ISSN Online: 2756-3898, ISSN Print: 2714-500X https://doi.org/10.47514/phyaccess.2026.6.2.002

Factors Influencing Households' Intention to Adopt Solar Photovoltaic Technology for Net Metering in Mzuzu City, Malawi

Lottie Singini[1], Chikumbusko Kaonga[2], and Christabel Kambala[3]

[1] School of Science and Technology, Malawi University of Business and Applied Sciences, P/Bag 303, Blantyre, Malawi
[2] Department of Physics and Biochemical Sciences, Malawi University of Business and Applied Sciences, P/Bag 303, Blantyre, Malawi
[3] Department of Public Health and Environmental Sciences, Malawi University of Business and Applied Sciences, P/Bag 303, Blantyre, Malawi

Corresponding E-mail: lottisingini@gmail.com

Received 31-05-2026
Accepted for publication 02-07-2026
Published 07-07-2026

Abstract

Adoption of solar photovoltaic (PV) technology is essential for the successful implementation of Malawi's newly introduced net-metering framework. However, evidence on urban household adoption intentions remains limited. This study investigated the sociodemographic and perceptual factors influencing households' intention to adopt solar PV for net-metering in Mzuzu City, Malawi. A descriptive survey of 182 grid-connected households was conducted, and binary logistic regression, guided by the Theory of Planned Behaviour (TPB) and the Technology Acceptance Model (TAM), was used to identify significant predictors of adoption intention. The regression model was statistically significant ($\chi^2 = 82.84$, $p < 0.001$), explained 49% of the variation in adoption intention (Nagelkerke $R^2 = 0.49$), and correctly classified 80.2% of households. House ownership emerged as the strongest predictor of adoption intention, followed by economic perception, environmental perception, household size, electricity expenditure, gender, and education level, while age, marital status, income source, and social and technical perceptions were not significant. The findings indicate that household adoption intention is driven primarily by structural characteristics and perceived economic and environmental benefits rather than demographic factors alone. The study further identifies landlord–tenant constraints and regulatory uncertainty as key barriers unique to the net-metering context, providing evidence to guide policies and targeted interventions that can accelerate household participation in Malawi's emerging net-metering programme.

Keywords: Solar photovoltaic adoption; net metering; technology acceptance; binary logistic regression; household intention; urban Malawi; Theory of Planned Behaviour.

I. Introduction

The global transition from fossil fuel-based energy systems to renewable energy technologies (RETs) forms the foundation of international climate change mitigation strategies for achieving Sustainable Development Goal 7 (SDG7), which targets universal access to affordable, reliable, sustainable, and modern energy by 2030 [1-2]. Solar photovoltaic (PV) technology has emerged as a central component of this transition, with projections suggesting it will account for 37% of global electricity supply by 2050 [3]. The rapid cost reduction of solar PV, combined with enabling policies, has accelerated distributed generation adoption in both developed and developing countries.

Net metering is one of the most widely adopted regulatory framework mechanisms for incentivising distributed solar PV generation. Under the net metering framework, customers who generate electricity from solar PV systems can offset their surplus generation against their grid consumption, effectively reducing their bill credits [4-5]. Net metering creates a direct financial return on investment that accelerates solar PV adoption in cities and municipalities across developed and developing economies [6]. In Africa, countries including Mauritius, South Africa, Lesotho, and Egypt have incorporated net metering into their renewable energy frameworks as a tool for expanding generation capacity and improving electricity access [7].

Malawi faces acute energy challenges characterised by limited electricity access, with only 25% of the population connected to electricity; frequent power outages; heavy dependence on hydropower, which accounts for approximately 90% of electricity generation; and increasing electricity demand driven by rapid urbanisation and population growth [8]. These challenges have negatively affected household welfare, industrial productivity, and overall socioeconomic development, highlighting the need for diversified and sustainable energy solutions such as solar PV systems and net metering. In response, the Government of Malawi introduced net metering rules through the Malawi Energy Regulatory Authority (MERA) in 2025, enabling grid-connected customers in residential, commercial, industrial, agricultural, and mining sectors to offset excess solar generation against their electricity bills [9]. This represents a significant policy development with the potential to accelerate distributed solar PV adoption in urban areas where grid connectivity is highest.

Despite growing interest in solar PV systems in Malawi, existing studies have largely focused on rural electrification, mini-grids, and small-scale household solar applications in off-grid settings [10-11]. Consequently, limited empirical evidence exists regarding urban households' intentions to adopt grid-connected solar PV systems under formal regulatory mechanisms such as net metering. Unlike conventional solar PV adoption studies that primarily examine energy access and reliability benefits, net metering introduces a distinct set of considerations: (1) a policy-specific economic incentive whereby consumers offset their electricity bills through exported solar generation, fundamentally altering the financial calculus of adoption compared to standalone off-grid systems; (2) a structural barrier in the form of the landlord-tenant investment problem, whereby renters cannot install solar PV systems on property they do not own even if they wish to; and (3) regulatory uncertainty arising from the novelty of Malawi's net metering rules (MERA, 2025), meaning awareness and understanding of the policy vary substantially across the urban population. These contextual factors require empirical investigation that existing rural-focused or off-grid adoption studies cannot provide. This study, therefore, contributes the first systematic empirical evidence on the sociodemographic and perceptual factors influencing urban household adoption intention within a net metering policy context in Malawi, and its findings offer a comparative reference point for other sub-Saharan African countries at similar stages of net metering implementation.

Understanding these factors is essential for the effective implementation of the net metering framework. Studies indicate that technology adoption does not occur spontaneously; rather, it is shaped by a combination of internal household characteristics (such as income, education, and household size) and external perceptual factors (such as perceived economic benefit, environmental concern, and technical confidence) [12]. Designing effective policies and programmes to promote net metering uptake requires a clear empirical picture of which factors drive and inhibit adoption intention among the target population.

This study addresses this gap by investigating the sociodemographic and perceptual determinants of urban households' intention to adopt solar PV for net metering in Mzuzu, Malawi. Specifically, the study characterises the sociodemographic profile of the study population and their current electricity consumption patterns, assesses household perceptions of solar PV for net metering, and identifies factors that significantly predict adoption intention using binary logistic regression. Finally, the study derives evidence-based recommendations for policymakers and practitioners seeking to accelerate net metering uptake in urban Malawi.

II. Theoretical Framework

This study is grounded on two complementary theoretical frameworks widely applied in technology adoption research: the Technology Acceptance Model (TAM) and the Theory of Planned Behaviour (TPB). TAM, originally developed by Davis [13], proposes that technology adoption is primarily influenced by two key perceptual constructs: perceived usefulness and perceived ease of use. Perceived usefulness refers to the extent to which an individual believes that using technology will enhance their performance, while perceived ease of use reflects the degree to which the technology is expected to be free of effort. In the context of solar PV systems and net metering, perceived usefulness aligns with expected economic benefits, such as electricity bill savings through net metering credits, as well as environmental benefits associated with reduced carbon emissions. Perceived ease of use corresponds to perceived technical suitability, including household confidence in the installation, operation, and maintenance of the system. Both dimensions are directly relevant to net metering adoption, where the financial return and operational simplicity of the system are central to the adoption decision.

The TPB, developed by [14], explains behavioural intention through three determinants: attitudes toward the behaviour, subjective norms, and perceived behavioural control. Attitudes reflect an individual’s positive or negative evaluation of adopting solar PV systems. Subjective norms capture perceived social pressure from family, peers, and community members regarding the adoption decision. Perceived behaviour control refers to an individual’s perceived ability to perform the behaviour, which in this study is reflected in enabling conditions such as house ownership, income level, and education.

Together, TAM and TPB provide a robust conceptual foundation for this study. Sociodemographic variables (including gender, education, household size, income source, house ownership, electricity expenditure, marital status, and age) present structural enabling or constraining conditions that shape perceived behaviour control. While the four perceptual variables (social, economic, technical, and environmental perception) directly operationalise the attitudinal and normative dimensions of both frameworks. This integrated approach supports a comprehensive understanding of determinants of solar PV adoption for net metering among urban households.

III. Materials and Methods

A. *Study Area and Population*

The study was conducted in Mzuzu City, located in northern Malawi at coordinates 11.44° S, 34.01° E. Mzuzu is Malawi’s third-largest city and one of the fastest-growing commercial cities. Like other urban areas in Malawi, the city experiences frequent power outages attributable to increasing electricity demand and ageing transmission infrastructure, thereby creating a strong motivation for distributed generation among grid-connected consumers.

The study targeted grid-connected households in four residential areas of Mzuzu, namely Chimaliro (study area 1), Katoto area 4 (study area 2), SOS (study area 3), and Kaning’ina (study area 4). According to the Mzuzu City Council's 2023 census, the four study areas have a combined population of 825 households, which constituted the study population. These areas were purposively selected because their residents are predominantly high-income earners who own or rent formal housing suitable for rooftop solar PV installation. In addition, the areas are among the most affected by load shedding due to high electricity demand. Only households without existing solar PV systems were included in the study to assess adoption intention among probable future adopters rather than current users. The study population and its distribution across the four areas are presented in Table I.

Table 1. Study population distribution across residential areas.

Residential Area	Number of Households
Study Area 1 (Chimaliro)	504
Study Area 2 (Area 4)	133
Study Area 3 (SOS)	106
Study Area 4 (Kaning’ina)	82
Total	825

B. *Research Design*

A descriptive cross-sectional survey design was employed in this study. This design was considered appropriate for quantifying the prevalence of adoption intention and examining the statistical associations between predictor variables and the adoption outcome within a defined population at a single point in time. Data collection was conducted between March and July 2024, before the formal introduction of Malawi's net metering rules in 2025. Although the Malawi net metering rules were introduced in 2025, the scheme had not yet been operationalised at the time of this study. Consequently, households had no direct experience with net metering, and awareness of the policy remained limited. To ensure a common understanding among respondents, the questionnaire provided a brief explanation of the net metering concept, including its policy basis, operational requirements, and potential financial benefits. Respondents were then asked to indicate their intention to adopt solar photovoltaic (PV) systems under such a framework. Therefore, this study assesses prospective adoption intentions in anticipation of a future operational net metering programme rather than actual participation in an existing scheme.

C. *Sample Size and Sampling Procedure*

The required sample size was calculated using Slovin’s formula at a 95% confidence level with a margin of error of 5% as presented in (1).

$$n = \frac{N}{1+Ne^2} \quad (1)$$

Where n is the required sample size, N = 825 is the study population, and $e = 0.05$ is the acceptable margin of error. Substituting: $n = 825 / (1 + 825 \times 0.05^2) = 825 / 3.0625 \approx 270$ households.

A multistage sampling design was employed for the study, combining cluster sampling and simple random sampling. Cluster sampling was considered appropriate for ensuring geographic representation of the study population, with the four residential areas serving as clusters. The sample was proportionally drawn from each cluster to ensure representative coverage of the study population. The proportional allocation formula used to determine the sample size for each cluster is presented in (2).

$$n_i = \frac{N_i}{N} \times n \quad (2)$$

Where n_i is the number of households sampled from cluster i, N_i is the cluster population, N is the total population, and n is the total sample size.

Within each cluster, households were selected by simple random sampling, giving each household an equal probability of inclusion. The resulting sample distribution is presented in Table II.

Table II. Proportional sample allocation by residential area.

Residential Area	Households	Sample Size
Study Area 1	504	164
Study Area 2	133	44
Study Area 3	106	35
Study Area 4	82	27
Total	825	270

D. Data Collection Instrument

Quantitative data were collected using a structured questionnaire administered through a drop-and-pick method. Under this approach, questionnaires were delivered directly to the household head or a designated adult household member and collected after five days. This method was considered appropriate for accommodating the working schedules of the target population while also allowing respondents sufficient time to consult relevant household documents (such as electricity bills) when completing the questionnaire.

The questionnaire comprised three sections:

1. Section A: Dependent variable, adoption intention (dichotomous: Yes = 1 / No = 0), defined as the household's intention to install a solar PV system for net metering. Behavioural intention has also been recognised as a significant predictor in several recent studies on residential solar PV adoption [15].
2. Section B: Sociodemographic independent variables; eight variables were assessed, namely age of household head, gender of household head, marital status, highest education level attained, main income source, household size, average monthly electricity expenditure, and house ownership status.
3. Section C: Perceptual independent variables; four constructs comprising social, economic, technical, and environmental perception of solar PV for net metering. Each construct was measured using a three-point scale (No Idea = 1, Agree = 2, Disagree = 3). Questionnaire items were adapted from validated instruments used in comparable adoption studies [12], [16]. A three-point scale was adopted in recognition that the surveyed population had limited prior exposure to net metering; finer-grained five- or seven-point scales risk creating artificial distinctions in perception where respondents lack sufficient information to discriminate meaningfully. Each construct was measured by a single summary item derived from the validated instruments, and the constructs are therefore treated as single-item measures in the regression model rather than multi-item scales; Cronbach's alpha does not apply to single-item constructs.

Continuous variables were categorised for analysis. Age was grouped as youth (15–24 years), active adults (25–60 years), and elderly (61 years and above). Household size was classified as small (1–4 members), medium (5–8 members), and large (9 or more members). Monthly electricity expenditure was grouped as low (below MWK 30,000/month), medium (MWK 31,000–40,000/month), and high (above MWK 41,000/month).

Categorical variables were coded numerically to facilitate statistical analysis. Binary variables, including house ownership, marital status, gender, education level, income source, and age, were assigned numeric codes representing their respective categories. Ordinal variables such as household size and monthly electricity expenditure were coded sequentially according to increasing category levels as presented in Table IV. These coded variables were subsequently used in the logistic regression analysis to examine factors influencing household intentions to adopt solar PV net metering.

E. Data Quality and Missing Data

Out of the 270 questionnaires that were distributed, 196 were returned, representing a 72.6% return rate. Out of the returned questionnaires, 14 were excluded from analysis due to incomplete responses to key variables, specifically, missing values on the dependent variable or more than two missing perceptual items. This resulted in a final analytical sample of 182 questionnaires, representing a 67.4% usable response rate. The excluded questionnaires did not differ systematically from retained questionnaires on the sociodemographic variables that could be assessed, suggesting that exclusion did not introduce substantial selection bias. Furthermore, the 67.4% response rate exceeds the 60% threshold commonly considered adequate for generalisation in social science survey research.

F. Sample Adequacy for Logistic Regression

The logistic regression model was estimated using 182 observations and 12 predictor variables. Sample adequacy was assessed using the events-per-variable (EPV) criterion commonly applied in logistic regression analyses. The smaller outcome category comprised 80 non-adopters, yielding approximately 6.7 non-events per predictor variable. Although this value falls below the traditional recommendation of 10 EPV proposed by [17], subsequent methodological studies have demonstrated that reliable logistic regression estimates can often be obtained with lower EPV values, particularly when predictors are not highly correlated, and the model exhibits satisfactory fit [18]. Several diagnostic indicators support the adequacy of the model. Variance Inflation Factor (VIF) values ranged from 1.09 to 1.32, indicating no evidence of problematic multicollinearity among predictors. In addition, the Hosmer–Lemeshow goodness-of-fit test was non-significant ($p = 0.711$), suggesting an adequate fit between the model and the observed data. The regression coefficients also exhibited stable standard errors, with no indication of numerical instability or separation problems. Consequently, while the sample size should be regarded as modest relative to the number of predictors, it was considered sufficient for the exploratory and explanatory objectives of this study. Nevertheless, future studies employing larger samples would be valuable for confirming the robustness of the estimated effects.

G. *Analytical Methods*

Data were analysed using IBM SPSS Statistics Version 20. Descriptive statistics (frequencies and percentages) were used to characterise the sample. Binary logistic regression was employed to model the probability of adoption intention (Yes = 1) as a function of the sociodemographic and perceptual predictor variables. The logistic regression model takes the form of (3).

$$\ln\left[\frac{P(T=1)}{1-P(Y=1)}\right] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k + \varepsilon \quad (3)$$

Where $P(Y=1)$ is the probability that a household intends to adopt solar PV, β_0 is the intercept, $\beta_1 \ldots \beta_k$ are the regression coefficients for predictor variables $X_1 \ldots X_k$, and ε is the error term.

Statistical significance was assessed at $p < 0.05$. Odds ratios ($OR = e^{\beta}$) were used to quantify the direction and magnitude of each predictor's effect. $OR > 1$ indicates a positive association with adoption intention; $OR < 1$ indicates a negative association. Multicollinearity was assessed using the Variance Inflation Factor (VIF); all predictors yielded VIF values below 2.0 (range: 1.09–1.32), confirming the absence of problematic multicollinearity. Influential observations were assessed using Cook's Distance and standardised residuals; no observations exceeded Cook's Distance thresholds or standardised residual values of ±3.0, confirming model stability. Categorical variables were entered using dummy coding, with reference categories specified in Table 5. Model fit was assessed using: the Omnibus test of model coefficients (χ^2), the Hosmer-Lemeshow goodness-of-fit test ($p > 0.05$ indicates adequate fit), Nagelkerke R^2 (pseudo-R^2 measure of variance explained), and overall classification accuracy.

IV. RESULTS AND DISCUSSION

A. *Results*

1) *Household Adoption Intention*

Of the 182 households in the analytical sample, 102 (56.0%) expressed an intention to adopt solar PV for net metering (coded Yes = 1, potential adopters), while 80 (44.0%) indicated no intention to adopt (coded No = 0, non-adopters). This slight majority of households expressing adoption provides a sound basis for modelling the determinants of adoption, as it indicates a meaningful variation in the dependent variable. The relatively balanced distribution between adopters and non-adopters further suggests that solar PV adoption for net metering is not yet a default decision among households in Mzuzu; therefore, understanding the distinguishing factors is analytically valuable.

2) *Sociodemographic Characteristics*

Table III presents the sociodemographic profile of 182 households in the analytical sample.

Table III. Sociodemographic characteristics of the analytical sample (n = 182).

Variable	Category & Coding	Frequency	Percentage (%)
House Ownership	Owned = 1	91	50.0
	Rented = 2	91	50.0
Marital Status	Married = 1	125	68.7
	Unmarried = 2 (single/widowed/divorced)	57	31.3
Gender of Household Head	Male = 1	124	68.1
	Female = 2	58	31.9
Education Level	Non-Tertiary = 1 (primary/secondary)	84	53.8
	Tertiary/College = 2	98	46.2
Main Income Source	Self-employed/Business = 1	100	54.9
	Formal Employment = 2	82	45.1
Age of Household Head	Youths (below 24 years) = 1	26	14.3
	Adults (above 24 years) = 2	156	85.7
Household Size	Small (1–5 members) = 1	91	50.0
	Medium (6–8 members) = 2	73	40.1
	Large (9+ members) = 3	18	9.9
Monthly Electricity Expenditure	Low (<MWK 30,000 / <USD 16.2) = 1	51	28.0
	Medium (MWK 31,000–40,000 / USD 16.8–21.6) = 2	84	46.2
	High (>MWK 41,000 / >USD 22.2) = 3	47	25.8
Total		182	100

All currency conversions use an exchange rate of MWK 1,850 per USD, which was the prevailing rate during the analysis period.

3) *Household Perceptions of Solar PV for Net Metering*

Table IV. Household perceptions of solar PV for net metering (n = 182)

Response	Social n (%)	Economic n (%)	Technical n (%)	Environmental n (%)
No Idea	13 (7.1)	2 (1.1)	18 (9.9)	3 (1.6)
Agree	93 (51.1)	98 (53.8)	97 (53.3)	108 (59.3)
Disagree	76 (41.8)	82 (45.1)	67 (36.8)	71 (39.0)

Table IV summarises household perceptions of solar PV adoption for net metering across four key dimensions: social, economic, technical, and environmental. Overall, most of the respondents demonstrated agreement with the stated benefits of solar PV for net metering, with environmental perception recording the highest agreement rate (59.3%) and social perception the lowest (51.1%).

4) *Binary Logistic Regression Results*

The binary logistic regression model was statistically significant overall (Omnibus $\chi^2(12) = 82.84$, $p < 0.001$), indicating that the set of predictors collectively explains a significant proportion of variance in adoption intention. The Hosmer-Lemeshow goodness-of-fit test was non-significant ($p = 0.711$), confirming that the model adequately fits the data. The model accounts for 49% of the variance in adoption intention (Nagelkerke $R^2 = 0.49$) and correctly classifies 80.2% of cases, with a sensitivity of 84.3% (proportion of actual adopters correctly predicted as adopters). The full regression results are presented in Table V.

Table V. Binary logistic regression results: predictors of household intention to adopt solar PV for net metering (n = 182).

Predictor Variable	B	S.E.	Wald	p-value	OR (95% CI)	VIF
Gender (ref: Female)	−0.74	0.33	4.98	0.026*	0.4771 (0.25–0.92)	1.21
Education (ref: tertiary)	−0.81	0.30	7.30	0.007**	0.4449 (0.25–0.81)	1.18
Household Size (ref: Small)	+0.67	0.25	7.06	0.008**	1.9542 (1.19–3.20)	1.14
Electricity Expenditure (ref: Low)	+0.53	0.26	4.28	0.039*	1.6989 (1.02–2.83)	1.32
House Ownership (ref: Rented)	+1.42	0.35	16.46	<0.001***	4.1371 (2.09–8.21)	1.09
Economic Perception (ref: Disagree)	+1.08	0.33	10.78	0.001**	2.9447 (1.54–5.61)	1.28
Environmental Perception (ref: Disagree)	+0.71	0.30	5.48	0.019*	2.0330 (1.12–3.68)	1.19
Age (ref: Youth)	−0.21	0.31	0.44	0.506	0.8106 (0.44–1.49)	1.23
Marital Status (ref: Unmarried)	−0.04	0.28	0.02	0.880	0.9608 (0.56–1.66)	1.16
Income Source (ref: Employed)	−0.38	0.24	2.55	0.112	0.6839 (0.43–1.09)	1.11
Social Perception (ref: Disagree)	−0.18	0.26	0.47	0.491	0.8353 (0.50–1.40)	1.22
Technical Perception (ref: Disagree)	−0.23	0.27	0.70	0.402	0.7945 (0.47–1.35)	1.17
Constant (β_0)	−0.62	0.48	1.67	0.197	—	—

Note: * represent $p < 0.05$; ** represent $p < 0.01$; *** represent $p < 0.001$. B is the unstandardised logistic regression coefficient; S.E. is the standard error; OR is the odds ratio; CI is the confidence interval; VIF is the Variance Inflation Factor.

The strongest predictor was house ownership, where homeowners were over four times more likely to intend to adopt solar PV compared to renters (OR = 4.1371, 95% CI [2.09, 8.21], p < 0.001). Economic perception was also a strong positive predictor, with those who agreed with economic benefits being nearly three times more likely to intend to adopt (OR = 2.9447, 95% CI [1.54, 5.61], p = 0.001). Household size showed that larger households had nearly twice the odds of intending to adopt compared to smaller households (OR = 1.9542, 95% CI [1.19, 3.20], p = 0.008). Similarly, environmental perception (OR = 2.0330, 95% CI [1.12, 3.68], p = .019) and electricity expenditure (OR = 1.6989, 95% CI [1.02, 2.83], p = 0.039) were positively associated with adoption intention. Conversely, gender and education level were significantly associated with lower adoption intention. Male-headed households had 52% lower odds of intending to adopt solar PV net metering than female-headed households (OR = 0.4771, 95% CI [0.25, 0.92], p = .026). Similarly, respondents with tertiary education exhibited 55% lower odds of adoption intention compared with those with non-tertiary education (OR = 0.4449, 95% CI [0.25, 0.81], p = .007). The remaining five predictors, age, marital status, income source, social perception, and technical perception, were not statistically significant ($p > 0.05$).

B. Discussion

1) Gender of Household Head

Gender was a statistically significant predictor of adoption intention (p = 0.026), with male-headed households exhibiting lower odds of intending to adopt solar PV under a net metering arrangement compared to female-headed households (OR = 0.4771). This finding suggests that female-headed households were more likely to express an intention to adopt the technology. From the perspective of the Technology Acceptance Model (TAM), female household heads may perceive solar PV as more useful in addressing household energy challenges, particularly where electricity interruptions affect domestic activities such as lighting, food preservation, and household management. Similarly, the Theory of Planned Behaviour (TPB) suggests that women may hold more favourable attitudes toward technologies that improve household welfare and energy security, thereby strengthening adoption intentions. This result is consistent with previous studies that have identified gender as an important determinant of renewable energy adoption. Reference [19] found that female household heads in rural Pakistan are significantly more likely to adopt solar PV systems compared to male-headed households, while [20] found that male-headed households are less likely to adopt solar energy technology compared to female-headed counterparts in Ethiopia. However, the direction and magnitude of gender effects vary across contexts, reflecting differences in socioeconomic conditions, household decision-making structures, and access to financial resources. In the Malawian context, female-headed households may perceive greater benefits from reliable and affordable electricity, particularly given their central role in household energy management. The finding suggests that gender-sensitive awareness and outreach programmes could enhance participation in future net metering initiatives, while ensuring that both male- and female-headed households have access to information on the economic and environmental benefits of solar PV systems.

2) Education Level

Education level was a statistically significant predictor of adoption intention (OR = 0.4449, 95% CI: 0.25–0.81, p = 0.007). The results indicate that respondents with tertiary education had 55% lower odds of intending to adopt solar PV net metering compared with those with non-tertiary education. This finding contrasts with much of the renewable energy literature, which generally reports a positive relationship between education and solar PV technology adoption [20], [21]. However, the relationship between education and renewable energy adoption is not universally consistent. Some studies have reported weak or insignificant effects, suggesting that the influence of education may depend on other contextual factors. Therefore, while the present study confirms that education is an important determinant of adoption intention, the specific mechanisms through which education influences household decisions in the Malawian net metering context remain uncertain because these pathways were not directly measured in the survey. Future research should examine potential mediating factors, such as energy literacy, financial knowledge, and policy awareness, to better understand how educational attainment shapes adoption decisions.

3) Household Size

Household size was positively and significantly associated with adoption intention (p = 0.008, OR = 1.9542). This finding corresponds with that of Huebner [22], who reported that larger households tend to have higher electricity demand, resulting in greater electricity expenditures and, consequently, a stronger economic incentive to adopt solar PV systems. This aligns directly with the TAM construct of perceived usefulness: the larger the household, the more tangible the benefit of distributed generation. The finding is consistent with [21], who reported a significant positive association between household size and solar PV adoption in Pakistan, and supports the TPB interpretation that perceived behavioural control, proxied by the financial incentive to act, is stronger in larger households. From a policy perspective, promotional interventions should prioritise medium and large households as the highest-return targets for net metering uptake. In the context of Malawi's emerging net metering framework, the result suggests that larger households may represent an important market segment for future solar PV deployment. Nevertheless, because actual participation in net metering was not observed and the scheme had not yet been operationalised at the time of the study, the findings should be interpreted as reflecting adoption intentions rather than realised adoption behaviour.

4) Monthly Electricity Expenditure

Monthly electricity expenditure was a positive and statistically significant predictor of adoption intention (p = 0.039, OR = 1.6989), indicating that households with higher electricity bills were approximately 1.7 times more likely to express an intention to adopt solar PV under a net metering arrangement than households with lower electricity expenditures. This finding suggests that anticipated cost savings play an important role in shaping adoption decisions. The result is consistent with the Technology Acceptance Model (TAM), particularly the concept of perceived usefulness, whereby households are more likely to adopt a technology when they perceive clear economic benefits from its use. For households facing higher electricity costs, solar PV systems may offer an attractive opportunity to reduce dependence on grid electricity and lower monthly energy expenditures. This finding is consistent with previous studies that have identified electricity costs as a key driver of residential solar PV adoption. [23], found that higher electricity tariffs significantly increased the likelihood of residential solar PV adoption in Qatar, while [24] reported that changes in electricity pricing structures influenced household investment decisions in Italy. Similar findings have been reported in other jurisdictions where rising electricity costs improve the economic attractiveness of distributed renewable energy technologies. In the Malawian context, where electricity tariffs have increased in recent years, households with higher electricity expenditures may perceive greater potential benefits from generating their own electricity through solar PV systems. Given that Malawi's net metering framework had not yet been operationalised at the time of this study, these findings reflect expected rather than experienced economic benefits. Nevertheless, they suggest that the economic case for solar PV is likely to be an important determinant of future participation once the net metering scheme becomes fully operational.

5) House Ownership

House ownership was the strongest predictor of adoption intention in the model ($p < 0.001$, OR = 4.1371), with owner-occupier households being more than four times as likely to express an intention to adopt solar PV under a net metering arrangement compared to households living in rented accommodation. This finding highlights the importance of property ownership in shaping household willingness to invest in distributed renewable energy technologies. The finding is consistent with previous studies that have identified homeownership as a significant determinant of residential solar PV adoption. For example, [25] found that homeowners were substantially more likely to invest in solar technologies than renters due to greater control over property modifications and stronger incentives to undertake long-term energy investments. In the present study, approximately half of the respondents resided in rented accommodation, suggesting that tenure status may represent an important structural constraint to future participation in Malawi's net metering scheme. Given that the scheme had not yet been operationalised at the time of data collection, the result reflects intended rather than actual adoption behaviour. Nevertheless, it highlights the need for policy mechanisms that broaden access to distributed renewable energy technologies beyond owner-occupied dwellings. Potential approaches could include incentives for landlords to install solar PV systems, shared-benefit arrangements between landlords and tenants, or other innovative financing and ownership models that reduce tenure-related barriers to participation.

6) Economic and Environmental Perception

Both economic perception ($p = 0.001$, OR = 2.9447) and environmental perception ($p = 0.019$, OR = 2.0330) were statistically significant and positively associated with adoption intention. Households that perceive solar PV as economically beneficial, specifically in reducing electricity bills through net metering credits, are nearly three times more likely to express adoption intention than those who do not. This is the second strongest effect in the model after house ownership and reflects the central role of perceived financial utility in technology adoption decisions. The environmental perception finding indicates that households that believe solar PV contributes to environmental conservation are approximately twice as likely to intend adoption, consistent with the TPB's attitudinal dimension and with findings from Malaysia [16]. This contrasts with [26], who found environmental perception non-significant, likely reflecting contextual differences.

Social and technical perceptions were not statistically significant in this model ($p = 0.491$ and $p = 0.402$, respectively), suggesting that household adoption intention is driven primarily by economic self-interest and environmental values rather than social conformity or technical confidence. This finding has implications for net metering communication strategy: campaigns emphasising bill savings and environmental impact are likely to be more effective than those emphasising social norms or ease of installation.

7) Non-Significant Predictors: Age, Marital Status, and Income Source

Age ($p = 0.506$), marital status ($p = 0.880$), and income source ($p = 0.112$) were not statistically significant predictors of adoption intention in this study. The non-significance of age suggests that the motivation to adopt solar PV for net metering is broadly consistent across age cohorts in this urban sample, in contrast to findings in some rural or developing-economy contexts where younger adopters predominate [21]. This may reflect the specific nature of the net metering decision, which is primarily financial rather than technological, making it equally relevant to adults of all ages who face electricity bills. The non-significance of marital status and income source suggests that the dichotomous categorisations used (married/unmarried; employed/self-employed) may not capture the economically relevant variation in these constructs. Future studies should consider continuous income measures and more granular marital status categories.

8) Limitations

Several limitations of this study should be acknowledged. First, the study was conducted in four residential areas of Mzuzu City; therefore, the findings may not be fully generalisable to the populations of other cities in Malawi. Other cities may differ in terms of income distribution, housing characteristics, and electricity infrastructure, which could influence adoption intention.

Second, the study measured key perceptual constructs, including economic, environmental, social, and technical perceptions, using single-item indicators assessed on a three-point response scale (Agree, Disagree, and No Idea). While this approach reduced respondent burden and facilitated survey administration, the three-point scale limited the granularity of attitudinal measurement compared to conventional five- or seven-point Likert scales. In addition, single-item measures may not fully capture the multidimensional nature of these constructs and may exhibit lower reliability than validated multi-item scales. Future research should employ validated multi-item scales with broader response categories to improve measurement reliability, construct validity, and the ability to detect more nuanced variations in household perceptions toward solar PV adoption under net metering arrangements.

Third, the cross-sectional design captures stated intention at a single point in time. However, intention does not always translate into actual behaviour; longitudinal studies tracking actual adoption following the rollout of Malawi's net metering framework would provide more direct evidence of adoption determinants.

Fourth, data collection was conducted between March and July 2024, before the introduction and subsequent operationalisation of Malawi's Net Metering Rules in 2025. To address respondents' limited familiarity with the concept, a standardised net metering information sheet (see Section III B). Nevertheless, the study assesses household intentions toward a proposed policy framework rather than participation in a fully operational net metering scheme. Consequently, respondents' evaluations were based on anticipated rather than experienced costs, benefits, and technical requirements. Future research should replicate this study once the net metering framework is fully implemented and public awareness has increased, to examine whether the determinants of adoption intention identified in this study remain significant and whether their relative influence changes as households gain practical experience with the scheme.

V. Conclusion

This study investigated the sociodemographic and perceptual factors influencing urban households' intention to adopt solar PV technology for net metering in Mzuzu City, Malawi. Drawing on the Theory of Planned Behaviour and the Technology Acceptance Model, binary logistic regression analysis of 182 household survey responses identified seven statistically significant predictors of adoption intention. The study's contribution lies in providing the first systematic empirical evidence of adoption intention determinants in the specific context of Malawi's net metering framework, demonstrating that this policy context introduces structural barriers, particularly the landlord-tenant investment problem and regulatory uncertainty, that are not typically prominent in conventional off-grid solar PV adoption studies.

House ownership emerged as the most powerful predictor (OR = 4.1371), reflecting the structural barrier that rental housing presents to PV investment under a net metering framework. Economic perception (OR = 2.9447) and environmental perception (OR = 2.0330) were the most influential attitudinal predictors, confirming that households respond primarily to perceived financial utility and environmental values. Household size (OR = 1.9542) and electricity expenditure (OR = 1.6989) both showed positive associations, reinforcing that higher energy demand and expenditure motivate adoption intention. Gender showed a negative association for male-headed households (OR = 0.4771), indicating that female household heads are relatively more inclined to express adoption intention. Education showed a negative association for tertiary-educated respondents (OR = 0.4449); the mechanism underlying this counterintuitive finding remains uncertain and warrants further investigation.

These findings indicate that the success of Malawi's net metering policy will depend not only on awareness of the programme but also on addressing structural and financial barriers to adoption. Policies that facilitate access to financing, incentivise property owners to invest in solar PV for rental properties, and align tariff structures with investment returns will be critical in accelerating uptake. Without such targeted interventions, adoption may remain limited despite favourable policy conditions.

Future research should extend this framework to other urban centres in Malawi, employ validated multi-item measurement instruments for perceptual variables, incorporate direct measures of financial risk tolerance and regulatory awareness, and monitor adoption patterns longitudinally following the full implementation of established net metering rules.

Author Contribution

Lottie Singini: Conceptualisation, data collection, formal analysis, and writing the original draft. Chikumbusko Kaonga and Christabel Kambala: Supervision, methodology review, writing review, and editing.

All authors approved the final version.

Funding

This research received no external funding.

Data Availability

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

Ethics Statement

This study involved human participants. Informed consent was obtained from all respondents before questionnaire administration. Participation was voluntary and anonymised. The study was conducted in accordance with relevant institutional ethical guidelines. Before data collection, ethical clearance was obtained from the Mzuzu University Research Ethics Committee (Ref. No. MZUNIREC/DOR/23/53).

References

[1] Q. Hassan et al., "The role of renewable energy in the global energy transformation," Renewable Energy

Focus, vol. 48, Art. no. 100545, 2024, doi: 10.1016/j.ref.2024.100545.

[2] A. Kowalska-Pyzalska, "Introduction to innovative energy services (IES) in transitioning energy markets", in Diffusion of Innovative Energy Services. Cambridge, MA, USA: Academic Press, 2024, pp. 1-19, doi: 10.1016/B978-0-12-822882-1.00007-X.

[3] X. Zeng, M. Gómez, V. Fthenakis, M. Jacobson, and J. Li, "Global Solar Energy Transition and End-of-Life PV Forecasts Through 2050," Research Square, Jul. 2025. doi: 10.21203/rs.3.rs-7042450/v1.

[4] A. Lawson, Net Metering: In Brief. Washington, DC, USA: Congressional Research Service, 2019. [Online]. Available: https://www.crs.gov

[5] E. Tratnik and M. Beković, "Empowering active users: A case study with economic analysis of the electric energy cost calculation post-net-metering abolition in Slovenia," Energies, vol. 17, no. 6, Art. no. 1501, 2024, doi: 10.3390/en17061501.

[6] I. Sajjad, M. Manganelli, L. Martirano, R. Napoli, G. Chicco, and G. Parise, "Net-metering benefits for residential customers: The economic advantages of a proposed user-centric model in Italy", IEEE Industry Applications Magazine, vol. 24, no. 4, pp. 39-49, Jul./Aug. 2018. doi: 10.1109/MIAS.2017.2740459.

[7] International Renewable Energy Agency (IRENA), Africa 2030: Roadmap for a Renewable Energy Future. Abu Dhabi, United Arab Emirates: International Renewable Energy Agency, 2015. [Online]. Available: https://www.irena.org/remap

[8] H. B. Chamdimba, W. Langa, A. Nyirenda, R. T. Dama, and J. Taulo, "Transitioning beyond basic energy access: Opportunities and constraints for renewable energy-driven productive use in Malawi," Renewable Energies, vol. 4, no. 1, 2026, doi: 10.1177/27533735261431075.

[9] Malawi Energy Regulatory Authority (MERA), Net Metering Rules. Lilongwe, Malawi: Malawi Energy Regulatory Authority, 2025. [Online]. Available: https://mera.mw/other-tools/ (Accessed: Jan. 10, 2026).

[10] M. A. Beatrice and K. Jiang, "Assessing factors influencing solar energy adoption among small and medium enterprises in Mzuzu City, Malawi," Energy and Power Engineering, vol. 16, no. 7, pp. 257-284, 2024, doi: 10.4236/epe.2024.167012.

[11] C. Lindsey, Determinants of Solar Panel Adoption, Disadoption and Use in Malawi. Master's thesis, School for Environment and Sustainability, University of Michigan, Ann Arbor, MI, USA, 2022.

[12] D. Etongo and H. Naidu, "Determinants of household adoption of solar energy technology in Seychelles in a context of 100% access to electricity," Discover Sustainability, vol. 3, no. 1, 2022, doi: 10.1007/s43621-022-00108-4.

[13] F. D. Davis, "Perceived usefulness, perceived ease of use, and user acceptance of information technology," MIS Quarterly, vol. 13, no. 3, pp. 319-340, Sep. 1989, doi: 10.2307/249008.

[14] I. Ajzen, "The theory of planned behaviour", Organisational Behaviour and Human Decision Processes, vol. 50, no. 2, pp. 179-211, 1991, doi: 10.1016/0749-5978(91)90020-T.

[15] R. Sala, S. Germán, M. C. Alonso-García, F. García-Rosillo, and J.-B. Navarro, "What does it matter? Analysing the role of attitudes in the adoption of solar photovoltaic technology in Spain," Heliyon, vol. 11, no. 16, Art. no. e44167, 2025, doi: 10.1016/j.heliyon.2025.e44167.

[16] W. Cheam, L. Lau, and C. Wei, "Factors influencing residents' intention to adopt solar photovoltaic technology: A case study from Klang Valley, Malaysia," Clean Energy, vol. 5, no. 3, pp. 464-473, Sep. 2021, doi: 10.1093/ce/zkab021.

[17] P. Peduzzi, J. Concato, E. Kemper, T. R. Holford, and A. R. Feinstein, "A simulation study of the number of events per variable in logistic regression analysis," Journal of Clinical Epidemiology, vol. 49, no. 12, pp. 1373-1379, Dec. 1996, doi: 10.1016/S0895-4356(96)00236-3.

[18] E. Vittinghoff and C. E. McCulloch, "Relaxing the rule of ten events per variable in logistic and Cox regression," American Journal of Epidemiology, vol. 165, no. 6, pp. 710-718, Mar. 2007, doi: 10.1093/aje/kwk052.

[19] M. Ahmar, F. Ali, Y. Jiang, Y. Wang, and K. Iqbal, "Determinants of adoption and the type of solar PV technology adopted in rural Pakistan," Frontiers in Environmental Science, vol. 10, Art. no. 895622, 2022, doi: 10.3389/fenvs.2022.895622.

[20] D. D. Guta, "Determinants of household adoption of solar energy technology in rural Ethiopia," Journal of Cleaner Production, vol. 204, pp. 193-204, 2018, doi: 10.1016/j.jclepro.2018.09.016.

[21] S. R. Shakeel, H. Yousaf, M. Irfan, and A. Rajala, "Solar PV adoption at household level: Insights based on a systematic literature review," Energy Strategy Reviews, vol. 48, Art. no. 101178, 2023, doi: 10.1016/j.esr.2023.101178.

[22] G. Huebner, D. Shipworth, I. Hamilton, Z. Chalabi, and T. Oreszczyn, "Understanding electricity consumption: A comparative contribution of building factors, socio-demographics, appliances, behaviours and attitudes," Applied Energy, vol. 177,

pp. 692-702, 2016, doi: 10.1016/j.apenergy.2016.04.075.
[23] N. Mohandes, A. Sanfilippo, and M. Al Fakhri, "Modelling residential adoption of solar energy in the Arabian Gulf region," Renewable Energy, vol. 131, pp. 381-389, 2019, doi: 10.1016/j.renene.2018.07.048.
[24] F. Cucchiella, I. D'Adamo, M. Gastaldi, and V. Stornelli, "Solar photovoltaic panels combined with energy storage in a residential building: An economic analysis," Sustainability, vol. 10, no. 9, Art. no. 3117, 2018, doi: 10.3390/su10093117.
[25] M. Alipour, H. Salim, R. A. Stewart, and O. Sahin, "Residential solar photovoltaic adoption behaviour: End-to-end review of theories, methods and approaches," Renewable Energy, vol. 170, pp. 471-486, 2021, doi: 10.1016/j.renene.2021.01.128.
[26] N. S. N. A. Aziz, N. A. Wahid, M. A. Sallam, and S. K. Ariffin, "Factors influencing Malaysian consumers' intention to purchase green energy: The case of solar panel," Global Business and Management Research, Special Issue, vol. 9, no. 4s, pp. 328-346, 2017.