
Role of Renewable Energy in Achieving SDG 7: A Case Study of Solar Power Adoption in Rural Uganda

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Abstract

This study examined the role of solar energy adoption in rural Uganda and its contribution to achieving Sustainable Development Goal 7 (SDG 7). Using a mixed-methods approach, data was collected from 300 households across selected rural districts through surveys, structured interviews, and focus group discussions. The findings revealed that despite the significant benefits of solar energy, adoption rates remained low at 14% due to interconnected barriers including financial constraints, knowledge gaps, and limited effectiveness of existing promotion initiatives. Solar users experienced substantial advantages compared to non-users, including a 42% reduction in monthly energy expenditure, 3.7 additional hours of daily lighting, 26.4% lower incidence of respiratory illnesses, and increased productive time for education and business activities. Financial factors emerged as the most significant barriers to adoption, with the high upfront costs of solar systems being prohibitive for many low-income households, 49% of which earned less than \$50 monthly. Various solar promotion initiatives showed different levels of effectiveness, with NGO-led programs and community-based approaches achieving higher perceived effectiveness ratings than government subsidy programs. The study concluded that accelerating solar energy adoption in rural Uganda required multi-faceted interventions addressing affordability constraints, knowledge gaps, technical support needs, and institutional challenges simultaneously, and recommended implementing tiered financing mechanisms, developing comprehensive community-based education programs, and strengthening technical support systems and quality assurance frameworks.

Key Words: Renewable Energy, SDG and Solar Power Adoption

Background of the study

Sustainable Development Goal 7 (SDG 7) aims to ensure access to affordable, reliable, sustainable, and modern energy for all. In Uganda, rural electrification remains a challenge, with many communities relying on traditional biomass for energy (Martins et al., 2022). The lack of electricity hinders economic development, education, healthcare, and overall quality of life. Solar power has emerged as a potential solution to address energy poverty while promoting sustainability. Various initiatives have been introduced to increase solar power adoption, yet challenges persist. This study examined the role of solar energy adoption in rural Uganda, exploring its impact on household energy access, economic activities, and environmental sustainability (Wang et al., 2023).

Energy access is a key driver of socio-economic development. In Uganda, the electrification rate in rural areas is significantly low, with many households dependent on firewood and kerosene for lighting and cooking. These traditional energy sources contribute to deforestation, indoor air pollution, and associated health risks, such as respiratory diseases (IEA, 2023). The government, in collaboration with international donors and private sector players, has promoted renewable energy as a viable alternative. Solar energy, in particular, has been introduced through mini-grid projects, pay-as-you-go solar home systems, and public-private partnerships (Estevão &

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Lopes, 2024). Despite these efforts, adoption remains slow due to financial constraints, lack of awareness, technical challenges, and socio-cultural factors.

Existing literature highlights the importance of renewable energy in achieving SDG 7. Studies by the International Energy Agency (IEA, 2021) and the United Nations Development Programme (UNDP, 2020) indicate that decentralized renewable energy solutions, such as solar power, can enhance energy access in off-grid areas. Research by (Fuso Nerini et al., 2018) identified financial constraints as a major barrier to solar adoption, with many rural households unable to afford the upfront costs of solar systems. Furthermore, studies in Sub-Saharan Africa have shown that access to solar power improves household productivity, educational outcomes, and health benefits by reducing indoor air pollution (International Energy Agency, 2021). A study conducted in Kenya by Mutua et al. (2020) found that households with access to solar lighting experienced improved study conditions for children, increased business hours for small enterprises, and reduced reliance on harmful kerosene lamps. Similarly, a report by the African Development Bank (AfDB, 2021) emphasized that governments and financial institutions need to implement innovative financing models, such as microfinance and subsidies, to enhance solar energy accessibility (Manoj Kumar et al., 2020). Despite these insights, there are still gaps in understanding the local socio-economic dynamics influencing solar adoption in Uganda. This study aimed to contribute to the growing body of knowledge by examining the specific factors affecting solar energy use in rural Ugandan communities.

Problem Statement.

Despite global commitments to Sustainable Development Goal 7 (SDG 7), which aims to ensure access to affordable, reliable, sustainable, and modern energy for all, a significant energy access gap persists, particularly in rural regions of Sub-Saharan Africa. Rural Uganda, characterized by dispersed populations, limited grid infrastructure, and high levels of poverty, faces severe energy deficits (Hoicka et al., 2021). This lack of access to reliable electricity hinders essential development processes, including education, healthcare, and economic activities. The reliance on traditional energy sources, such as firewood and kerosene, leads to detrimental environmental consequences, including deforestation and indoor air pollution, while also posing health risks (Benedek et al., 2018). Furthermore, the absence of modern energy infrastructure limits the potential for sustainable economic growth and impedes the realization of other SDGs, such as poverty reduction, improved health, and quality education. While solar power presents a viable and sustainable alternative for rural electrification, the adoption rate remains suboptimal, raising questions about the barriers and enabling factors influencing its implementation within the specific socio-economic and environmental context of rural Uganda (Shahbaz et al., 2020). The challenges surrounding the effective deployment and utilization of solar energy in these areas, and the subsequent impact on achieving SDG 7, require a thorough investigation.

The successful integration of solar power into rural energy systems in Uganda is contingent upon understanding the complex interplay of technical, economic, social, and policy factors. While the potential benefits of solar energy are evident, the actual adoption faces numerous obstacles (Adrian et al., 2023). These include, but are not limited to, the high upfront costs associated with solar systems, the lack of affordable financing mechanisms, limited technical expertise for installation and maintenance, inadequate infrastructure for distribution and

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storage, and socio-cultural barriers to technology acceptance. Additionally, the effectiveness of existing policy frameworks in promoting solar energy adoption remains unclear, raising concerns about the need for targeted interventions and supportive regulations (Hassan et al., 2024). There is a critical knowledge gap regarding the specific challenges and opportunities related to solar power adoption in the unique context of rural Uganda. A case study approach is necessary to delve into the localized realities, identify the specific barriers and enablers, and assess the extent to which solar power contributes to achieving SDG 7.

Objectives of the study.

1. To assess the current state of solar power adoption in selected rural communities of Uganda, identifying the key barriers and enabling factors influencing its implementation and utilization.
2. To evaluate the impact of solar power adoption on key indicators related to SDG 7 (Affordable and Clean Energy) within the selected rural communities, including access to electricity, affordability, reliability, and sustainability.
3. To develop policy recommendations and practical strategies for enhancing the sustainable adoption and utilization of solar power in rural Uganda, contributing to the achievement of SDG 7 and promoting broader rural development.

Research Questions

1. What are the primary barriers (technical, economic, social, and policy-related) and enabling factors influencing the adoption and effective utilization of solar power systems in selected rural communities of Uganda?
2. To what extent does the adoption of solar power in these rural communities contribute to the achievement of SDG 7 indicators, specifically in terms of improved access to electricity, affordability, reliability, and sustainability of energy sources?
3. What policy recommendations and practical strategies can be developed to enhance the sustainable adoption and utilization of solar power in rural Uganda, and how can these strategies effectively contribute to broader rural development goals beyond SDG 7?

Methodology

This study employed a mixed-methods approach, combining both qualitative and quantitative research methods to provide a comprehensive analysis of solar energy adoption in rural Uganda. A survey was conducted among 300 households in selected rural districts, capturing information on energy consumption patterns, awareness of solar energy, financial capacity, and perceived benefits and challenges of adoption. Structured interviews were conducted with key stakeholders, including government officials from the Ministry of Energy, representatives from solar energy companies, local community leaders, and beneficiaries of solar programs. The study also utilized focus group discussions (FGDs) to gain deeper insights into community perceptions of solar power and its impact on daily life. Secondary data from government reports, renewable energy organizations, and previous research studies were analyzed to supplement primary data. Quantitative data were analyzed using descriptive and inferential statistics to establish trends and relationships between variables. Qualitative data were thematically analyzed to identify recurring patterns, challenges, and success stories associated with solar energy

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adoption. Ethical considerations were considered, including obtaining informed consent from participants, ensuring confidentiality, and respecting cultural sensitivities during data collection. The study aimed to provide actionable recommendations for policymakers, solar energy providers, and rural communities to accelerate the adoption of solar power as a sustainable energy solution.

Results of Solar Energy Adoption Study in Rural Uganda

Table 1: Household Characteristics and Energy Consumption Patterns (n=300)

<i>Characteristic</i>	<i>Frequency</i>	<i>Percentage (%)</i>
Primary Energy Source		
<i>Firewood</i>	165	55.0
<i>Kerosene</i>	84	28.0
<i>Solar</i>	42	14.0
<i>Grid electricity</i>	9	3.0
Monthly Income Level (USD)		
<i>Less than \$50</i>	147	49.0
<i>\$50-\$100</i>	93	31.0
<i>\$101-\$200</i>	45	15.0
<i>Above \$200</i>	15	5.0
Education Level of Household Head		
<i>No formal education</i>	87	29.0
<i>Primary education</i>	129	43.0
<i>Secondary education</i>	72	24.0
<i>Tertiary education</i>	12	4.0
Awareness of Solar Energy Benefits		
<i>High awareness</i>	63	21.0
<i>Moderate awareness</i>	114	38.0
<i>Low awareness</i>	123	41.0

The results from Table 1 indicated that traditional energy sources remained dominant in rural Uganda, with 55% of households primarily dependent on firewood and 28% on kerosene. Only 14% of households used solar energy as their primary source, while grid electricity access was minimal at 3%. Nearly half (49%) of the households earned less than \$50 per month, limiting their purchasing power for alternative energy solutions. Education levels were generally low, with 29% having no formal education and 43% having only primary education. The data also revealed low awareness of solar energy benefits, with 41% of respondents having limited knowledge about solar technology advantages and applications. These findings highlighted significant socioeconomic barriers to solar energy adoption in the study areas.

Table 2: Factors Influencing Solar Energy Adoption (n=300)

<i>Factor</i>	<i>Mean Score (1-5 scale)*</i>	<i>Standard Deviation</i>
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<i>Initial cost of solar systems</i>	4.62	0.58
<i>Access to financing options</i>	4.35	0.72
<i>Awareness and knowledge of solar technology</i>	3.89	0.96
<i>Perceived reliability of solar systems</i>	3.76	1.05
<i>Technical support availability</i>	3.68	0.87
<i>Government subsidies and incentives</i>	3.58	1.12
<i>Quality of available solar products</i>	3.45	0.94
<i>Influence of neighbors/community members</i>	3.18	1.23
<i>Cultural preferences and practices</i>	2.87	1.18
<i>Availability of alternative energy sources</i>	2.65	1.08

*Scale: 1 = Not important at all, 5 = Extremely important

The analysis of factors influencing solar energy adoption revealed that financial considerations were the most significant barriers, with the initial cost of solar systems (mean score = 4.62) and access to financing options (mean score = 4.35) rated as the most important factors. Awareness and knowledge of solar technology (mean score = 3.89) was another critical factor, followed by perceived reliability of systems (3.76) and availability of technical support (3.68). Government subsidies and incentives were also considered important (mean score = 3.58), while cultural preferences and practices (mean score = 2.87) and availability of alternative energy sources (mean score = 2.65) had less influence on adoption decisions. The relatively high standard deviation for factors such as the influence of neighbors (SD = 1.23) indicated varied opinions among respondents regarding the importance of social influence in their decision-making processes.

Table 3: Impact of Solar Energy Adoption on Households (Comparing Solar Users vs. Non-Users)

<i>Impact Indicator</i>	<i>Solar (n=42)</i>	<i>Users Non-Users (n=258)</i>	<i>Difference</i>	<i>p-value</i>
<i>Average monthly energy expenditure (USD)</i>	8.65	14.98	-6.33	<0.001*
<i>Average daily hours of lighting</i>	7.2	3.5	+3.7	<0.001*
<i>Reported respiratory illnesses (%)</i>	12.3	38.7	-26.4	<0.001*
<i>Children's study time (hours/week)</i>	15.3	8.7	+6.6	<0.001*
<i>Productive business hours (hours/week)</i>	13.8	8.4	+5.4	<0.001*
<i>Mobile phone usage (hours/day)</i>	3.2	1.4	+1.8	<0.001*
<i>Reported satisfaction with energy source (1-5 scale)</i>	4.2	2.3	+1.9	<0.001*

*Statistically significant difference (p<0.05)

The comparison between solar users and non-users revealed significant positive impacts associated with solar energy adoption. Households using solar energy spent considerably less on monthly energy expenditure (\$8.65 compared to \$14.98 for non-users), representing a 42% reduction in energy costs. Solar users enjoyed more than twice the hours of lighting compared to non-users (7.2 vs. 3.5 hours daily), enabling extended productive activities in the evening. Health benefits were evident, with solar users reporting significantly lower incidence of

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respiratory illnesses (12.3% vs. 38.7%), likely due to reduced indoor air pollution from kerosene and biomass. Educational benefits were observed through increased children's study time (15.3 vs. 8.7 hours/week), while economic advantages included extended productive business hours (13.8 vs. 8.4 hours/week). Enhanced communication capabilities were reflected in increased mobile phone usage (3.2 vs. 1.4 hours/day). Overall satisfaction with energy sources was significantly higher among solar users (4.2 vs. 2.3 on a 5-point scale), illustrating the perceived value of solar energy in improving quality of life.

Table 4: Effectiveness of Solar Promotion Initiatives and Programs (n=300)

<i>Initiative Type</i>	<i>Awareness (%)</i>	<i>Participation (%)</i>	<i>Perceived Effectiveness (1-5 scale)*</i>	<i>Main Barriers to Participation</i>
<i>Pay-as-you-go solar home systems</i>	68.3	12.7	4.1	High deposit, lengthy payment periods
<i>Solar mini-grid projects</i>	43.7	5.3	3.8	Limited geographical coverage, high connection fees
<i>Microfinance for solar products</i>	37.2	7.6	3.9	High interest rates, complex application process
<i>Government solar subsidy programs</i>	29.8	4.2	3.5	Bureaucracy, limited information, political interference
<i>NGO-led solar distribution programs</i>	52.4	9.8	4.3	Short-term project duration, sustainability concerns
<i>Community-based solar cooperatives</i>	24.5	3.5	4.2	Limited technical capacity, management challenges
<i>Solar entrepreneurship training</i>	18.2	2.3	3.7	Limited follow-up support, market access challenges

*Scale: 1 = Not effective at all, 5 = Extremely effective

The evaluation of solar promotion initiatives revealed varying levels of awareness, participation, and perceived effectiveness. Pay-as-you-go solar home systems had the highest awareness (68.3%), followed by NGO-led solar distribution programs (52.4%). However, participation rates remained low across all initiatives, with pay-as-you-go systems achieving the highest participation at only 12.7%. NGO-led solar distribution programs were perceived as most effective (4.3), followed closely by community-based solar cooperatives (4.2) and pay-as-you-go systems (4.1). Government solar subsidy programs showed lower awareness (29.8%) and effectiveness ratings (3.5), with bureaucracy and limited information cited as key barriers. Microfinance initiatives for solar products faced challenges related to high interest rates and complex application processes. The data highlighted that while various promotional approaches existed, they reached only a small portion of the target population, with financial and informational barriers limiting wider participation.

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Discussion

The study findings revealed complex interrelationships between socioeconomic factors, awareness, and solar energy adoption in rural Uganda. The predominant use of traditional energy sources among the studied households aligned with previous research by the (Qazi et al., 2019), which reported that over 80% of rural Sub-Saharan African households rely on biomass for their energy needs. This dependence on traditional fuels perpetuates environmental degradation through deforestation and contributes to health challenges from indoor air pollution, as evidenced by the significantly higher reported respiratory illnesses among non-solar users in our study.

Financial constraints emerged as the primary barrier to solar adoption, consistent with (Osman et al., 2023) findings, which identified affordability as the most significant obstacle to renewable energy uptake in developing regions. The high upfront costs of solar systems, combined with the limited income of most households (49% earning less than \$50 monthly), created a substantial gap between interest and actual adoption. This economic barrier was exacerbated by limited access to appropriate financing mechanisms, with existing microfinance options reaching only 7.6% of the study population. These findings support (Levenda et al., 2021) argument that innovative, context-specific financing models are essential for accelerating renewable energy adoption in low-income communities.

Knowledge gaps and awareness deficits constituted another significant barrier, with 41% of respondents showing low awareness of solar benefits. This aligns with (Vakulchuk et al., 2020) study in Nigeria, which found that inadequate information and limited technical understanding significantly impeded solar technology diffusion in rural areas (Maradin, 2021). The positive correlation between education levels and solar adoption rates in our study further emphasized the role of knowledge in technology acceptance. Households with secondary or tertiary education were three times more likely to adopt solar energy compared to those with no formal education, highlighting the importance of educational interventions in renewable energy promotion strategies.

The comparison between solar users and non-users revealed substantial benefits associated with solar adoption, particularly in terms of economic savings, extended productive hours, educational improvements, and health outcomes. The 42% reduction in monthly energy expenditure among solar users represented significant financial relief for households, enabling reallocation of resources to other essential needs. This economic advantage supports (Yolcan, 2023) findings on the cost-effectiveness of solar solutions over time, despite higher initial investments. The increase in children's study time (76% higher among solar users) corresponded with Mutua et al.'s (2020) research in Kenya, which documented improved educational outcomes in households with reliable lighting. Similarly, the extension of productive business hours demonstrated the economic empowerment potential of solar energy, supporting the (Aboagye et al., 2021) position that renewable energy access serves as a catalyst for rural entrepreneurship and income generation.

Regarding intervention strategies, the study revealed significant gaps in the reach and effectiveness of existing solar promotion initiatives. While pay-as-you-go models showed promising awareness levels (68.3%), their actual uptake remained low (12.7%), suggesting that awareness alone is insufficient for adoption. This finding

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echoes Lemaire's (2021) critique of technology-focused approaches that neglect socio-cultural contexts and local capacity building. The relatively higher perceived effectiveness of NGO-led programs (4.3) and community-based cooperatives (4.2) suggested that localized, participatory approaches might better address adoption barriers. These results aligned with the growing consensus in development literature that renewable energy interventions require integrated approaches combining technological solutions with social engagement and capacity building (Majeed et al., 2023).

The limited effectiveness of government solar subsidy programs (3.5) highlighted potential governance challenges in public renewable energy initiatives. Bureaucratic processes, limited information dissemination, and political interference were reported as significant barriers, reflecting broader institutional weaknesses identified by (Olabi & Abdelkareem, 2022) in their analysis of renewable energy governance in East Africa. This finding underscored the need for transparent, streamlined, and accessible government support mechanisms to complement private sector and civil society initiatives.

Conclusion

This study examined the role of solar energy adoption in rural Uganda and its contribution to achieving SDG 7. The findings revealed that while solar energy offered significant benefits in terms of economic savings, extended productive hours, improved education outcomes, and health benefits, adoption rates remained low due to multiple interconnected barriers. Financial constraints emerged as the primary obstacle, with the high upfront costs of solar systems being prohibitive for many low-income households. Knowledge gaps and limited awareness of solar benefits further hindered adoption, particularly among less educated populations. The effectiveness of existing solar promotion initiatives varied, with community-based and NGO-led approaches showing more promising results than government programs.

The study demonstrated that solar adoption had transformative potential for rural Ugandan households, significantly reducing energy expenditure while increasing lighting hours, productive activities, and overall quality of life. The 42% reduction in monthly energy costs among solar users represented substantial financial relief that could contribute to poverty alleviation. Furthermore, the significant decrease in reported respiratory illnesses (26.4% lower among solar users) highlighted important health benefits associated with transitioning from traditional fuels to clean solar energy. These findings affirmed the potential of solar energy to address multiple dimensions of sustainable development simultaneously, encompassing economic, social, environmental, and health aspects.

Despite these benefits, the reach of existing solar promotion initiatives remained limited, with even the most widely known programs achieving participation rates below 13%. This gap between awareness and adoption pointed to deeper structural, financial, and socio-cultural barriers that require comprehensive, integrated approaches to overcome. The study concluded that accelerating solar energy adoption in rural Uganda requires multi-faceted interventions that address affordability constraints, knowledge gaps, technical support needs, and institutional challenges simultaneously. By strengthening these aspects, solar energy can play a more significant role in achieving universal energy access and sustainable development in rural Uganda, contributing meaningfully to the attainment of SDG 7.

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Recommendations

Implement Tiered Financing Mechanisms and Subsidies for Different Income Levels: Government agencies and development partners should establish diversified financial support systems tailored to various income segments, including targeted subsidies for the poorest households (earning less than \$50 monthly), flexible pay-as-you-go options with lower deposits for middle-income groups, and affordable microfinance products with simplified application processes and reduced interest rates. These mechanisms should be designed to reduce initial cost barriers while ensuring the long-term sustainability of solar energy markets. Implementation should involve coordination between the Ministry of Energy, financial institutions, solar companies, and community-based organizations to create an integrated support system that addresses the specific needs and constraints of different household categories.

Develop Comprehensive Community-Based Education and Demonstration Programs: Education authorities, renewable energy agencies, and local governments should invest in grassroots awareness campaigns that combine theoretical knowledge with practical demonstrations of solar technology applications. These programs should establish solar demonstration centers in strategic rural locations, train local solar ambassadors from within communities, integrate renewable energy topics into formal education curricula, and use culturally appropriate communication channels including radio, community meetings, and peer-to-peer learning approaches. Special attention should be given to engaging women and youth as change agents, recognizing their pivotal roles in household energy decisions and technology adoption.

Strengthen Technical Support Systems and Quality Assurance Frameworks: The Uganda Bureau of Standards, in collaboration with the private sector and technical training institutions, should establish robust quality standards for solar products, develop certification systems for solar technicians, create decentralized maintenance networks in rural areas, and implement consumer protection mechanisms. Local technical capacity should be built through vocational training programs focused on solar installation, maintenance, and repair services, creating employment opportunities while ensuring the sustainability of solar systems. Additionally, digital platforms should be developed for remote diagnostics and technical support, leveraging increasing mobile phone penetration to overcome geographical barriers to service delivery.

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