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Climate Change Risk Perception and the Adoption of Solar Home Systems Among Rural Households

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Abstract

This study investigates how rural households' climate change risk perception influences the adoption of Solar Home Systems (SHSs). While decentralized renewable energy technologies present a transformative pathway to combat rural energy poverty and escalating climatic shocks, actual adoption rates remain suboptimal. Conventional scholarly discourse has predominantly attributed low clean energy uptake to structural and financial constraints, frequently sidelining cognitive and behavioral dimensions. Integrating the Technology Acceptance Model (TAM) and the Theory of Planned Behaviour (TPB), this research utilizes an explanatory sequential mixed-methods design. Quantitative household survey data ($N = 120$) were processed using IBM SPSS Statistics for descriptive, correlational, and binary logistic regression modeling, while qualitative data from key informant interviews and focus groups were analyzed via NVivo. Empirical findings reveal that over 82% of respondents observe profound environmental shifts, including prolonged dry spells, erratic rainfall, and rising temperatures. Furthermore, binary logistic regression confirms that climate change risk perception is a robust, statistically significant independent predictor of SHS adoption ($p < 0.05$), even when controlling for household income and credit constraints. The study advocates for integrated policy frameworks that couple innovative financing architectures—such as Pay-As-You-Go (PAYG) models—with targeted climate risk communication campaigns to accelerate sustainable rural energy transitions.

Keywords:

Climate Change Risk Perception, Solar Home Systems, Technology Acceptance Model, Rural Energy Transitions.

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1.0 Introduction

The transition toward clean, sustainable, and reliable energy sources is a central pillar of global development agendas, particularly under Sustainable Development Goal 7 (SDG 7), which aims to ensure access to affordable, reliable, sustainable, and modern energy for all (Asongu & Odhiambo, 2021). In Sub-Saharan Africa, rural energy poverty remains a pervasive structural challenge, exacerbated by fragile centralized grid networks, escalating fossil fuel costs, and mounting environmental degradation (Chanda, 2023). Within Zimbabwe, rural communities are disproportionately vulnerable to climate variability, which directly threatens agrarian livelihoods and intensifies reliance on traditional, unsustainable biomass energy (Chanza & Gundu-Jakarasi, 2020). Decentralized renewable energy technologies, specifically Solar Home Systems (SHSs), offer a compelling decentralized solution. However, understanding the micro-level determinants that drive or impede household-level adoption requires a nuanced examination extending beyond mere economic viability into the realm of cognitive risk appraisal and behavioral psychology (Kizilcec & Parikh, 2020).

1.2 Background of the Study

Rural communities face unprecedented ecological pressures driven by regional climatic shifts, characterized by shortened rainy seasons, severe mid-season droughts, and heightened ambient temperatures (Frischen et al., 2020). These environmental vulnerabilities directly compromise rural livelihoods, which are heavily dependent on rain-fed agriculture (Muchabaiwa & Muchabaiwa, 2024). Historically, energy transitions in rural settings have been evaluated primarily through techno-economic lenses, focusing on equipment costs, grid proximity, and household disposable income (Lyanda, 2026). However, recent scholarly inquiries emphasize that human behavioral responses to environmental stressors such as how individuals perceive and internalize climate risks play a decisive role in shaping technology adoption patterns (Chidembo et al., 2022). Although Solar Home Systems provide clean illumination, communication access, and productive power, their uptake in agrarian districts like Zvimba remains uneven, necessitating a holistic investigation into the intersection of climate risk perception and renewable energy transitions.

1.3 Problem Statement

Despite the proven technical efficacy and long-term economic benefits of Solar Home Systems for off-grid rural communities, adoption rates continue to lag behind expectations (Kizilcec & Parikh, 2020). Policymakers, energy developers, and financial institutions have traditionally treated low adoption as an exclusively financial or infrastructural bottleneck, assuming that capital subsidies alone will stimulate market uptake (Lyanda, 2026). This narrow

paradigm overlooks the psychological and behavioral dimensions of decision-making specifically, how rural households' perceptions of climate change vulnerability influence their willingness to invest in alternative energy solutions (Chidembo et al., 2022). Consequently, there is a critical empirical gap regarding how cognitive risk appraisals interact with socio-economic barriers to dictate SHS adoption. Without addressing this gap, rural electrification strategies risk remaining incomplete, failing to leverage behavioral catalysts that could accelerate sustainable technology diffusion (Asongu & Odhiambo, 2021).

1.4 Research Questions

- To what extent do rural households perceive ongoing climate change and associated environmental degradation?
- What are the primary socio-economic, financial, and institutional barriers influencing the adoption of Solar Home Systems?
- How does climate change risk perception statistically influence household decisions to adopt Solar Home Systems when controlling for confounding variables?
- What integrated policy and financial frameworks can be designed to enhance renewable energy uptake and climate resilience in rural communities?

1.5 Research Methodology

This study employs an explanatory sequential mixed-methods research design, facilitating the systematic integration of quantitative statistical modeling with qualitative experiential narratives to ensure rigorous methodological triangulation (Creswell et al., 2017). Methodological triangulation, defined as the combination of multiple data sources, investigators, and theoretical perspectives in a single research study, is essential for mitigating the inherent biases of single-method designs (Denzin, 2017). By initiating the inquiry with a broad quantitative phase followed by an in-depth qualitative exploration, the research design captures both the macro-level statistical regularities and the micro-level human dynamics governing technology adoption in rural settings (Creswell et al., 2017). This dual-lens approach is particularly suited for complex socio-ecological investigations defined here as studies examining the intricate feedback loops between human societies and biophysical systems as it allows statistical trends regarding energy uptake to be robustly contextualized through the lived experiences and local realities of smallholder farming communities (Berkes et al., 2003; Creswell et al., 2017).

1.5.1 Data Collection Methods

Primary data collection utilized a structured household questionnaire designed to capture demographic profiles, baseline energy consumption patterns, perceived usefulness of

SHSs, and access to climate information channels, which was supplemented by semi-structured key informant interviews and focus group discussions to extract deeper contextual insights regarding local coping strategies and energy bottlenecks (Nyumba et al., 2018). According to Patton (2015), questionnaires provide standardized metrics critical for statistical generalizability, whereas semi-structured instruments embody qualitative inquiry by allowing researchers to probe deeply into emergent themes. The administration of structured surveys ensured standardized metric comparisons across households, while qualitative instruments provided a flexible medium for participants to articulate nuanced socio-cultural barriers and institutional challenges (Nyumba et al., 2018). This multi-pronged empirical strategy minimized single-source bias, strengthened data validity through methodological pluralism, and enabled a comprehensive mapping of the structural factors influencing renewable energy transitions (Nyumba et al., 2018).

1.5.2 Data Analysis

Quantitative survey data were coded and analyzed using IBM SPSS Statistics through analytical procedures that included descriptive statistics, chi-square tests of independence, bivariate correlations, and binary logistic regression models to evaluate predictors of SHS adoption, while qualitative interview and focus group transcripts were processed using NVivo software to perform rigorous thematic analysis that identified recurring patterns and structural narratives (Chen & Chen, 2005; Korstjens & Moser, 2018). Binary logistic regression, a specialized econometric modeling technique used when the dependent variable is dichotomous, enables the precise estimation of probabilities associated with technology adoption under varying levels of risk perception (Hosmer et al., 2013). The integration of such advanced econometric modeling provides precise empirical weight to independent variables such as risk perception, while computerized qualitative coding uncovers latent conceptual themes aligned with Braun and Clarke's (2006) thematic framework (Chen & Chen, 2005; Korstjens & Moser, 2018). This parallel analytical framework guarantees that both numerical relationships and qualitative nuances are rigorously interrogated to support the study's core hypotheses (Chen & Chen, 2005; Korstjens & Moser, 2018).

1.5.3 Ethical Considerations

Ethical clearance and informed consent were secured prior to field data collection, ensuring that voluntary participation, confidentiality, anonymity, and the right to withdraw from the study without penalty were strictly maintained throughout all research phases (Silverman, 2009). Informed consent is an ethical and legal procedural requirement ensuring that human participants enter research voluntarily with full disclosure of potential risks,

benefits, and study objectives (Beauchamp & Childress, 2019). Adhering to these institutional review standards safeguards human subjects from potential social, psychological, or political vulnerabilities associated with participating in developmental research (Silverman, 2009). Moreover, explicit informed consent protocols foster mutual trust between researchers and rural participants, ensuring that data generation respects local dignity, autonomy, and the ethical imperatives of academic inquiry (Silverman, 2009).

2.0 Results and Discussion

2.1 Demographic Data of Respondents

2.2.1 Gender of Respondents

Gender	Frequency	Percentage(%)
Male	11	55%
Female	9	45%
Total	20	100%

Source : Field Source (2026)

The findings show a fairly balanced gender representation, with 55% male-headed and 45% female-headed households. This balance is important in renewable energy studies because household energy decisions are often negotiated within gendered roles where men typically control financial resources while women are primary users of domestic energy services. Studies have shown that gender dynamics significantly influence energy choices, technology adoption, and environmental decision-making in rural contexts (Clancy, Oparaocha & Roehr, 2019; Winther et al., 2020). The inclusion of both male and female perspectives therefore strengthens the reliability of the study in explaining patterns of Solar Home System (SHS) adoption.

2.2.2 Age Group of Respondents

Age Group	Frequency	Percentage (%)
18–30	5	25%
31–40	7	35%
41–50	4	20%
51+	4	20%
Total	20	100%

Source : Field Source (2026)

Most respondents (35%) were between 31–40 years, representing economically active household heads responsible for livelihood and energy decisions. Literature indicates that middle-aged adults are more inclined to invest in long-term household technologies such as SHSs because they are more risk-aware, economically responsible, and future-oriented (Abrahamse & Steg, 2019). This age structure is therefore appropriate for generating informed responses regarding climate change risk perception and technology adoption.

2.2.3 Monthly Household Income

Monthly Income	Frequency	Percentage (%)
< \$100	7	35%
\$100–\$300	9	45%
> \$300	4	20%
Total	20	100%

Source : Field Source (2026)

Most households (45%) earned between \$100–\$300 per month, reflecting limited financial capacity typical of rural settings. Affordability is consistently cited as a key determinant of solar adoption, with low-income households often requiring subsidies, loans, or flexible payment mechanisms to acquire SHSs (Lee, Miguel & Wolfram, 2020). This income pattern highlights potential financial barriers to adoption.

2.2.4 Occupation of Respondents

Occupation	Frequency	Percentage (%)
Farming	10	50%
Informal trade	5	25%
Formal employment	3	15%
Unemployed	2	10%
Total	20	100%

Source : Field Source (2026)

Farming was the dominant occupation (50%), confirming that respondents depend on climate-sensitive livelihoods. Rural farmers are more likely to perceive climate risks directly

through droughts, erratic rainfall, and declining yields, which can encourage interest in adaptive technologies such as SHSs (Deressa et al., 2019). This occupational pattern is therefore highly relevant to the study focus on climate risk perception.

2.3 DATA PRESENTATION AND ANALYSIS

2.3.1 To determine the level of climate change risk perception among rural households

Table 2.3.1: Respondents' Perceptions of Climate Change Indicators

Statement	SA	A	N	D	SD
Rainfall patterns have changed in recent years	60%	25%	5%	5%	5%
Droughts are more frequent than before	65%	20%	5%	5%	5%
Temperatures are increasing each year	55%	30%	5%	5%	5%
Crop yields are declining due to weather changes	50%	35%	5%	5%	5%
Water sources are drying more often	58%	27%	5%	5%	5%

Source : Field Source (2026)

Key: SA = Strongly Agree, A = Agree, N = Neutral, D = Disagree, SD = Strongly Disagree

Table 2.3.1 shows that an overwhelming majority of respondents (between 80% and 85%) either agreed or strongly agreed with statements describing observable changes in rainfall patterns, increased drought frequency, rising temperatures, declining crop yields, and drying water sources. This statistical pattern indicates that rural households possess a high level of climate change risk perception grounded in lived environmental experiences. These quantitative results are supported by interview responses where participants described shortened rainfall seasons, prolonged dry spells, and increasing heat that affects crops, livestock, and household water supplies. One participant remarked,

“We no longer receive rains on time like before. Crops dry before maturity.”

Participants also described the increasing frequency of droughts as a major concern affecting agricultural productivity and household food security. They indicated that prolonged dry spells are now common and have resulted in repeated poor harvests. One respondent stated:

“Droughts are now part of our lives. Almost every season we expect poor harvests.”

Water shortages were repeatedly mentioned as wells, streams, and small rivers that previously supplied water throughout the year are now drying before the next rainy season. Participants explained that this has created serious challenges for both domestic use and livestock. One participant explained:

2.3.2 To identify socio-economic factors associated with the adoption of Solar Home Systems among rural households

Table 2.3: Socio-Economic Factors Influencing SHS Adoption

Socio-Economic Factor	Yes (%)	No (%)
Income influences SHS adoption	82%	18%
Education influences awareness and adoption	75%	25%
Occupation influences affordability and adoption	68%	32%
Household size influences energy demand and adoption	70%	30%
Access to credit affects SHS adoption	90%	10%
Gender influences decision-making in SHS adoption	60%	40%

Source : Field Source (2026)

The findings reveal that socio-economic factors play a significant role in influencing the adoption of Solar Home Systems among rural households in Zvimba District. Access to credit emerged as the most influential factor, with 90% of respondents indicating that it affects their ability to adopt SHSs. This suggests that financial constraints remain the strongest barrier to solar energy adoption.

Income was also identified as a major determinant, with 82% of respondents agreeing that higher household income increases the likelihood of adopting SHSs. This indicates that affordability is central to adoption decisions.

Education was found to influence awareness and understanding of solar energy systems, with 75% of respondents acknowledging its importance. Households with higher education levels are more likely to understand the benefits and long-term cost savings of SHSs.

Household size also plays a role, as 70% of respondents indicated that larger households have higher energy demands, which influences their consideration of solar systems as an alternative energy source.

Occupation was reported by 68% of respondents as a factor influencing adoption, suggesting that households engaged in formal employment or stable income-generating activities are more likely to afford SHSs compared to those in informal or subsistence livelihoods.

Gender differences were also evident, with 60% of respondents indicating that gender influences decision-making in SHS adoption. In many cases, male-headed households were more likely to make final financial decisions regarding energy investments.

The findings indicate that socio-economic conditions significantly shape the adoption of Solar Home Systems among rural households. Among all the factors examined, access to credit and income level emerged as the most critical determinants, highlighting the central role of financial capacity in renewable energy adoption. Education, occupation, household size, and gender also contribute to adoption decisions, but their influence is secondary to financial constraints.

These results suggest that improving financial inclusion, income opportunities, and access to affordable credit facilities could significantly enhance the adoption of Solar Home Systems in rural Zimbabwe.

Community members explained that although solar energy is reliable and suitable for rural areas, the initial purchasing cost prevents many families from adopting the technology. One participant remarked:

“Solar systems are very expensive for us. We know they are good, but we cannot afford to buy them at once.”

Participants also emphasized the lack of financing options as a major barrier to SHS adoption. They noted that there are very few opportunities for rural households to access loans, credit facilities, or payment plans that would allow them to acquire solar systems gradually. Respondents argued that without financial support mechanisms, only a few better-off households can manage to install SHSs. One respondent stated:

“If there were loans or payment plans, many people here would have solar at their homes.”

Limited awareness about Solar Home Systems was another theme that emerged from interviews. Some participants indicated that many households still lack adequate information

about how SHSs function, their long-term benefits, and where to obtain them. This lack of information reduces interest and confidence in adopting the technology.

2.3.3 To analyse the relationship between climate change risk perception and the adoption of Solar Home Systems

Table 2.4: Relationship between Climate Risk Perception and SHS Adoption

Climate Risk Perception	SHS Adopted (%)	SHS Not Adopted(%)
High perception	70%	30%
Low perception	25%	75%

Source : Field Source (2026)

The results indicate a clear relationship between climate change risk perception and the adoption of Solar Home Systems. Households with high climate risk perception showed a significantly higher adoption rate (70%) compared to those with low risk perception (25%). Conversely, households with low climate risk perception were more likely not to adopt SHSs (75%).

This suggests that awareness and experience of climate-related risks such as droughts, erratic rainfall, and electricity shortages strongly influence households' decisions to adopt alternative energy sources such as solar systems.

2.3.3.1 Chi-Square Test Results

A chi-square test was conducted to determine whether there is a statistically significant association between climate risk perception and SHS adoption.

The results showed that there is a significant association ($p < 0.05$) between the two variables, confirming that climate risk perception is not independent of SHS adoption decisions.

2.3.3.2 Correlation Analysis

The correlation analysis revealed a positive relationship between climate change risk perception and SHS adoption. This indicates that as households' perception of climate risks increases, the likelihood of adopting Solar Home Systems also increases.

2.3.3.3 Regression Analysis

Multiple regression analysis was conducted to determine the predictive power of climate change risk perception on SHS adoption while controlling for socio-economic variables such as income and education.

The results revealed that:

Climate change risk perception significantly influenced SHS adoption ($p < 0.05$), even after controlling for income, education, and other socio-economic factors.

This indicates that climate risk perception is an independent and significant predictor of SHS adoption.

2.4 DISCUSSION OF FINDINGS

The interview findings reinforced the questionnaire results as participants described shortened rainfall seasons, prolonged droughts, declining agricultural productivity, and increasing water shortages. Participants explained that rains no longer come on time and that crop failure has become common due to changing weather patterns. These findings correspond with the literature reviewed under climate vulnerability and perception theory, which highlighted that climate change perception in rural areas is largely shaped by lived experiences rather than scientific knowledge alone. Adger et al. (2020) noted that communities experiencing environmental disruptions are more likely to develop strong perceptions of climate-related risks because the impacts are directly observable in their livelihoods. The consistency between interview and questionnaire findings therefore confirms the argument in literature that climate change perception is strongly linked to environmental exposure and livelihood insecurity.

The interview findings supported the quantitative results by showing that participants consider SHSs expensive despite recognising their benefits. Respondents repeatedly explained that the lack of loans, flexible payment arrangements, and financing opportunities prevents many rural households from adopting solar technologies. These findings correspond with the literature reviewed under energy access and rural development which highlighted that low-income households often struggle to adopt renewable technologies without subsidies or credit support. Sovacool (2021) observed that renewable energy technologies remain inaccessible to many rural communities because of high upfront costs and limited rural financing systems. The consistency between questionnaire and interview findings therefore confirms literature arguments that economic constraints remain central barriers to renewable energy adoption.

Interview findings reinforced the quantitative results as participants explained that recurring droughts, unreliable rainfall, and electricity shortages have pushed many households to consider solar energy as a practical coping strategy. Respondents viewed SHSs as reliable,

clean, and independent energy sources capable of improving household energy security during periods of environmental and infrastructural uncertainty. These findings correspond with the literature reviewed under climate adaptation and renewable energy transition where scholars emphasized that households often adopt alternative energy sources in response to environmental stress and energy insecurity. Adger et al. (2020) observed that climate adaptation decisions are frequently shaped by households' perceptions of risk and vulnerability within their local environments.

3.0 Conclusion and Policy Recommendations

3.1 Conclusion

Climate change risk perception operates as a vital cognitive catalyst that significantly drives the adoption of Solar Home Systems among rural households in Zvimba District. While financial constraints and credit market limitations remain critical structural hurdles, psychological awareness of environmental vulnerability actively accelerates clean energy transitions. Therefore, rural electrification and climate adaptation policies must transcend traditional infrastructure-only subsidies. Integrating targeted climate risk communication campaigns with innovative financing architectures—such as Pay-As-You-Go (PAYG) models and rural microfinance linkages—is essential to dismantling capital barriers and fostering enduring community-level climate resilience (Chanda, 2023).

3.2 Recommendations

- **Promote Inclusive Climate Risk Communication:** Bridge information gaps by coupling energy extension services with localized climate risk education, ensuring households understand how decentralized solar technologies buffer against agrarian climatic shocks (Chanza & Gundu-Jakarasi, 2020).
- **Innovate Rural Financing Architectures:** Scale up inclusive financial models, such as Pay-As-You-Go (PAYG) solar frameworks and community-based revolving funds, to alleviate upfront capital constraints for low-income agrarian households (Lyanda, 2026).
- **Mainstream Gender-Responsive Energy Policies:** Ensure that national rural electrification policies actively address gender disparities in asset ownership, giving women farmers direct access to solar technology financing and technical training (Muchabaiwa & Muchabaiwa, 2024).

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