations, but potential investors could be discouraged by an uncoordinated framework regarding tariff-setting since their consideration would be long-term financial viability (Akinlabi and Oladokun, 2021). Most recent instances of duplicated designs for state- and federal-level institutions tend to create unnecessary competition, with resulting inefficiencies uncoordinated in the process of rural electrification (Abba et al., n.d.).

Financing stands as another huge barrier to progress. Despite catalytic funds are being made available by various donor-supported programs, Nigeria is yet to have domestic financing vehicles adequately developed, specifically in the context of renewable energy projects. Affordability is a major issue for rural communities, while the developer cannot access low-interest loans that suit the scaling-up of such projects on the other extreme. It has been maintained in some techno-economic studies that hybrid configurations of PV-battery-diesel systems will yield better cost-effectiveness of mini-grids, with barrier funding to such a scheme (Elegeonye et al., 2023). Policy frameworks that would allow community cooperatives and microfinance institutions to be involved in energy programs can solve this barrier since cooperatives have historically been effective in rural electrification by enhancing local ownership and financial sustainability (Madubueze et al., n.d.).

Above all, the institutional setting must also carry with it a gender-and-social-inclusive lens. Energy access policies that do not acknowledge women's roles in household energy use and in rural enterprise risk tempering the transformative potential of electrification. When gender dimensions are integrated into energy planning and targeted for specific subsidies such as for women-owned enterprises; or appointments of women in local energy committees, for Ajia (2025) this could mean social equity and sustainability in the long run for mini-grid projects. When women-specific subsidies like those targeting women-owned enterprises or appointments in local energy committees are included in energy planning with gender considerations, Ajia (2025) argues, such will ensure social equity and the sustainability of mini-grid programs over a longer period. On a continental scale, Nigeria's commitments under the African Union's Agenda 2063 in addition to the Sustainable Development Goals (SDG 7) further reinforce the argument for the need for a

coordinated institutional approach for expansion of renewable energy. Regional and international partnerships provide technical assistance, policy alignment, and investment flows in complementarity to national efforts (Sesan et al., 2024).

In sum, Nigeria's policy and institutional framework has created the enabling environment for renewable energy development, but existing gaps in coordination, financing, and inclusiveness remain. To benefit solar mini-grids and other decentralized energy systems to the fullest for rural development, a reform to be truly championed is very urgent to strengthen institutional accountability mechanisms, simplify the regulatory environment, and embed social equity considerations within the corridors of activities these institutions undertake. Renewable energy access could be put into full use as both a state and national driver for inclusive rural transformation with the right provisions for the alignment of policies, political will, and institutions (Toyin et al., 2023).

4. Gendered Dimensions of Energy Access

4.1. Women's socio-economic roles in rural communities

Rural women play important socio-economic roles which are directly linked to energy usage and availability. For instance, with time, the woman uses domestic energy, including cooking and heating, collection of water, and processing of food that tends to be time- and energy- intensive activities in one's daily routine and overall well-being (Köhlin et al., 2011). Women are part of the value chain involved in the agricultural sector where they also contribute from planting, harvesting to processing, and marketing produce. Most of these activities are done in a labor-intensive manner instead of relying on machines, which constrains productivity and limits income generation (Godson-Ibeji et al., 2021).

Beyond their homes and farms, informal and small enterprises such as tailoring, hairdressing, and food vending are also managed by women, with the potential to diversify into new livelihood opportunities if reliable electricity access becomes available. For instance, solar-powered freezers and milling machines lessen the physical toil involved for women while increasing their options for income earning (Akinyemi et al., 2021). Schools and health centers have been electrified; indeed, the impact is multiplier-in-as-much as women caregivers now have better maternal health services and improved educational opportunities for their children, especially the girl child (Parikh, 2011).

Socio-economic contributions from women extend beyond the confines of their traditional roles. They have also increasingly found themselves contained and identified as active contributors in community governance, cooperatives and energy-user groups. Where women participate in energy committees or cooperatives, electrification projects seem to achieve positively higher levels of sustainability and local ownership (Clancy et al., 2019). In communities, women's networks greatly enable her not only a beneficiary but also a critical change agent in the rural energy transitions. She can always be referred to as an advocate of change for the rural energy transitions (Carabajal et al. 2024).

Energy might also be associated with delaying effect, as it provides women more free time spent with their children and at play since they do not have to draw water or collect firewood. In fact, they view electricity as a new alteration such that it gives freedom. Displacing wood in cooking with electricity may have additional effects elsewhere in the value chain, as stove importation from countries at various levels of development tends to be biased toward urban areas and hence likely to be available to only select women.

Most women are not patrons of the electricity market; they take along with them household responsibilities that compete within the limited budgets that typically characterize rural households. It is through this relative deprivation that many women find it necessary to learn the skills and undertake the necessary adaptation to use new technology rather than considering it to be a luxurious rather than basic requirement for daily survival.

The transformation brought about by electricity in the household is generally more indirect, making it difficult for the impact to be quantified. For example, if a woman collects firewood for a few hours a day, she is more likely to have time to attend an income-generating activity or self-help group than if she is not busy collecting firewood. In fact, attendance at such meetings could be understood as work, where one gets a meal for attending. Otherwise, an analysis of the return of investment to electricity would have considered how electricity influences the time for attending such important activities.

4.2. Barriers to energy access for women

Women continue to play central roles in energy management, yet they face systemic barriers that limit their equity in access to energy and its benefits. Financial exclusion is one key constraint. Rural women often lack access to land title or can use it as collateral in a formal banking system to secure loans for energy-related investments (Oparaocha and

Dutta, 2011). Even when some microfinance institutions do offer loans to women, the very high interest rates might deter them or they may not have sufficient financial literacy. In many households, it is men who control the purse strings and this limits the ability of women to prioritize the expenditure on energy solutions that could lighten their load (Ryan, 2014).

Socio-cultural norms merely act as a reinforcement of these inequalities. Energy programs are very often designed and implemented with little consideration for gender; hence women are underrepresented in governance, training and decision-making processes (Mohideen, 2018). Such exclusion reduces the chances of an adequate response to women's specific energy needs such as access to clean cooking technologies or affordable small-scale electrification. Also, traditional gender roles can further stigmatize women in technical areas, limiting their chances of working in energy-related jobs and businesses (UN Women, 2021).

Geography, therefore, makes a bad situation all the worse. Remote ruralities within which energy infrastructures are least developed accommodate women more than any other gender. Their sustained dependence on biomass fuels such as firewood exposes them to overwhelming health hazards, ranging from respiratory diseases to eye problems from indoor air pollution (World Health Organization, 2014). On the other hand, time for fuel collection is perceived as loss of time needed for income-generating activities, education, and civic engagement. In some contexts, traveling to collect firewood exposes women and girls to gender-based violence (Famewo and Uwala, 2022).

Fragmented policy implementation acts as the base for limiting gender mainstreaming. Some national and international frameworks call for gender equality in energy access, but enforcement of those policies is weak and rarely gender-disaggregated data gets through the doors, making it very difficult to formulate policies that respond to the realities of women (Clancy et al., 2019). Furthermore, energy subsidies are poorly targeted and often bypass the most vulnerable, thereby reinforcing the gender disparity in energy affordability and use (Elegeonye et al., 2023).

These barriers serve as a reminder that the increasing energy access cannot now afford to be classified merely as a technical challenge. Without intentional gender-sensitive policies and institutional arrangements that promote inclusiveness, the energy transition will merely entrench existing inequalities. By meeting the energy needs of women and appreciating their contributions to energy planning (e.g., through targeted subsidies, training, and participation in cooperatives), energy outcomes are expected to lean beyond merely improved access to energy to encompass wider social and economic transformations (Clancy et al., 2019).

5. Solar Mini-Grids and Women's Empowerment

5.1. Economic empowerment

Solar mini-grids are becoming effective agents for enhancing women's economic empowerment in rural communities. Access to decentralized and reliable electricity allows women to move away from subsistence activities to higher-value undertakings, such as agro-processing, tailoring, refrigeration, and entering digital services. Solar-powered milling machines, for instance, help minimize the toil of manual food processing, thus allowing women to save time and scale-up production (Carabajal et al., 2024). In the same manner, refrigeration and cold storage infrastructure can further encourage women's participation in value chains for perishable products, especially in the agriculture and fisheries sectors. Women's post-harvest losses will be reduced, thus enabling them to generate extra incomes and reinvest these resources back into their households and businesses (Tenenbaum et al., 2024).

Electrification through mini-grids reduces barriers on women entrepreneurs by providing alternatives to expensive diesel power or kerosene lamps. Women plung at their reduced costs when this happens in addition to making their local competitiveness wise (Elegeonye et al., 2023). Besides entrepreneurship concerns, women also access improved modalities for communication and information technology by charging their mobile phones and internet-enabled services, broadening their economic networks, and including finances through these. (Chidera Abonyi, 2019). In cases where women's cooperatives are directly involved in mini-grid operation, such projects create new roles for women in leadership and improve their bargaining power in the households (Akinyemi et al., 2021; Lee, 2020).

5.2. Educational opportunities

Solar mini-grids have absolutely enhanced educational opportunities for girls and women. Power or electricity available for long hours can mean longer hours of studying into the nights, giving girls opportunities to catch up on schoolwork despite their other home duties (Tsekane et al., 2024). Electricity in schools allows digital learning tools to be used,

lighting improvements, and access to modern teaching resources. All contributed to improved learning outcomes (Clancy et al., 2019).

Most importantly, mini-grids contribute to improved working environments for female teachers, who often operate under challenging conditions in remote electrification areas. With electrical provision to such areas, they become a bit more enticing for qualified teachers, thus increasing the overall quality of education (Mohideen, 2018). In addition, electrification and mechanization reduce the time spent on household chores such as grinding, cooking, or fetching water, saving many girls from dropping out due to increased domestic work (Parikh, 2011). Community training centers powered through solar mini-grids empower women to acquire technical and vocational skills, which includes the maintenance of renewable energy, ICT, and small business management thus breaking gender stereotypes in terms of course offerings while enhancing employability and self-confidence (Chidera Abonyi, 2019).

5.3. Health and household well-being

Solar mini-grids greatly enhance the health and well-being of women. Clean cooking solutions powered by solar energy replace firewood and kerosene and reduce indoor air-pollution exposure, which affects women mainly during food preparation and household chores (World Health Organization, 2014). With exposure to smoke diminishes, incidences of respiratory illnesses and eye and health problems will also be lower (Ryan, 2014).

With regard to healthcare delivery, solar-powered mini-grids ensure lighting and refrigeration at rural clinics, running diagnostic equipment, and preserving maternal and child health by lowering mortality and providing better prenatal and postnatal care (Oparaocha and Dutta, 2011). For instance, the electric water pump-powered water supply saves labor by lessening the distance that must usually be walked a great deal. This is accompanied by physical relieve and spent time that can be used purposely for rest or income-generating jobs (Famewo and Uwala, 2022).

Electrification also improves safety, enabling both indoor and outdoor lighting, thereby limiting exposure to gender-based violence during night hours. The improved safety, along with access to reliable information and communication through radio or mobile phones, builds up women's resilience in cases of emergencies or climate-related challenges (UN Women, 2021). By providing much more than simple energy access, solar mini-grids set off a structural transformation in women's lives by creating pathways for economic empowerment, improved educational opportunities, and enhanced well-being. Therefore, in order to maximize such beneficial effects, mini-grid projects must be developed and executed along gender-responsive lines so that women not only benefit but also become active promoters of sustainable rural development.

6. Case Studies from Rural Nigeria

6.1. Gbamu-Gbamu Solar Mini-Grid (Ogun State)

The 85-kW solar hybrid mini-grid in Gbamu-Gbamu is one of the flagship renewable energy projects in the country with support from the Rural Electrification Agency and private developers. Women depended much on kerosene lamps for lighting before electrification and also spent long distances and ample cash traveling to mill crops or preserve fish. The mini-grid allows women traders and fish sellers to utilize cold-storage facilities, which reduces post-harvest losses and enhances food safety (Bishoge, Kombe, and Mvile, 2020). This has significantly added to productivity for tailors and hairdressers, thereby extending working hours as a result of the reliable electricity, while even young students, especially girls, study under better conditions after dark. By way of decentralized electrification, the project shows how women’s economic empowerment, educational opportunities, and health have been enhanced, thus further reinforcing the gender justice aspect of Nigeria’s energy transition (Clancy and Feenstra, 2019).

6.2. Nigeria Electrification Project (NEP)

The Nigerian Electrification Project, which is co-financed by the World Bank and African Development Bank, plans to roll out thousands of solar mini-grids across the country. Pilot communities that benefit from these facilities have given women farmers access to machinery for agro-processing, like rice threshers and cassava graters, thus relieving them of the burden of drudgery in manual labor (Sovacool and Drupady, 2016). The energy-user associations have also involved women's cooperatives in tariff negotiations and service delivery arrangements, which is participatory role (Ijoma, 2021). Such participatory roles indicate a new dimension to gender norms, with women increasingly being acknowledged as stakeholders in energy governance, not passive consumers. The institutional pathways that NEP provides for women's empowerment and gender justice where energy transformations are inclusively designed (Nzeanorue et al., 2024).

6.3. Solar Power for Health Clinics in Northern Nigeria

Certain health facilities in Northern Nigeria used to rely on less-than-effective services being powered by diesel generators, which made health service delivery incomplete. Such clinics are now electrified by new solar-powered mini-grids that will provide the transformed gendered livelihoods. Among these benefits are those for women who can now have safe nighttime deliveries with refrigerated vaccines available to light for emergency care (Parikh, 2011). In addition, there will be improvements in working conditions for female health workers which, in turn, provide them with better quality service delivery. These results confront gender disparity concerning healthcare access, demonstrating how renewable energies significantly improve women's health and well-being (Onyeji, Bazilian, and Nussbaumer, 2012). Most importantly, this kind of solar electrification improves the confidence of the local healthcare system, with greater numbers of women feeling encouraged to access medical attention during childbirth-the foundation to lessen maternal mortality (Raman et al., 2025).

6.4. Market Electrification in Lagos Peripheries

Peri-urban markets situated in the outskirts of Lagos further offer an illustrative example of gendered impacts of mini-grids. These markets are largely populated by women traders, food vendors, and seamstresses who had relied on kerosene lamps and petrol generators that were both expensive and hazardous before solar mini-grids came into play. Now women save so much on the fuel that they work in safer and healthier environments free from fumes and toxins (Ijoma, 2021). With increased disposable income, household welfare, social conditions, and children's education receive a boost. Availability of lighting improves women's safety whilst working hours extending into the night, allowing for reduced exposure to gender-based risks (Sovacool and Drupady, 2016). Subtly or expressively, such modifications place renewable energy access against measures of gender justice, social inclusion, and women's rights (Raman et al., 2025).

Across Nigeria's diverse contexts, solar mini-grids are not just a technical answer to energy poverty; they represent avenues toward gender justice. From rural farming communities to peri-urban markets and health facilities, these projects are challenging economic participation of women and health outcomes while addressing structures of inequality in energy governance. Yet the barriers to development include the affordability of the service, limited women's representation in technical roles, and cultural norms that restrict participation. Addressing these gaps would ensure that renewable energy transitions in Nigeria do not just push sustainability but also ensure women empowerment with real meaning (Bishoge, Kombe, and Mvile, 2020).

7. Challenges and Limitations

7.1. Financial, Technical, and Cultural Barriers

Several barriers have slowed the popularization of solar mini-grids in rural Nigeria despite their significant advantages. According to Bhattacharyya (2015), high upfront capital costs and limited access to low-interest financing are primary obstacles for both private investors and rural households. The study by Elegance et al. (2023) on rural communities shows that many households led by women do not have collateral or sufficient financial literacy to qualify for loans to make energy investments. However, there are also technical barriers to the effective deployment of these systems.

Akinlabi and Oladokun (2021) show that mini-grid systems are able to survive on the condition of careful planning and hybrid energy source integration as well as having well-trained maintenance personnel to ensure reliability. Poor distribution infrastructure and inadequate storage solutions often mismatch supply and local consumption-reducing efficiency and endangering project sustainability according to Natividad and Benalcazar (2023). Finally, Tenenbaum et al. (2024) noted that designs of hybrid systems should match local energy demand to be functional over time.

Besides these, there are cultural and social barriers. Raman et al. (2025) noted that cultural barriers dictate how women should participate in decision-making at the community level, although they are responsible for most household energy management. Limited awareness and training opportunities make women less successful in realizing benefits accrued from electrification programs, as reported by Clancy and Feenstra (2019). Onyeji et al. (2012) noted that the traditional dependence on biomass fuels and kerosene drastically slow renewables acceptance. For example, community engagement and local education are highlighted very much by Sovacool and Drupady (2016) for overcoming social resistance.

7.2. Sustainability Concerns

The sustainability of solar mini-grid projects rests on sound governance, economic viability, and inclusive social structures. Østergaard et al. (2022) indicated that weak institutional support can lead to maintenance neglect and tariff

disputes. Thus, detrimental effects undermine the project longevity. Carabajal et al. (2024) discovered that without proper revenue mechanisms, relying on donor funding or subsidies becomes unsustainable, considering that local people will not be able to pay operating costs.

Environmental sustainability is another critical concern. Ha and Kumar (2021) studied battery management, which, if not properly disposed of and mismanaged by the system, may create local environmental hazards. Social sustainability is based on the principles of inclusiveness. The project must involve good practices along with women, youth, and marginalized groups so as not to further entrench existing inequalities and limit the transformational possibility of energy access (Raman et al. 2025). Clancy and Feenstra (2019) also reiterated that gender-sensitive policy inclusion is also needed for equity in benefits.

These challenges can only be decisively tackled through multi-pronged interventions. Bhattacharyya (2015) advocated microfinance schemes, public-private partnerships, and cooperatives as alternative means of improving affordability. Capacity building for local technicians and demand-side management systems has been shown to enhance technical reliability (Akinlabi and Oladokun 2021). Raman et al. (2025) established that targeted training programs and gender-sensitive community engagement will ensure that solar mini-grids engender both energy access and equity. Such is the fortune of rural electrification in Nigeria where the financial barriers, technical ones, cultural barriers, and sustainability barriers were addressed in a wholesome manner for real long-term success and true gender justice.

8. Policy and Governance Implications

8.1. Strategies for Inclusive Renewable Energy Programs

Renewable energy programs should, therefore, be incorporated into the solar mini-grid framework for rural areas in Nigeria to cater more directly to disadvantaged groups, particularly women. Participatory planning with the inclusion of women in energy-user committees (Saleh, 2024) enhances local ownership and sustains the long-term viability of the projects. Gender-sensitive financing mechanisms like micro-loans and subsidies for women's-run businesses will assist in improving economic empowerment and equal access to energy (Sesan et al., 2024).

The technical design should also be considered. Mahmood notes here that local capacity-building programs for technicians, in particular, women and youth, on the operation and maintenance of mini-grids are important for creating more reliable as well as job-creating mini-grids (2024). Decentralized structures, according to Edomah et al. (2021), are meant to harmonize consumption trends within the locality with improved efficiency and user satisfaction. If regulatory issues address these requirements, they should also touch upon inclusiveness by requiring the gender-segregated datagregation and data reporting. Lakeman (2025) proposes such measures, enabling the concentration of targeted interventions that guarantee renewable energy programs address social inequalities in a proactive way. Johnson et al. (2019) have explored a very real possibility of creating highly efficient energy planning based on cultural and social aspect integration into the framework. According to Sesan et al. (2024), gender-sensitive financing mechanisms such as micro-loans and subsidies for businesses operated by women can improve economic empowerment and equal access to energy.

The technical design should also be considered. Mahmood (2024) cites that capacity-building programs for local technicians, particularly women and youth, on the operation and maintenance of mini-grids are essential. This approach will not only increase reliability but will also create jobs. Edomah et al. (2021) revealed that decentralized structures aim to harmonize the consumption trends within the locality with improved efficiency and user satisfaction.

Regulatory issues should also touch upon inclusiveness by making requirements for gender-segregated data-aggregation and data reporting. Lakeman (2025) suggests that such measures allow focusing on targeted interventions to ensure that programs related to renewable energy proactively address social inequalities. Johnson et al. (2019) assessed a very real possibility of creating highly efficient energy planning by including cultural and social aspects into the framework.

8.2. Recommendations for Stakeholders

Streamlining permitting processes, allowing long-term subsidies for private investors, and setting up clear laws regarding renewable energy can help the government support renewable energy programs. Nelson and Kuriakose (2017) assert that these measures can speed up adoption while securing the community bottom lines.They are encouraged to partner with local women cooperatives and community groups in developing and operating these mini-grids. As Saleh (2024) revealed, this increases ownership and the possibility of sustainability of the project. Community-

based organizations handle issues such as training programs and awareness campaigns and even participatory decision making, ensuring that marginalized groups, especially women, have a voice in energy governance (Johnson et al., 2019).

More pilot models and replication of good practices in gender-sensitive governance should be funded by donors or international development agencies. Willingness-to-pay studies in rural Nigeria households and enterprises have demonstrated pricing avenues to attaining equitable access without jeopardizing financial viability.

Finally, monitoring and evaluation need to be continuous. Lakeman (2025) stated that regular assessments of the social, economic, and environmental impacts can give the coordination a sense of vigilance in responding to emerging challenges and weight in gender justice reinforcing. All lead to renewable energy programs that yield continuingly sustainable access to electricity and tangible empowerment for women in rural communities.

9. Conclusion

This study points to the ongoing changing nature of solar mini-grids, and how they can contribute to renewable energy transitions, with gender justice matters in rural Nigeria. Women can engage themselves more in the economic sector besides education and health with a regular and decentralized supply of electricity. Solar mini-grids do not only minimize energy poverty but also dispute traditional gender norms where women become active stakeholders in energy governance and community development. However, challenges to be overcome include but are not limited to financial restrictions, technology limitations, the socio-cultural dimensions, and the sustainability of these projects in the long-run. Policy and governance should complement every effort through gender-sensitive environment, participatory decision-making, and collaboration among the stakeholders in government, NGOs, groups of women and men, and private organizations.

Future research should not only focus on the effects of deploying solar mini-grids on women's empowerment but also on how they contribute to increasing resilience within the communities and enhancing the local economies. This should also look into novel financing mechanisms, technical solutions, and governance models that align renewable energy transitions with social equity and sustainable development. Solar mini-grids, with the design and construction of inclusive approaches, can serve as catalysts of the structural transformation being drawn in linking energy access and gender justice in rural Nigeria.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflicts of interest.

References

[1] Abba, Z. Y. I., Balta-Ozkan, N., and Drew, G. Renewable and Sustainable Energy Transition.

[2] Africa, U. U. P. EMPOWERING WOMEN FOR SUSTAINABLE ENERGY SOLUTIONS TO ADDRESS CLIMATE CHANGE.

[3] Ahlborg, H., and Hammar, L. (2014). Drivers and barriers to rural electrification in Tanzania and Mozambique–Grid-extension, off-grid, and renewable energy technologies. Renewable energy, 61, 117-124.

[4] Ajia, A. T. (2025). Policy Challenges and Opportunities for Renewable Energy Development in Nigeria: A Systematic Review. African Journal of Environmental Sciences and Renewable Energy, 18(1), 115-137.

[5] Akinlabi, A. K., and Oladokun, V. O. (2021). A review of interconnected minigrid solution for underserved distribution network in Nigeria. Technology and Economics of Smart Grids and Sustainable Energy, 6(1), 11.

[6] Akinlabi, A. K., and Oladokun, V. O. (2021). A review of interconnected minigrid solution for underserved distribution network in Nigeria. Technology and Economics of Smart Grids and Sustainable Energy, 6(1), 11.

[7] Akinyemi, O., Sesan, T., Adu, O., Sokeye, B., Longtar, C., Chimdi-Ejiogu, N., and Sinzogan, C. (2021). Small-scale offgrid energy systems: Improve productivity by increasing women's access to electricity in rural Nigeria'. Policy brief, 230.

[8] Akinyemi, O., Sesan, T., Adu, O., Sokeye, B., Longtar, C., Chimdi-Ejiogu, N., and Sinzogan, C. (2021). Small-scale offgrid energy systems: Improve productivity by increasing women's access to electricity in rural Nigeria'. Policy brief, 230.

[9] Amiliana, V., and Suliswanto, M. S. W. (2025). Infrastructure development as a catalyst for sustainable economic growth in OIC countries. Jurnal Ekonomi and Studi Pembangunan, 26(1), 115-134.

[10] Asiimwe, H. (2024). Smart Grids? Intersectional Discursive Analyses on Gender and Sustainable Renewable Energy Development in East Africa (Doctoral dissertation, Universitätsbibliothek).

[11] Babalola, S. O., Daramola, M. O., and Iwarere, S. A. (2022). Socio-economic impacts of energy access through off-grid systems in rural communities: a case study of southwest Nigeria. Philosophical Transactions of the Royal Society A, 380(2221), 20210140.

[12] Balogun, A. Q. (2024). Energy access and renewable energy consumption in Nigeria: an X-ray of the industrial output. ENERGY, 4(1), 221-235.

[13] Bauhardt, C., and Harcourt, W. (Eds.). (2018). Feminist political ecology and the economics of care. London: Routledge.

[14] Bazilian, M., and Pielke, R. (2013). Making energy access meaningful. Issues in science and technology, 29(4), 74-78.

[15] Bhattacharyya, S. C. (2015). Mini-grid based electrification in Bangladesh: Technical configuration and business analysis. Renewable Energy, 75, 745-761.

[16] Bhattacharyya, S. C. (2015). Mini-grid based electrification in Bangladesh: Technical configuration and business analysis. Renewable Energy, 75, 745-761.

[17] Bhattacharyya, S. C., and Palit, D. (Eds.). (2014). Mini-grids for rural electrification of developing countries: analysis and case studies from South Asia. Springer.

[18] Blok, K., and Bots, P. Modelling of Global Energy Demand in the Transportation Sector A Country by Country Approach.

[19] Carabajal, A. T., Orsot, A., Moudio, M. P. E., Haggai, T., Okonkwo, C. J., Jarrard III, G. T., and Selby, N. S. (2024). Social and economic impact analysis of solar mini-grids in rural Africa: a cohort study from Kenya and Nigeria. Environmental Research: Infrastructure and Sustainability, 4(2), 025005.

[20] Carabajal, A. T., Orsot, A., Moudio, M. P. E., Haggai, T., Okonkwo, C. J., Jarrard III, G. T., and Selby, N. S. (2024). Social and economic impact analysis of solar mini-grids in rural Africa: a cohort study from Kenya and Nigeria. Environmental Research: Infrastructure and Sustainability, 4(2), 025005.

[21] Carabajal, A. T., Orsot, A., Moudio, M. P. E., Haggai, T., Okonkwo, C. J., Jarrard III, G. T., and Selby, N. S. (2024). Social and economic impact analysis of solar mini-grids in rural Africa: a cohort study from Kenya and Nigeria. Environmental Research: Infrastructure and Sustainability, 4(2), 025005.

[22] Chant, S., and Sweetman, C. (2012). Fixing women or fixing the world?'Smart economics', efficiency approaches, and gender equality in development. Gender and Development, 20(3), 517-529.

[23] Chidera Abonyi, D. (2019). Feasibility Study for a Solar PV (Hybrid) Mini-grid System for Small Businesses in Lagos, Nigeria (Master's thesis, PAUWES).

[24] Chidera Abonyi, D. (2019). Feasibility Study for a Solar PV (Hybrid) Mini-grid System for Small Businesses in Lagos, Nigeria (Master's thesis, PAUWES).

[25] Cicowiez, M., Akinyemi, O., Sesan, T., Adu, O., and Sokeye, B. (2022). Gender-differentiated impacts of a rural electrification policy in Nigeria. Energy Policy, 162, 112774.

[26] Clancy, J., and Feenstra, M. (2019). Women, gender equality and the energy transition in the EU. Publications Office of the European Union.

[27] Clancy, J., Barnett, A., Cecelski, E., Pachauri, S., Dutta, S., Oparaocha, S., and Kooijman, A. (2019). Gender in the transition to sustainable energy for all: From evidence to inclusive policies.

[28] Cornwall, A. (2016). Women's empowerment: What works?. Journal of International Development, 28(3), 342-359.

[29] Cowell, R. (2016). Global Energy Justice: Problems, Principles, and Practices.

[30] Edomah, N., Ndulue, G., and Lemaire, X. (2021). A review of stakeholders and interventions in Nigeria's electricity sector. Heliyon, 7(9).

[31] Elegeonye, H. I., Owolabi, A. B., Ohunakin, O. S., Yakub, A. O., Yahaya, A., Same, N. N., ... and Huh, J. S. (2023). Techno-economic optimization of mini-grid systems in Nigeria: A case study of a PV–battery–diesel hybrid system. Energies, 16(12), 4645.

[32] Elegeonye, H. I., Owolabi, A. B., Ohunakin, O. S., Yakub, A. O., Yahaya, A., Same, N. N., ... and Huh, J. S. (2023). Techno-economic optimization of mini-grid systems in Nigeria: A case study of a PV–battery–diesel hybrid system. Energies, 16(12), 4645.

[33] Elegeonye, H. I., Owolabi, A. B., Ohunakin, O. S., Yakub, A. O., Yahaya, A., Same, N. N., ... and Huh, J. S. (2023). Techno-economic optimization of mini-grid systems in Nigeria: A case study of a PV–battery–diesel hybrid system. Energies, 16(12), 4645.

[34] Emordi, C. C. (2015). A complex systems approach to energy poverty in sub-Saharan Africa: Nigeria as a case study. Arizona State University.

[35] Energy Sector Management Assistance Programme. (2017). Mini Grids in Nigeria: A Case Study of a Promising Market. World Bank.

[36] Ezebuihe, J. A., Parlasca, M. C., and Qaim, M. (2024). Links between rural electrification and gendered off-farm employment in sub-Saharan Africa.

[37] Famewo, A. S., and Uwala, V. A. (2022). Socio-economic impacts of rural energy poverty on women and students in Esa-Oke, Nigeria. Journal of Sustainability and Environmental Management, 1(2), 84-93.

[38] Famewo, A. S., and Uwala, V. A. (2022). Socio-economic impacts of rural energy poverty on women and students in Esa-Oke, Nigeria. Journal of Sustainability and Environmental Management, 1(2), 84-93.

[39] Finlay, E., Kilby, P., Spencer, R., and Wu, J. (Eds.). (2024). Rethinking Gender in Development Practice: Lessons from the Field. Taylor and Francis.

[40] Godson-Ibeji, C. C., JU, C., Ajaero, J. O., and Markalbert, U. S. (2021). Rural energy needs of smallholder women farmers for improved farm productivity and rural business enterprises in Abia state, Nigeria.

[41] Gupta, J., and Prodani, K. (2022). Sustainable development, climate change and planetary justice: governance challenges. In Handbook on Governance and Development (pp. 212-229). Edward Elgar Publishing.

[42] Ha, Y. H., and Kumar, S. S. (2021). Investigating decentralized renewable energy systems under different governance approaches in Nepal and Indonesia: How does governance fail?. Energy Research and Social Science, 80, 102214.

[43] Jaho, P. (2024). Energy poverty and gender equality in education.

[44] Jaho, P. (2024). Energy poverty and gender equality in education.

[45] Janghorban, P., Sesan, T., Salihu, M. K., Ohunakin, O., and Chinichian, N. (2024). Willingness to Pay for an Electricity Connection: A Choice Experiment Among Rural Households and Enterprises in Nigeria. arXiv preprint arXiv:2407.15757.

[46] Johnson, O. W., Gerber, V., and Muhoza, C. (2019). Gender, culture and energy transitions in rural Africa. Energy Research and Social Science, 49, 169-179.

[47] Johnson, O. W., Gerber, V., and Muhoza, C. (2019). Gender, culture and energy transitions in rural Africa. Energy Research and Social Science, 49, 169-179.

[48] Khalifa, Y. Gender equality, equity and women's empowerment framework: a proposed framework to assess and monitor gender equality, equity and women's empowerment in modern energy cooking services (MECS).

[49] Köhlin, G., Sills, E. O., Pattanayak, S. K., and Wilfong, C. (2011). Energy, gender and development: what are the linkages? Where is the evidence?. Where is the Evidence.

[50] Lakeman, S. (2025). Gender equality in Africa's energy transition. Nature Energy, 1-3.

[51] Lee, S. Y. (2020). Promoting women's empowerment through access to electricity: a case study of the mini-grid project in a rural village in Myanmar.

[52] Listo, R. (2018). Gender myths in energy poverty literature: a critical discourse analysis. Energy Research and Social Science, 38, 9-18.

[53] Longe, O. M. (2021). An assessment of the energy poverty and gender nexus towards clean energy adoption in rural South Africa. Energies, 14(12), 3708.

[54] MacGregor, S. (Ed.). (2017). Routledge handbook of gender and environment. Taylor and Francis.

[55] Madubueze, M. H. C., Nwokike, C., EGBERI, A. E., and NWOBI, F. O. Engineering the Governance Dynamics for Agrivoltaics Adoption in Nigeria: Developmental Issues, Policy Options for a Greener Energy Future. Policy Options for a Greener Energy Future.

[56] Mahmood, A. (2024). POLICY TOOLKIT.

[57] Medupin, C. (2020). Women in environmental sciences (WiES) and the UN SDGs: A catalyst for achieving a sustainable future for all. Sustainability, 12(17), 7116.

[58] Mohideen, R. (2018). Energy technology innovation in South Asia: implications for gender equality and social inclusion.

[59] Mohideen, R. (2018). Energy technology innovation in South Asia: implications for gender equality and social inclusion.

[60] Mperejekumana, P., Shen, L., Zhong, S., Gaballah, M. S., and Muhirwa, F. (2024). Exploring the potential of decentralized renewable energy conversion systems on water, energy, and food security in Africa. Energy Conversion and Management, 315, 118757.

[61] Mukhtar, M., Obiora, S., Yimen, N., Quixin, Z., Bamisile, O., Jidele, P., and Irivboje, Y. I. (2021). Effect of inadequate electrification on Nigeria's economic development and environmental sustainability. Sustainability, 13(4), 2229.

[62] Natividad, L. E., and Benalcazar, P. (2023). Hybrid renewable energy systems for sustainable rural development: Perspectives and challenges in energy systems modeling. Energies, 16(3), 1328.

[63] Natividad, L. E., and Benalcazar, P. (2023). Hybrid renewable energy systems for sustainable rural development: Perspectives and challenges in energy systems modeling. Energies, 16(3), 1328.

[64] Nelson, S., and Kuriakose, A. T. (2017). Gender and renewable energy: Entry points for women's livelihoods and employment. Climate Investment Funds.

[65] Nzeanorue, C. C., Sobajo, M. S., Okpala, B. C., Opeyemi, A. M., Stephen, V. I., Madukwe, C. M., ... and Ugbine, O. F. (2024). A Comprehensive Analysis of Sustainable Energy Development: A Review of Existing Research. Path of Science, 10(7), 1014-1024.

[66] Odo, D. B., Yang, I. A., Green, D., and Knibbs, L. D. (2021). Women's empowerment and household fuel use in 31 African countries: a cross-sectional analysis of households in the Demographic and Health Survey. Environmental Research Letters, 16(2), 025012.

[67] Okoli, N. (2024). Exploring the impact of conditional cash transfers on economic empowerment and clean energy use among poor women in urban Nigeria.

[68] Onyeji, I., Bazilian, M., and Nussbaumer, P. (2012). Contextualizing electricity access in sub-Saharan Africa. Energy for Sustainable Development, 16(4), 520-527.

[69] Oparaocha, S., and Dutta, S. (2011). Gender and energy for sustainable development. Current Opinion in Environmental Sustainability, 3(4), 265-271.

[70] Oparaocha, S., and Dutta, S. (2011). Gender and energy for sustainable development. Current Opinion in Environmental Sustainability, 3(4), 265-271.

[71] Østergaard, P. A., Duic, N., Noorollahi, Y., and Kalogirou, S. (2022). Renewable energy for sustainable development. Renewable energy, 199, 1145-1152.

[72] Parikh, J. (2011). Hardships and health impacts on women due to traditional cooking fuels: A case study of Himachal Pradesh, India. Energy Policy, 39(12), 7587-7594.

[73] Perrett, T. Energy Access and Urban Livelihoods: the impact of clean energy access on the livelihoods of low-income, urban enterprises in Accra, Ghana (Doctoral dissertation, Loughborough University).

[74] Ponnambalam, S., and Ilampoornan, M. K. (2025). Policy and Socio-Economic Impacts of Renewable-Integrated Smart Grids in Developing Economies. International Journal of Educational Practices and Engineering (IJEPE), 2(4), 101-117.

[75] Raman, R., Ustenko, V., Filho, W. L., and Nedungadi, P. (2025). Energy justice and gender: bridging equity, access, and policy for sustainable development. Discover Sustainability, 6(1), 558.

[76] Robeyns, I. (2017). Wellbeing, freedom and social justice: The capability approach re-examined (p. 266). Open book publishers.

[77] Ryan, S. E. (2014). Rethinking gender and identity in energy studies. Energy Research and Social Science, 1, 96-105.

[78] Ryan, S. E. (2014). Rethinking gender and identity in energy studies. Energy Research and Social Science, 1, 96-105.

[79] Saleh, M. T. (2024). Mini-Grids: Empowering Africa's Sustainable Energy Transition. Advances in Science and Technology, 142, 67-77.

[80] Segura-Rodríguez, I., Bhandari, R., and Sanogo, S. (2025). Repurpose of abandoned mini-grids in rural areas: Analysis of potential strategies. Energy for Sustainable Development, 87, 101762.

[81] Sesan, T., Uduka, U., Baker, L., Ugwu, O., Eleri, E., and Bhattacharyya, S. (2024). Exploring the connections between mini-grid market regulation and energy access expansion: The case of Nigeria. Energy Policy, 184, 113891.

[82] Sesan, T., Uduka, U., Baker, L., Ugwu, O., Eleri, E., and Bhattacharyya, S. (2024). Exploring the connections between mini-grid market regulation and energy access expansion: The case of Nigeria. Energy Policy, 184, 113891.

[83] Sievert, M. (2024). Rural electrification and domestic violence in Sub-Saharan Africa (No. 1078). Ruhr Economic Papers.

[84] Sovacool, B. K. (2021). Who are the victims of low-carbon transitions? Towards a political ecology of climate change mitigation. Energy research and social science, 73, 101916.

[85] Sovacool, B. K., and Drupady, I. M. (2016). Energy access, poverty, and development: the governance of small-scale renewable energy in developing Asia. Routledge.

[86] Stojanovski, O., Thurber, M., and Wolak, F. (2017). Rural energy access through solar home systems: Use patterns and opportunities for improvement. Energy for Sustainable Development, 37, 33-50.

[87] Suberu, M. Y., Mustafa, M. W., Bashir, N., Muhamad, N. A., and Mokhtar, A. S. (2013). Power sector renewable energy integration for expanding access to electricity in sub-Saharan Africa. Renewable and Sustainable Energy Reviews, 25, 630-642.

[88] Tagliapietra, S., Occhiali, G., Nano, E., and Kalcik, R. (2020). The impact of electrification on labour market outcomes in Nigeria. Economia Politica, 37(3), 737-779.

[89] Tandrayen-Ragoobur, V. (2024). Gender and energy poverty in Africa: An intersectional approach. In Women and the energy sector: Gender inequality and sustainability in production and consumption (pp. 263-295). Cham: Springer International Publishing.

[90] Tandrayen-Ragoobur, V. (2024). Gender and energy poverty in Africa: An intersectional approach. In Women and the energy sector: Gender inequality and sustainability in production and consumption (pp. 263-295). Cham: Springer International Publishing.

[91] Tenenbaum, B., Greacen, C., and Shrestha, A. (2024). Mini Grid Solutions for Underserved Customers: New Insights from Nigeria and India. World Bank Publications.

[92] Tenenbaum, B., Greacen, C., and Shrestha, A. (2024). Mini Grid Solutions for Underserved Customers: New Insights from Nigeria and India. World Bank Publications.

[93] Toyin, D. A., Lachman, A., Aku, C. A., Anya, E. K., Ogundiran, A., Best, R. A., and Orji, U. (2023). Towards A Sustainable Energy Future For Nigeria: Regulations, Challenges, and Opportunities. Challenges, and Opportunities (October 25, 2023).

[94] Tsekane, P. N., Bessala, J. M. N., Tedga, P. N., and Samba, M. C. (2024). Access to energy and women's human capital in sub-Saharan Africa. Heliyon, 10(19).

[95] UN Women. (2021). Feminist perspectives on sustainable development and energy transitions. UN Women Policy Brief.

[96] Walking along the lines of power: A systems approach to understanding co-emergence of society, environment, and electricity technology in rural Tanzania. Energy Research and Social Science, 5, 20–33.

[97] Willingness to Pay for an Electricity Connection: A Choice Experiment Among Rural Households and Enterprises in Nigeria.

[98] Winther, T., Ulsrud, K., and Saini, A. (2018). Solar-powered electricity access: Implications for women's empowerment in rural Kenya. Energy research and social science, 44, 61-74.

[99] World Health Organization. (2014). WHO guidelines for indoor air quality: household fuel combustion. World Health Organization.

[100] World Health Organization. (2014). WHO guidelines for indoor air quality: household fuel combustion. World Health Organization.

[101] Yadoo, A., and Cruickshank, H. (2010). The value of cooperatives in rural electrification. Energy policy, 38(6), 2941-2947.