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Adoption of Energy-Efficient Lighting: Practices and Potential for Carbon Reduction among Small-scale Traders in Kenyan Market Centres

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Abstract

Globally, studies have highlighted the environmental, economic, and social benefits of replacing high-emission lighting sources such as kerosene lamps and incandescent bulbs with cleaner alternatives like LED lights and solar-powered lamps. However, despite growing research in this field, limited attention has been given to the impact of this transition on small scale traders, who form a significant part of the economy in many developing countries. This study examined solar energy absorption and access patterns among traders in a likely semi-rural Kenyan context, focusing on demographics, primary lighting sources, and lighting devices preferences. The study adopted a cross-sectional descriptive survey design targeting microenterprises in Kenya. The study was conducted in trading centres within four counties, (Kericho Nakuru, Baringo, and Kisumu) where economic activity is visibly concentrated. The sample size for the study was 384 small-scale traders, with each county contributing 96 small-scale traders. Data was collected using structured questionnaires administered face – to – face, observation checklist, key informant interview guide and focus group discussion guide. Qualitative data was analyzed thematically while quantitative data was analyzed descriptively using percentages and inferentially using Chi-square. The sample shows a marked gender imbalance, with females comprising 87.7% (335 respondents) versus 12.3% males (47), suggesting that more women are engaged in small-scale trading and manage lighting for cooking, childcare, and evening tasks common in off-grid communities. Education levels are dominated by secondary school completion (57.9%, 221 respondents), followed by primary school completion (28.0%, 107), tertiary (9.2%, 35), and none (0.5%, 2), with minor missing data (4.5%); this profile aligns with East African trends (50-60% adult secondary rates) and supports adoption of user-friendly solar technologies, though primary-only groups may need simplified maintenance training. Primary lighting sources highlight solar dominance at 88.0% (336 respondents using solar lamps/systems), far outpacing grid electricity (8.6%, 33), "other" sources (2.1%, 8), candles (0.5%, 2), and negligible kerosene lamps or generators (0.3% each). The chi-square results revealed a significant rate of adoption of solar lamps by small scale traders. This reflects robust off-grid solar penetration in sub-Saharan Africa, displacing health-risky kerosene (reducing respiratory issues and weekly costs of ~$1-2/household) amid unreliable grids. Frequently used lighting devices favor LEDs (65.2%, 249), rechargeable torches (24.1%, 92), and fluorescent tubes (8.4%, 32), with rare incandescent use (0.3%) and minimal missing data (1.8%). LED prevalence pairs efficiently with solar (low wattage, 10,000+ hour lifespan), enabling 4-6 hours of nightly use and 80% cost savings over kerosene, while torches address portable needs like farming. Overall, results affirm solar's scalability for energy poverty alleviation and gender-specific challenges, though gender skew limits male perspectives, and "other" sources warrant further probing for hybrids. Targeted interventions could boost tertiary education uptake and rainy-season reliability.

Key words: Energy-efficient lighting, Carbon reduction, High-carbon emission lighting Small-scale traders, Market centres, Kenya.

Introduction

The transition to low-emission and energy-saving lighting has been widely recognized as an effective strategy for reducing carbon emissions, improving energy efficiency, and promoting sustainable development (Kabeyi and Olanrewaju, 2022). Various studies have highlighted the environmental, economic, and social benefits of replacing high-emission lighting sources (such as kerosene lamps and incandescent bulbs) with cleaner alternatives like LED lights and solar-powered lamps (Lin et. al, 2023; Mukisa et al, 2022).

Globally, studies on carbon savings from low-emission lighting have focused mainly on Energy Efficiency and Emission Reductions. Research by the International Energy Agency (IEA) indicates that LED lighting consumes 80-90% less energy than traditional incandescent bulbs, leading to significant reductions in CO_2 emissions (IEA, 2022). Additionally, studies on solar lanterns in off-grid areas show that replacing kerosene lamps can reduce 1 to 3 metric tons of CO_2 per household per year (Lighting Global, 2021).

Studies also highlight the health hazards of kerosene lamps, including indoor air pollution, respiratory illnesses, and fire risks (World Health Organization, 2021). The economic impact of energy-efficient lighting is well documented, with research showing that businesses increase their working hours and profitability when they switch to better lighting solutions (UNDP, 2020). However, despite growing research in this field, limited attention has been given to the impact of this transition on small scale traders, who form a significant part of the economy in many developing countries.

In Kenya, SMEs play an important role in the country's economy by providing employment and income generating opportunities. According to the Kenya National Bureau of Statistics (KNBS, 2016), the SME segment made a significant contribution to the employment and economic activities of the country. Since these SMEs operate for long hours, their source of lighting is key to their operations. Thus, lighting efficiency can lower the cost of doing business and at the same time, contribute to national goals of energy efficiency and low-carbon objectives (KNBS, 2016; Ministry of Energy, 2020).

The use of energy-efficient lighting systems such as LED is one of the ways for Kenyan SMEs to minimize electricity consumption. Compared to incandescent lighting systems, LEDs offer better energy-saving results and a longer operational period. The National Energy Efficiency and Conservation Strategy of Kenya identifies lighting efficiency as an important energy-saving intervention, and advocates for the promotion of the energy-efficient systems in different sectors (Ministry of Energy, 2020). The relevance of lighting efficiency is further enhanced through the adoption of energy performance standards and labelling initiatives for appliances and equipment in Kenya (Energy and Petroleum Regulatory Authority (EPRA), 2023).

Evidence from rural Kenya suggests that access to electricity is linked to changes in energy consumption and adoption of electric appliances and technologies (Lee et al., 2016; Lee et al., 2020). Such findings are essential to understand how SMEs in Kenya have moved from traditional lighting technologies to more efficient lighting systems. However, adoption of low-carbon lighting solutions is still a problem for most small and medium enterprises (SMEs) in Kenya. This could be due to access to finance, information limitations, and perception of the risk of investment which inhibit energy-efficient investment by SMEs in developing countries (IFC, 2012). This study examined solar energy absorption and access patterns among traders in a likely semi-rural Kenyan markets, focusing on demographics, primary lighting sources, and lighting devices preferences

Materials and Methods

The study adopted a cross-sectional descriptive survey design targeting microenterprises in Kenya. The study mainly focused on small-scale traders who operate primarily in the evening and night hours, given the study's emphasis on lighting efficiency and carbon-saving transitions. The study targeted four counties of Kericho, Nakuru, Baringo, and Kisumu which were purposively selected to capture critical variation in ecological zones, energy access, trading patterns, and potential for carbon savings. The selection criteria included ecological and climatic diversity, patterns of energy access and lighting usage, geographical distribution, and practical considerations. Specifically, Baringo represents semi-arid rural zones; Kisumu typifies dense lakeside urban settings; Kericho reflects highland agricultural economies; and Nakuru serves as a peri-urban hub with mixed socio-economic and infrastructural conditions.

Data was collected in selected trading centres within counties of Kericho, Nakuru, Baringo, and Kisumu, where economic activity is visibly concentrated. These centres were purposively chosen to reflect a mix of urban, peri-urban, and rural contexts, trading density, and energy use patterns relevant to the study objectives. The sample size was determined using the standard Cochran Sample Size Formula for Infinite Populations which led to 384 small-scale traders, with each county contributing 96 small-scale traders. The individual small-scale traders were systematically selected by picking every 3rd or 4th trader encountered in a row of stalls—depending on local conditions. This hybrid approach ensures practical, inclusive, and context-sensitive data collection aligned with the study's objectives. The traders were engaged based on their visible use of lighting technologies, ensuring inclusion of both those using energy-efficient lighting and those still relying on polluting or inefficient sources such as kerosene lamps, open flames, or outdated bulbs. Data was collected using structured questionnaires administered face-to-face, observation checklist, key informant interview guide and focus group discussion guide. The research instruments were validated through expert review.

Data Analysis

Qualitative data from focus group discussion and key informant interviews was analyzed by thematic content analysis while quantitative data was analyzed descriptively using frequencies, percentages and means and inferentially using Chi-square. This was done using the computer software, SPSS.

Results and Discussion

In this section we discuss the results of the study. The section will include the descriptive statistics of gender, education level of the traders, the sources of primary light they are currently using and the type of bulbs they are using and chi-square tests.

Gender of the respondents

The impact of gender on adoption of technology is evident in access to financial resources, decision-making, and business ownership. Male traders generally have easy access to finance, productive resources, and investment, thus they can easily adopt energy-efficient lighting technologies compared to female traders. On the other hand, women-led microenterprises encounter financial difficulties in adopting improved technologies. The results on respondents' gender is presented in table 2.

Table 1: Gender of the Respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	male	47	12.3	12.3	12.3
	female	335	87.7	87.7	100.0
	Total	382	100.0	100.0	

The study sample consists of 382 respondents, with a striking gender imbalance: 47 males (12.3%) and 335 females (87.7%). This heavy skew toward females suggests that women participate more in small-scale trading and therefore are managing daily energy needs especially in rural or low-income areas in in developing countries, including Kenya. For instance, in off-grid or solar-dependent communities, women often handle lighting for cooking, childcare, and evening activities. This distribution limits generalizability to male perspectives but highlights gender-specific energy access challenges, like women's higher exposure to indoor air pollution from traditional lamps if modern options fail. Researchers should note potential selection bias, perhaps from female-focused NGOs or self-selection in solar adoption programs.

Gender inequality is cited by the International Energy Agency (IEA, 2022) as a hindrance to the adoption of clean energy technology in many developing nations. ENERGIA (2019) also pointed out that female entrepreneurs face a limited availability of financial resources making it difficult for them to acquire energy-efficient appliances despite being aware of its advantages.

However, recent research reveals that the gender gap is declining in Kenya because of the deliberate efforts taken in terms of financial inclusion of women. Financial programs such as the Women Enterprise Fund, as well as various forms of digital lending, have helped women gain more access to finance which in turn allows investing in business technology such as energy-efficient lights (World Bank, 2022). According to several studies conducted in urban informal markets, female traders are increasingly turning to LED lighting due to the reduction in operating costs and better security of their businesses at night (Practical Action, 2020). Some studies however have revealed statistically insignificant differences in adoption rates between men and women when other factors such as income, education, and business size are held constant (Bensch et al., 2015).

Level of education of the respondents

Level of education is one of the major determinants of adoption of environmentally friendly technologies. The level of education of traders positively correlates with the adoption of carbon-saving technologies due to greater knowledge about energy efficiency, environmental protection, and economic gains related to lower costs of electricity consumption. The level of education of the respondents is shown in table 2.

Table 2: Level of education of the respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	none	2	.5	.5	.5
	primary	107	28.0	29.3	29.9
	secondary	221	57.9	60.5	90.4
	tertiary	35	9.2	9.6	100.0
	Total	365	95.5	100.0	
Missing	System	17	4.5		
Total		382	100.0		

Education levels reveal a sample dominated by secondary education (221 respondents, 57.9%), followed by primary (207, 28%), tertiary (35, 9.2%), and none (2, 0.5%), with 17 missing (4.5%). This profile aligns with semi-rural or peri-urban populations, where secondary schooling is common but higher education remains scarce mirroring national trends in East Africa, where adult secondary completion hovers around 50-60%. The low "none" category indicates basic literacy, aiding adoption of user-friendly tech like solar lamps. However, the 27.4% primary-only group may face barriers understanding maintenance instructions, influencing reliance on simple devices. Missing data (3.3%) is minor but could stem from reluctance to disclose. Overall, this suggests that moderate education supports energy transitions, yet targeted training could boost tertiary uptake.

The significant role of education in energy transition has been reported in several studies. Lee et al. (2016) reported that households with better-educated household heads were significantly more likely to adopt solar home systems and other types of clean energy technologies due to increased environmental awareness and better financial decisions. Educated traders are able to get additional information about energy-saving technologies on the Internet, through extension agencies, and media campaigns. Moner-Girona et al. (2019) also observed that education enhances understanding of the cost-saving potential of energy-efficient appliances, thereby increasing adoption rates.

The Kenya National Bureau of Statistics (KNBS, 2023) observed that firms whose owners have secondary and tertiary education were more inclined to implement efficient energy technology than those run by people with only primary education. The finding is consistent with the Diffusion of Innovations Theory by Rogers (2003), which considers education as one of the essential traits of innovators.

On the other hand, there are instances where educational attainment does not necessarily imply adoption in situations of resource limitations. Educated traders would still use less efficient lighting technology because of the high costs involved in installing LED bulbs or solar power systems (IEA, 2022).

Main source of lighting among small scale traders

The results of the study reveal that the small scale traders were using a variety of lighting sources, including kerosene lamps, candles, grid electricity, solar lamps and generators at varied rates. The results of the main source of lighting among small-scale traders are presented in table 3.

Table 3: Main source of Lighting

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	kerosine lamp	1	.3	.3	.3
	candles	2	.5	.5	.8

	Grid electricity	33	8.6	8.7	9.4
	solar lamp/system	336	88.0	88.2	97.6
	generator	1	.3	.3	97.9
	other	8	2.1	2.1	100.0
	Total	381	99.7	100.0	
Missing	System	1	.3		
Total		382	100.0		

Lighting sources show overwhelming solar dominance: 336 respondents (88.0%) use solar lamps/systems, dwarfing grid electricity (33, 8.6%), candles (2, 0.5%), kerosene lamps or generators (1 each, 0.3%), other (8, 2.1%), and 1 missing (0.3%). This reflects successful off-grid solar penetration, likely in areas with unreliable national grids common in sub-Saharan Africa, where solar now powers 80-90% of rural lighting in adoption hotspots.

The prevalence of solar lighting can be attributed to its cost-effectiveness, mobility, reduced costs of installation, and ability to suit enterprises that operate in regions with no consistent or adequate supply of electricity. The off-grid solar power solutions have undergone considerable expansion in Kenya in the last decade due to support from the Kenyan government, the private sector, and pay-as-you-go (PAYG) schemes. Through such financing schemes, poor families and micro-businesses have been able to obtain solar installations at more affordable prices, thus addressing the high costs that are usually associated with renewable energy resources (GOGLA, 2024; IEA et al., 2023). The small and medium scale enterprises can benefit from solar lighting because it helps in saving on energy costs and guarantees lighting in the evening period.

The findings of the study are in line with other studies in Kenya and other countries in Sub-Saharan Africa. Lee et al. (2020) observed that the development of decentralized solar energy systems has enhanced the availability of modern energy to rural households and small business that have access to electricity through the grid only to a limited extent. IEA (IEA et al., 2023) also found out that off-grid solar products are one of the fastest-growing channels of electricity access in Africa, especially for small enterprises which need affordable and reliable lighting solutions. In this sense, the availability of solar products of different types has turned Kenya into one of the leading countries in the sphere of solar energy in Africa (GOGLA, 2024).

Kerosene's near-absence (0.3%) signals a shift from health-risky fuels, reducing respiratory issues and spending (kerosene costs ~$1-2/week per household). The falling usage rate of kerosene signifies growing understanding of the drawbacks of traditional lighting systems from economic, ecological, and health perspectives. The burning of kerosene results in emission of greenhouse gases such as carbon dioxide and black carbon along with exposure to indoor pollution, which is hazardous to human health (Lam et al., 2012; WHO, 2021).The 9.3% grid users may represent urban fringes with partial access. This result underscores solar's scalability for energy poverty alleviation, though "other" (2.1%) warrants probing for hybrids like biomass.

The negligible use of generators (0.3%) implies that small traders do not favor the utilization of either diesel or petrol-powered lighting (International Renewable Energy Agency [IRENA], 2023). This low use of generators could be as a result of high fuel costs, high upkeep costs, noise pollution, and carbon footprints due to the fossil fuels utilized.

Type of bulb or lighting most frequently used

The results of the type of bulbs used by small-scale traders are presented in table 4.The findings indicate that light-emitting diode (LED) bulbs were the dominant lighting technology used by small-scale traders.

Table 4: Type of bulb or lighting device most frequently used

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	1	.3	.3	.3
	incandescent	1	.3	.3	.5
	LED	249	65.2	66.4	66.9
	fluorescent tube	32	8.4	8.5	75.5
	rechargeable torch	92	24.1	24.5	100.0
	Total	375	98.2	100.0	
Missing	System	7	1.8		
Total		382	100.0		

Among lighting devices, LEDs lead at 249 users (65.2%), followed by rechargeable torches (92, 24.1%), fluorescent tubes (32, 8.4%), incandescent (1, 0.3%), and unclear codes (.00 and 5.00, 1 each, 0.3%), with 4 missing (1.2%). LED prevalence ties directly to solar sources, as they pair efficiently (low wattage, long life: 10,000+ hours vs. incandescent's 1,000). Torches (24.1%) indicate portable needs for mobile tasks, like farming or herding. Fluorescents' low share (8.4%) reflects higher power draw, unfit for small solar setups. Anomalies (0.3,) likely coding errors, but missing data (1.8%) is negligible. This pattern shows a modern, efficient shift: LEDs cut costs of up to 80% over kerosene bulbs and enable 4-6 hours nightly use on basic solar, while providing higher brightest efficiency and longer lifetime. Study by the International Energy Agency (IEA, 2023), reported that the energy consumption of LED illumination system can decrease from 75% to 90% compared to traditional incandescent systems. Such savings in energy expenses are particularly relevant for small business owners and traders who operate on limited budgets.

The extensive use of LED bulbs is also consistent with Kenya's efforts to enhance energy efficiency and promote sustainable energy consumption. The implementation of energy efficiency standards and market transformation programs by the government has resulted in accessibility/affordability of LED technologies in the country (Ministry of Energy, 2019). The penetration of solar home systems and portable solar lighting products has further expedited the use of LEDs because LEDs work well in systems that rely on renewable sources of energy, which, among other things, consume little energy (Lighting Global, 2022).Mills (2016) noted that the replacement of conventional lighting with LED technology helps to significantly cut energy costs for small businesses by improving lighting quality and allowing longer business operation time. Similarly, IEA (2023) shows that LED lighting has become widely accepted in the world because of decreasing prices, better product performance, and government policies that encourage the use of energy-efficient appliances.

The near-disappearance of incandescent bulbs among respondents is in line with global trends pertaining to energy-saving policies and consumers' preference for efficient technologies. Incandescent bulbs use energy very inefficient, with most of the current being converted into heat rather than light. UNEP, 2021 reported that many countries have phased out or restricted their manufacture and sale of incandescent bulbs as part of climate change mitigation strategies.

The test results of chi-square test revealed a significant rate of adoption the solar lamps by the small scale traders (Table 5).

Table 5: Test results of the source of lighting, type of lighting and energy transition

	source	what type of bulb or lighting device do you use most frequently	have you ever changed from a conventional source to a modern lighting option
Chi-Square	1415.142[a]	578.213[b]	396.112[c]
df	5	4	2
Asymp. Sig.	.000	.000	.000

a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 63.5.

b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 75.0.

c. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 125.0.

From the results, we observe that the chi-square value χ^2 (df = 5; N = 382) = 1415.142 with a p-value = 0.000 which is less than 0.05 significant level. This indicates that the traders have largely adopted the use of solar lamp as the main source of lighting over the other lighting systems. The results on the type of bulb or lighting device used frequently had a chi-square value χ^2 (df = 5; N = 382) = 578.213 with a p-value = 0.000 which is less than 0.05 significant level. This means that the study supports that majority of the traders use LED lights and rechargeable lamps as their source of light. Finally we observe from results that majority of traders had changed from a conventional source to a modern lighting option with a chi-square value χ^2 (df = 5; N = 382) = 396.112, with p-value = 0.000 which is less than 0.05 significant level.

Conclusion

The study concludes that women take part in small-scale trading activities and therefore participates more in reduction of carbon emissions by transiting to carbon saving lighting systems. Majority of traders had secondary education and above leading to high rate of low carbon lighting systems. It is also noted that majority of the traders had adopted solar lighting lamps. Higher education levels enhance awareness and facilitate adoption, while gender differences primarily reflect disparities in access to financial resources rather than differences in attitudes toward technology. Access to reliable alternative lighting sources, especially solar-powered systems and LED technologies, has accelerated the transition away from carbon-intensive lighting options.

Recommendations

To accelerate the transition toward sustainable energy practices, stakeholders must support small-scale traders in acquiring solar lighting systems, recognizing their vital role in curbing commercial carbon footprints. Beyond simple adoption, institutional frameworks should explore viable pathways that enable these traders to participate in and benefit financially from carbon trading mechanisms. Crucially, comprehensive policy interventions are needed to drive this transition; these measures should focus on elevating public awareness, expanding access to affordable financing mechanisms, strengthening gender-inclusive energy programs, and promoting the availability of renewable lighting technologies to ensure widespread and equitable adoption.

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Conflict of Interest Statement

At the time of publishing this paper, one of the authors (Maghanga C. M.) was the Editor-in-Chief of this Journal, but was entirely uninvolved in the peer-review process or editorial decisions regarding this manuscript. The authors declare no other competing interests.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Authorship Statement
We the Authors declare that each author contributed significantly to the conception, research, writing and preparation of the final work.

Ethical Approval and Research Licenses
Ethical approval for this study was obtained from Kabarak University Review and Ethics Committee (Approval No. 091025). Research permit was also granted by the National Commission for Science, Technology & Innovation (NACOSTI) License No: NACOSTI/P/25/4181800.

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