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Abstract

Limited access to clean and sustainable cooking energy remains a critical challenge in refugee communities worldwide. This study examined how subsidy mechanisms influence the affordability, adoption, and usability of renewable cooking energy technologies in three Rwandan refugee camps. A cross-sectional survey was administered to 301 refugee households (response rate: 77.8%) selected through stratified and systematic random sampling from a target population of 11,647 families. Data were analysed using Pearson correlation and simple linear regression. Results indicate that subsidies have a statistically significant negative relationship with affordability ($\beta = -.239$; $p = .000$) and usability ($\beta = -.149$; $p = .010$), while the relationship with adoption was negative but not statistically significant ($\beta = -.078$; $p = .175$). These counterintuitive findings suggest that current subsidy structures face implementation inefficiencies including intermediary capture, limited fuel cost coverage, and inadequate post-adoption support that undermine their intended impact. The study concludes that subsidies in their current form provide limited relief across all three dimensions and recommends direct consumer-side instruments, fuel subsidy integration, mandatory user training, and flexible financing mechanisms to strengthen subsidy effectiveness in displacement settings.

Keywords: *Adoption, Affordability, Renewable Cooking Energy, Refugee Camps, Subsidies, Usability*

1. Introduction

Access to clean, reliable, and affordable cooking energy remains a persistent and deeply entrenched challenge in humanitarian and displacement contexts. Despite global commitments to achieve universal energy access, an estimated 2.4 billion people worldwide continue to depend on traditional biomass fuels such as firewood, charcoal, and agricultural residues for their cooking needs (International Energy Agency [IEA], 2023a). This burden is disproportionately concentrated among low-income and displaced populations, where energy poverty is often intensified by limited livelihood opportunities, fragile markets, and inadequate infrastructure (Singh, Kumar & Sharma, 2022). In refugee settings, access to modern energy services is particularly constrained, forcing households to rely on environmentally unsustainable and health-damaging cooking practices (Humanitarian Energy, 2022).

Rwanda presents a relevant context for examining these dynamics. The country hosts more than 134,000 refugees and asylum seekers, primarily from the Democratic Republic of the Congo and Burundi, who reside in camps such as Kigeme, Kiziba, Mahama, Mugombwa, and Nyabiheke (United Nations High Commissioner for Refugees [UNHCR], 2024). Within these settlements, cooking energy access remains heavily dependent on traditional biomass, with approximately 85% of refugee households relying primarily on firewood (UNHCR, 2023a). This dependence contributes to environmental degradation, including deforestation and land pressure around camps, while also increasing exposure to indoor air pollution. Globally, household air pollution linked to inefficient cooking practices is responsible for an estimated 3.2 million premature deaths annually, with women and children being the most affected (World Health Organization [WHO], 2022; Kelebe, Tesfaye & Mulugeta, 2023). Beyond environmental and health concerns, reliance on traditional fuels also has important socio-economic implications. Time spent collecting firewood reduces opportunities for education and income-generating activities, particularly for women and girls (World Bank, 2023). In some cases, fuel collection exposes individuals to protection risks, including gender-based violence (Energy for Refugees, 2023). These interconnected challenges highlight the urgent need for sustainable and inclusive clean cooking solutions in refugee contexts.

In response, governments, humanitarian agencies, and development partners have implemented a range of interventions aimed at promoting the adoption of renewable and clean cooking technologies. These include improved biomass cookstoves, liquefied petroleum gas (LPG), and emerging alternatives such as pellet-based systems and solar-powered cooking devices (United Nations Environment Programme [UNEP], 2023; Practical Action, 2024). To facilitate access among economically constrained populations, various subsidy mechanisms have been introduced. These include direct upfront subsidies, fuel subsidies, results-based financing (RBF) schemes, tax exemptions, and donor-supported distribution models led by non-governmental organizations and private sector actors (GIZ, 2021; Bhatia & Angelou, 2023). Such approaches are designed to lower financial barriers, stimulate demand, and promote market development for clean cooking technologies.

However, despite the expansion of these subsidy-driven initiatives, their effectiveness in displacement settings remains insufficiently understood. Existing evidence suggests that while subsidies can reduce initial acquisition costs and encourage early adoption, they do not necessarily guarantee sustained and exclusive use of clean cooking technologies (Humanitarian Energy, 2022; World Bank, 2023). Three critical dimensions require further investigation. First, affordability extends beyond upfront costs to include recurring expenses such as fuel, maintenance, and replacement, which may limit long-term use (IEA, 2023a). Second, adoption is influenced by behavioral and socio-cultural factors, including household preferences, cooking practices, and levels of awareness (Niyonteze *et al.*, 2022). Third, usability

encompassing ease of operation, compatibility with local diets, cooking speed, and reliability plays a crucial role in determining whether households consistently use the technologies (Kelebe *et al.*, 2023; GIZ, 2021).

Moreover, refugee settings present unique structural and contextual challenges that distinguish them from typical rural or urban energy markets. These include dependence on humanitarian assistance, limited and unstable income sources, regulatory constraints, and underdeveloped supply chains for clean energy products (World Bank, 2023; UNDP, 2023a). As a result, findings from non-displacement contexts cannot be directly generalized to refugee populations. Nevertheless, much of the existing literature on clean cooking transitions has focused on stable communities, leaving a significant evidence gap regarding how subsidy mechanisms function in humanitarian environments (IEA, 2022; Humanitarian Energy, 2022).

This study sought to address this gap by examining the role of subsidy-based interventions in shaping access to renewable cooking technologies within Rwandan refugee camps. By focusing on Kigeme, Mahama, and Nyabiheke, where multiple clean cooking initiatives have been implemented.

This study generates empirical evidence from real-world program implementation to advance both academic understanding and practical policy development on clean cooking in humanitarian settings. It examines how subsidies influence three key dimensions: affordability, adoption, and the usability of renewable cooking technologies. The study sought to answer three research questions:

- i. What is the effect of subsidies on the affordability of renewable cooking technologies in selected Refugee Camps in Rwanda?
- ii. What is the effect of subsidies on the adoption of renewable cooking technologies in selected Refugee Camps in Rwanda?
- iii. What is the effect of subsidies on the usability of renewable cooking technologies in selected Refugee Camps in Rwanda?

The resulting insights are intended to support policymakers, humanitarian organizations, and energy sector actors in designing more targeted, inclusive, and sustainable subsidy approaches that go beyond initial access to ensure long-term impact. Strengthening clean cooking access in refugee contexts is not only essential for environmental protection and public health but also plays a vital role in enhancing dignity, resilience, and the socio-economic well-being of displaced populations (World Bank, 2023; UNDP, 2023a).

2. Literature Review

2.1 Subsidies and Affordability

Affordability in energy access is a multidimensional concept encompassing not only the upfront cost of technologies but also the recurrent costs of fuel and maintenance (Barnes *et al.*, 2017). Subsidy Theory holds that financial interventions lower the cost barrier and enable wider market participation among low-income populations (IEA, 2023; IRENA, 2022). In refugee settings, however, affordability challenges are exacerbated by restricted economic opportunities and heavy dependence on humanitarian assistance (Practical Action, 2021).

Empirical evidence on subsidy impacts on affordability is mixed. Singh *et al.* (2022) found that India's LPG subsidy increased stove adoption by 42% by halving upfront costs, yet sustained usage remained low due to unaffordable fuel refills. Similarly, Kelebe *et al.* (2023) reported that while urban LPG uptake in Ethiopia rose by 38%, only 21% of rural households maintained use beyond the subsidy period. In Rwanda specifically, UNHCR (2023)

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documented that 70% of targeted households received subsidized cooking technologies, yet usage dropped to 45% within six months largely due to high refill costs and insufficient income. These patterns collectively suggest that subsidies address entry-point costs but often fail to ensure lifecycle affordability.

2.2 Subsidies and Technology Adoption

Adoption reflects households' willingness and ability to integrate new technologies into daily routines. The Diffusion of Innovation (DOI) theory (Rogers, 1962) posits that subsidies, by reducing financial risk, can accelerate the diffusion curve and encourage early adoption. An IEA (2023) meta-analysis of over 50 clean cooking programs found that subsidies were the strongest driver of adoption in energy-poor regions, increasing uptake by an average of 20%, though outcomes were highly context-dependent.

In displacement settings, adoption is shaped by factors beyond cost alone. Niyonteze *et al.* (2022) found that while subsidies initially boosted adoption in Rwanda's Mahama and Kigeme camps, long-term use declined without continuous user support and culturally appropriate technologies. Köhlin *et al.* (2021) similarly found in Uganda's Bidi Bidi settlement that education levels, gender of household heads, and fuel availability significantly moderated subsidy-driven adoption outcomes. Practical Action (2023) reported that community-led distribution models outperformed centralised approaches, suggesting that implementation design matters as much as financial incentive levels.

2.3 Subsidies and Usability

Usability encompasses ease of use, time efficiency, cultural compatibility, and reliability of clean cooking technologies (GACC, 2016). Even when affordability and adoption challenges are addressed, poor usability can lead to technology abandonment. The Technology Acceptance Model (TAM; Davis, 1989) identifies perceived usefulness (PU) and perceived ease of use (PEOU) as key determinants of sustained technology use both of which can be influenced by subsidy-supported design quality and user training.

The African Development Bank (2023) found that 60% of stove users in a multi-country African study found subsidized technologies incompatible with their traditional cooking practices. GIZ (2021) reported that poor compatibility with local pot sizes and cooking times frequently led to disuse in humanitarian camps in Chad and Sudan. UNDP (2023) further documented that 60% of households in Sub-Saharan Africa returned to traditional fuels within 18–24 months, citing fuel supply constraints and the absence of local maintenance services. Niyonteze *et al.* (2022) noted that over 40% of users in Rwandan camps received no practical training, and 35% complained of altered food taste factors that significantly undermined technology retention.

2.4 Theoretical Framework

Three complementary theories guide this study. Subsidy Theory explains how financial interventions shape affordability by reducing cost barriers to market entry (World Bank, 2022). The Diffusion of Innovation Theory (Rogers, 1962) explains how subsidies catalyse adoption by reducing perceived financial risk during the early stages of technology diffusion. The Technology Acceptance Model (Davis, 1989) explains how perceived usefulness and ease of use determine sustained utilisation factors that subsidies can enhance through enabling access to higher-quality, user-friendly products and funding user training. Together, these frameworks provide a comprehensive lens for examining subsidy impacts across all three outcome dimensions studied.

3. Methodology

3.1 Research Design and Study Area

This study employed a cross-sectional quantitative research design. Data were collected from three refugee camps in Rwanda: Kigeme (Nyamagabe district), Mahama (Kirehe district), and Nyabiheke (Gatsibo district). These camps were purposively selected because they had been active beneficiaries of clean cooking energy programs and subsidy interventions, making them appropriate sites for examining subsidy effectiveness. The three camps collectively accommodate approximately 94,687 individuals across 11,647 households.

3.2 Sampling

The sample size was determined using Yamane's formula for known populations ($N = 11,647$; margin of error $e = 0.05$), yielding a target of 387 households. A multi-stage sampling approach was used: stratified random sampling categorised households by camp and energy usage patterns, after which systematic random sampling selected participants within each stratum. A total of 301 questionnaires were returned and found valid, yielding a response rate of 77.8% exceeding the accepted threshold for analytical credibility in survey research (Holtom *et al.*, 2022).

3.3 Data Collection

Structured questionnaires were administered digitally via Kobo Toolbox. The instrument comprised three sections: (1) demographic information; (2) Likert-scale items (1–5) measuring perceptions of subsidies, affordability, adoption, and usability; and (3) categorical items on income, technology type received, and payment preferences. Questionnaires were developed in English and translated into Kinyarwanda to ensure linguistic and cultural appropriateness. Trained local enumerators conducted data collection over a period of four weeks. A pilot study was conducted in an adjacent settlement prior to full-scale deployment to validate and refine instruments. Internal consistency was assessed using Cronbach's Alpha, with ≥ 0.70 as the acceptability threshold (Tavakol & Dennick, 2011). Ethical clearance was obtained from Mount Kenya University's Ethics Review Committee and Rwanda's Ministry in Charge of Emergency Management (MINEMA).

3.4 Data Analysis

Descriptive analysis was carried out using frequencies, percentages, means, and standard deviations to summarize all variables included in the study. In addition, Pearson correlation analysis was performed to explore the pairwise relationships between subsidies and each of the dependent variables, namely affordability, adoption, and usability. Simple linear regression analysis was carried out based on three models in view of affordability, adoption and usability. All statistical computations were conducted using IBM SPSS Statistics.

4. Results

4.1 Profile of Respondents

From the 301 respondents, majority (58.1%) were from Mahama camp, 22.6% from Nyabiheke, and 19.3% from Kigeme proportions broadly reflecting the relative population sizes of each settlement. The sample was predominantly male (80.4%), consistent with men being identified as household heads and primary program participants in camp settings. The

largest age group was 35–44 years (35.2%), followed by 45–54 (29.9%). Most households (62.1%) comprised 4–6 members. Economically, 48.2% of respondents relied on cash assistance from humanitarian agencies as their primary income source. Monthly household incomes clustered in the RF 30,000–49,999 range (48.8%), underscoring the severe financial precarity of the study population. Notably, 99% of respondents had received a subsidized cooking technology, of which 77.1% received an improved cookstove and 19.6% an LPG or biomass-LPG combination.

4.2 Affordability of Renewable Cooking Energy Technologies

Table 1 presents responses on affordability perceptions. Respondents strongly affirmed that subsidies helped them access technology initially (mean = 4.63; 63.1% strongly agreed). However, a starkly different picture emerged for ongoing costs: 45.8% disagreed that they could afford regular fuel refills (mean = 2.95), and 51.5% disagreed that technology prices matched their household income level (mean = 2.74). Conversely, 96.4% supported flexible payment options such as pay-as-you-go, and 97.7% indicated subsidies should cover fuel and maintenance reflecting strong demand for broader subsidy scope. The composite mean of 3.75 reflects moderate overall affordability perception.

Table 1. Affordability of Renewable Cooking Energy Technologies (n = 301)

Statement	SD%	D%	N%	A%	SA%	M
Subsidy helped me afford the technology	0	0	0.3	36.5	63.1	4.63
I can afford fuel refills regularly	1.0	45.8	17.9	27.9	7.3	2.95
Renewable fuel is cheaper than traditional fuels	0	8.3	22.3	57.1	12.3	3.73
Flexible payment options would improve affordability	0	3.7	0	77.7	18.6	4.11
Technology price matches household income level	2.3	51.5	15.6	30.6	0	2.74
Subsidies for both appliance and fuel are necessary	0	1.3	2.7	54.5	41.5	4.36
Composite Mean						3.75

Note: SD = Strongly Disagree; D = Disagree; N = Neutral; A = Agree; SA = Strongly Agree; M = Mean.

4.3 Adoption of Renewable Cooking Energy Technologies

Table 2 presents adoption-related responses. A strong majority (95.7%) agreed or strongly agreed that receiving a subsidy motivated their decision to adopt (mean = 4.28). However, 58.1% disagreed that subsidized technology was their primary cooking option (mean = 2.78), indicating that the majority still stack traditional fuels alongside the subsidized technology. Training and demonstrations were widely valued, with 91% agreeing they eased adoption (mean = 3.98). Social endorsement was strong 97% said they would recommend the technology to others (mean = 4.47). The composite mean of 3.90 suggests a generally positive adoption climate, though with significant qualifications around exclusive reliance on clean technologies.

Table 2. Adoption of Renewable Cooking Energy Technologies (n = 301)

Statement	SD%	D%	N%	A%	SA%	M
Receiving a subsidy motivated adoption	0	1.0	3.3	62.1	33.6	4.28
Subsidized technology is my primary cooking option	0	58.1	10.0	27.6	4.3	2.78
Training made it easier to adopt the technology	0	2.3	6.6	81.7	9.3	3.98
Subsidies encouraged other households to adopt	0	1.0	9.0	75.1	15.0	4.04
I would recommend the technology to others	0	0	3.0	46.8	50.2	4.47
Technology is widely accepted and trusted	0	0	25.2	67.1	7.6	3.82
Composite Mean						3.90

Note: SD = Strongly Disagree; D = Disagree; N = Neutral; A = Agree; SA = Strongly Agree; M = Mean.

4.4 Usability of Renewable Cooking Energy Technologies

Table 3 summarises usability perceptions. Respondents broadly affirmed that subsidies made stove use easier (85% agreed/strongly agreed; mean = 3.94) and that stove designs were safe around children (92% agreed; mean = 4.04). However, confidence in long-term utility was low, with 35.5% disagreeing that the stove would remain useful in future (mean = 2.99). Cultural compatibility was a critical concern: 67.1% reported their stoves did not suit local cooking practices including traditional pot sizes and meal types. Despite this, 93% reported no technical breakdowns, and 96.7% confirmed access to repair services. The composite mean of 3.58 reflects moderate usability, tempered by notable design-practice mismatches.

Table 3. Usability of Renewable Cooking Energy Technologies (n = 301)

Statement	SD%	D%	N%	A%	SA%	M
Subsidies made stove use easier	0	3.3	11.6	72.4	12.6	3.94
Users are satisfied with stove performance	0	17.6	28.6	49.8	4.0	3.40
Food quality and taste meet household expectations	0	0	38.5	55.5	6.0	3.67
Stove design is safe around children	0	0	8.0	79.7	12.3	4.04
Fuel consumption is efficient and saves resources	0	9.3	42.5	45.8	2.3	3.41
Confident the stove will remain useful in future	1.3	35.5	27.9	32.9	2.3	2.99
Composite Mean						3.58

Note: SD = Strongly Disagree; D = Disagree; N = Neutral; A = Agree; SA = Strongly Agree; M = Mean.

4.5 Correlation Analysis

Table 4 presents the Pearson correlation results. Subsidies showed a statistically significant negative relationship with affordability ($r = -.239$, $p = .000$) and usability ($r = -.149$, $p = .010$). The relationship with adoption was negative but not statistically significant ($r = -.078$, $p = .175$). These results indicate that higher subsidy exposure is paradoxically associated with lower perceived affordability and usability, while having no significant bearing on adoption behaviour.

Table 4. Pearson Correlation Results Subsidies and Outcome Variables (n = 301)

Variable Pair	Pearson r	Sig. (2-tailed)	Interpretation
Subsidies → Affordability	-.239**	.000	Significant
Subsidies → Adoption	-.078	.175	Not significant
Subsidies → Usability	-.149**	.010	Significant

Note: ** Significant at the 0.01 level (2-tailed).

4.6 Regression Analysis

4.6.1 Effect of Subsidies on Affordability of Renewable Cooking Energy Technologies

Table 5. Model Summary (Affordability)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.239	0.057	0.054	0.46163

Source: Refugee camps-based survey (2026)

The model shows a weak positive relationship, with subsidies explaining only 5.7% of the variation in affordability.

Table 6. ANOVA Model (Affordability)

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	3.867	1	3.867	18.148	0
Residual	63.716	299	0.213		
Total	67.584	300			

Source: Refugee camps-based survey (2026)

The model is statistically significant, indicating that subsidies have a significant effect on affordability.

Table 7. Coefficients (Affordability)

Model	B	Std. Error	Beta	t	Sig.
(Constant)	5.596	0.433		12.924	0
Subsidies	-0.387	0.091	-0.239	-4.26	0

Source: Refugee camps-based survey (2026)

Subsidies have a significant negative effect on affordability, meaning increased subsidies are associated with reduced affordability outcomes in this model.

4.6.2 Effect of Subsidies on Adoption of Renewable Cooking Energy Technologies

Table 8. Model Summary (Adoption)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.078	0.006	0.003	0.41249

Source: *Refugee camps-based survey (2026)*

The model shows a very weak relationship, with subsidies explaining only 0.6% of variation in adoption.

Table 9. ANOVA Model (Adoption)

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	0.315	1	0.315	1.852	0.175
Residual	50.874	299	0.17		
Total	51.19	300			

Source: *Refugee camps-based survey (2026)*

The model is not statistically significant, indicating that subsidies do not significantly affect adoption.

Table 10. Coefficients (Adoption)

Model	B	Std. Error	Beta	t	Sig.
(Constant)	4.422	0.387		11.43	0
Subsidies	-0.111	0.081	-0.078	-1.361	0.175

Source: *Refugee camps-based survey (2026)*

Subsidies have a negative but insignificant effect on adoption, suggesting no meaningful influence on household uptake.

4.6.3 Effect of Subsidies on Usability of Renewable Cooking Energy Technologies

Table 11. Model Summary (Usability)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.149	0.022	0.019	0.52906

Source: *Refugee camps-based survey (2026)*

The model indicates a weak relationship, with subsidies explaining 2.2% of variation in usability.

Table 12. ANOVA Model (Usability)

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	1.89	1	1.89	6.754	0.01
Residual	83.692	299	0.28		
Total	85.582	300			

Source: *Refugee camps-based survey (2026)*

The model is statistically significant, indicating that subsidies have a significant effect on usability and sustained use.

Table 13. Coefficients (Usability)

Model	B	Std. Error	Beta	t	Sig.
(Constant)	4.865	0.496		9.805	0
Subsidies	-0.271	0.104	-0.149	-2.599	0.01

Source: *Refugee camps-based survey (2026)*

Subsidies have a significant negative effect on usability, suggesting reduced continued utilization as subsidies increase.

5. Discussion

5.1 Subsidies and Affordability: A Counterintuitive Negative Effect

The finding that subsidies are negatively and significantly related with affordability ($\beta = -.239$; $p = .000$) is the most striking result of this study. Rather than enhancing perceived affordability, higher subsidy exposure appears to correlate with reduced affordability satisfaction. Several mechanisms may explain this paradox.

First, implementation inefficiencies may be causing subsidy value to be absorbed by intermediaries before reaching end users—a pattern documented across sub-Saharan African humanitarian contexts (Puzzolo *et al.*, 2019; Akinwale & Adetunji, 2021). Households may therefore receive technologies at prices higher than the fully-subsidized cost, generating a gap between expectation and experience. Second, the lifecycle affordability gap is critical: while upfront costs are subsidized, recurrent fuel and maintenance costs are not. With 45.8% of respondents unable to regularly afford fuel refills and 87% acknowledging they could not have acquired the technology without subsidy support, it is clear that subsidies create initial access without ensuring sustained financial viability. This pattern is consistent with findings from Ethiopia (Kelebe *et al.*, 2023) and Rwanda (UNHCR, 2023). Third, with subsidies explaining only 5.7% of affordability variance, structural factors, household income levels, local market prices, and supply chain conditions are far more dominant drivers of affordability than subsidy levels alone.

5.2 Subsidies and Adoption: Limited Direct Effect

The non-significant relationship between subsidies and adoption ($\beta = -.078$; $p = .175$) challenges the assumption that financial incentives are sufficient to drive technology adoption in humanitarian settings. Although 95% of respondents confirmed that subsidies influenced their adoption decision, and 87% acknowledged they could not have acquired the technology without support, the regression model reveals that subsidies do not significantly predict adoption behaviour across the sample.

This finding suggests that adoption is driven by factors beyond cost reductions alone. Cultural compatibility emerged as particularly significant: 67.1% of households reported their stove did not suit local cooking practices, and 58.1% disagreed that the subsidized technology was their primary cooking option—indicating persistent fuel stacking. These patterns align with Niyonteze *et al.* (2022), who found that despite initial subsidy-driven adoption in Rwandan camps, long-term use declined due to cultural barriers and insufficient training, and with Köhlin *et al.* (2021), who found that social and behavioral variables had greater influence on adoption than subsidy levels alone in Uganda's Bidi Bidi settlement. The non-significant model contrasts with Hanna, Duflo, and Greenstone (2016), who found strong subsidy effects in India

highlighting that contextual and institutional differences significantly moderate subsidy impacts on adoption.

5.3 Subsidies and Usability: Significant but Negative Relationship

The significant negative association between subsidies and usability ($\beta = -.149$; $p = .010$) suggests that while subsidies may facilitate initial access to technologies, they do not translate into positive user experiences and may even be associated with diminished usability outcomes. Several explanations are plausible. Technologies received through subsidized programs may be of lower quality or may not be matched to local user needs—prioritizing cost efficiency over design appropriateness. Furthermore, when technologies are perceived as externally imposed through aid programs, users may develop lower psychological ownership, reducing their motivation to adapt to or maintain the technology (Lewis & Pattanayak, 2012).

The finding that 67.1% of respondents said their stove did not suit local cooking practices is particularly revealing. Despite relatively high technical reliability (93% reported no breakdowns), the cultural mismatch undermines perceived usability at a fundamental level. This is consistent with GIZ (2021) and AfDB (2023), which documented widespread design-practice incompatibility across African humanitarian camps. Mobarak *et al.* (2019) further found that ongoing use of clean technologies is more determined by performance and user satisfaction than by initial cost savings—reinforcing that subsidies alone, without attention to usability, are insufficient to ensure sustained uptake. The contrast with Malla and Timilsina (2014) in Nepal, where well-structured subsidies combined with user support significantly enhanced sustained use, suggests that subsidy design and post-distribution support are critical mediating factors.

5.4 Implications for Policy and Programming

Together, the three findings carry important implications. Current subsidy structures in Rwanda's refugee camps appear to be insufficiently designed to drive the affordability, adoption, and usability outcomes they intend to achieve. The consistently negative direction of all three relationships even if not all are statistically significant—points to systemic issues in subsidy design and delivery. Financial incentives are a necessary but not sufficient condition for clean energy transitions in displacement settings. Subsidies must be embedded within broader programmatic frameworks that address lifecycle costs, cultural compatibility, user training, and institutional support.

6. Conclusion and Recommendations

This study provides empirical evidence that subsidies, as currently structured in Rwanda's refugee camps, have a significant but negative relationship with affordability ($\beta = -.239$; $p = .000$) and usability ($\beta = -.149$; $p = .010$), and no significant relationship with adoption ($\beta = -.078$; $p = .175$). These findings challenge the assumption that subsidies straightforwardly improve access to and use of clean cooking technologies in humanitarian settings.

Based on these conclusions, four recommendations are proposed. First, Rwanda's Ministry of Infrastructure and humanitarian partners should transition from supply-side subsidy instruments toward direct consumer-side mechanisms—such as household vouchers and point-of-sale discounts—to reduce intermediary capture and ensure full subsidy value reaches end users, particularly low-income households. Second, subsidy scope must be expanded to cover recurrent fuel and maintenance costs, not only technology acquisition, to address the lifecycle

affordability gap that currently undermines sustained use. Third, Rwanda Energy Group, in collaboration with Rwanda Standards Board, should mandate user training, minimum quality standards, and post-adoption maintenance support as conditions for subsidised program delivery thereby improving both usability and long-term retention. Fourth, flexible financing models including pay-as-you-go and microfinance linkages should be integrated into clean cooking programs to bridge the persistent gap between initial access and sustained household use.

Future studies should examine qualitative dimensions of household affordability trade-offs, the mechanisms of intermediary capture in subsidy delivery chains, and the comparative effectiveness of different subsidy instruments across varied refugee camp contexts. Advanced analytical methods, such as structural equation modelling, could further illuminate the complex interrelationships among subsidies, affordability, adoption, and usability.

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