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Influence of Household Awareness and Perceived Behavioural Control on the Adoption of Alternative Cooking Energies in Tanzania

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Abstract

The current study examined the influence of household awareness and perceived behavioural control on the adoption of alternative clean cooking energy. Drawing on the Theory of Planned Behavior and the Energy Ladder concept, the study explains how households make decisions regarding energy use. A quantitative cross-sectional research design was used. Data were collected from 400 households using a closed-ended structured questionnaire. Structural equation modelling (SEM) was applied to analyse the relationships among awareness, perceived behavioural control and adoption intention. The findings indicate that household's awareness has a strong and positive influence on adoption intentions. In particular, households with better understanding of the health, environmental, cost, and availability benefits of cleaner cooking options are more inclined to consider their use. Perceived behavioural control was also found to have a positive and statistically significant effect, suggesting that households who feel capable of accessing, affording, and using alternative cooking technologies are more likely to adopt them. The results further reveal a complementary relationship between awareness and perceived behavioural control. Access to clear and reliable information appears to enhance households' confidence in changing their cooking practices. At the same time, households that feel more capable in terms of affordability and accessibility tend to actively seek additional information about cleaner energy options. Empirically, the findings contribute to previous works on household cooking energy transition in developing countries by determining the effects of awareness and behavioural control. Results indicate that policy efforts should combine campaigns with practical support mechanisms. This may include subsidies, flexible financing alternatives, and technical assistance to promote the wider use of cleaner cooking energy at the household level.

Keywords: Alternative Cooking Energy, Awareness, Perceived Behavioral Control, Household

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Introduction

The transition from traditional to alternative clean cooking energies has drawn increasing global attention due to its implications for environmental protection, public health, and household welfare (Mperejekumana et al., 2024). Despite growing accessibility of cleaner cooking alternatives, many households continue to rely heavily on traditional biomass fuels. Firewood and charcoal remain dominant cooking energy sources despite their established links to deforestation, indoor air pollution, and health complications (Sanmathi, 2022). While alternatives such as liquefied petroleum gas (LPG), electricity, briquettes, and biogas are being promoted, adoption remains uneven, shaped by factors including awareness, income levels, cultural preferences, and perceptions of affordability (Rasimphi et al., 2024).

The persistent use of solid cooking fuels poses serious health risks, with the World Health Organization attributing over four million annual deaths worldwide to indoor air pollution (WHO, 2024; Roche et al., 2024). Despite increasing public awareness of these health consequences, transition toward cleaner cooking energies remains sluggish, particularly in developing regions. In many African countries, biomass fuels serve as the primary cooking energy source for over 80% of households, driven by high initial costs of cleaner options, unreliable fuel availability, inadequate distribution systems, and limited information dissemination (Mperejekumana et al., 2024; Timilsina & Malla, 2021).

Tanzania reflects these broader regional patterns. Traditional biomass dominates cooking practices, with firewood accounting for approximately 66.5% of household energy use and charcoal contributing about 24.6%, while only a small proportion depend on modern clean energy sources (Mhagama & Heriel, 2023). Government initiatives to promote cleaner cooking technologies have achieved modest adoption progress, with limited awareness of available alternatives, affordability concerns, and accessibility issues continuing to shape household decisions (EWURA, 2023).

Existing literature on clean cooking transitions has predominantly focused on structural and macro-level determinants including economic growth, market accessibility, energy efficiency, and financial development (Bharadwaj et al., 2022; Murshed, 2022; Jewitt et al., 2022; Ocen et al., 2024). However, less attention has been directed toward behavioural factors at the household level, particularly awareness and perceived behavioural control. Empirical evidence on these behavioural dimensions remains limited in the Tanzanian context, where social, cultural, and economic conditions vary considerably across regions.

This study examines how household awareness and perceived behavioural control influence the adoption of alternative cooking energy in Tanzania, specifically investigating whether understanding health, environmental, and economic benefits of cleaner fuels, along with households' perceived ability to access

and afford them, influences the transition away from traditional biomass. Findings aim to inform policy initiatives for increasing clean cooking energy use and advancing Tanzania's progress toward Sustainable Development Goals 7 (Affordable and Clean Energy) and 13 (Climate Action).

The pattern of alternative clean cooking energy use in Tanzania differs between rural and urban areas, with firewood predominantly used in rural settings and charcoal more common in urban areas (Barzehkar, 2024; Olowolayemo, 2023). Nyamoga et al. (2022) noted that charcoal serves as the primary cooking fuel for over 80% of households in both urban and peri-urban areas. Data from the Impact of Access to Sustainable Energy Survey (2021/22) confirm that approximately 67% of households in Mainland Tanzania rely on firewood, while nearly 25% depend on charcoal, with reliance more pronounced in rural areas where approximately 88% use firewood compared to about 30% in urban areas.

Recent National Bureau of Statistics data indicate that around 60.5% of households use firewood and charcoal as their primary cooking sources (NBS, 2023). In response, the government has introduced the National Clean Cooking Strategy to support transition to cleaner and more efficient cooking options. Despite this reliance on biomass, notable changes are occurring, with clean energy adoption, particularly LPG, increasing mainly in urban areas where nearly 20% of households depend on LPG for cooking (EWURA, 2023). World Bank data show that households using clean cooking energies increased from 1.5% in 2010 to 6.9% in 2021, though remaining far below the global average of 71% (World Bank, 2023). LPG consumption has grown exponentially from 5,000 metric tons in 2005 to 293,167 metric tons by June 2023 (EWURA, 2023).

Fuel stacking where households use multiple cooking fuels alternately represents a notable factor slowing the shift to cleaner energies, with households alternating between biomass and modern energies based on cost, availability, and meal type (Aamaas et al., 2024). Even where LPG is available, charcoal and firewood often persist due to traditional cooking habits, safety concerns, and limited knowledge of cleaner fuel advantages (Ishengoma & Igangula, 2021). The energy ladder theory suggests rising income levels catalyze movement from traditional toward cleaner cooking fuels, though this shift tends to be non-linear, with safety concerns, limited access to trusted information, and supply uncertainty discouraging full transitions (Ishengoma & Igangula, 2021). These concerns underscore the importance of awareness and perceived ability in shaping energy decisions, providing the foundation for this examination of behavioural factors influencing alternative clean cooking energy adoption in Tanzania.

Literature Review

Theory of Planned Behavior

The Theory of Planned Behavior (TPB), pioneered by Ajzen (1991), explains behaviour as a function of intention influenced by attitudes, subjective norms, and perceived behavioural control. This framework is applicable to this study because the decision to adopt alternative cooking energy involves informed judgement, access to resources, and readiness to depart from established practices. Household awareness contributes to attitude formation, as informed households about health, environmental, and economic effects of traditional fuels are more likely to view cleaner alternatives positively (Okereke et al., 2023).

Awareness also highlights risks like indoor air pollution and deforestation, supporting favourable evaluations of modern energy sources. While subjective norms are included in the TPB model, evidence from rural and peri-urban settings suggests cooking energy decisions are often made within households, with limited external social pressure (Zandamela & Kim, 2024). Consequently, greater weight is given to perceived behavioural control, which reflects how households evaluate affordability, access, ease of use, and technical support availability conditions influencing both intention and actual behaviour. Furthermore, awareness reinforces perceived behavioural control; when households understand available technologies, costs, maintenance needs, and supply conditions, they are better positioned to make informed decisions. This sense of readiness increases both the probability of intending to adopt and the chances of actual use.

Energy Ladder Theory

From the Energy Ladder Theory perspective, households move from traditional fuels to cleaner and more efficient energy sources as income, education, and access to services improve (Hosier & Dowd, 1987; Leach, 1992; Smith & Smith, 1987; Van der Kroon et al., 2013). In Tanzania perspective, many households still depend on biomass fuels such as firewoods and charcoal due to financial constraints and limited access to modern energy.Based on this situation, households usually begin with basic fuels like firewoods and charcoal and shift towards cleaner cooking options such as LPG, briquettes, pellets, or electricity as their financial condition improve. However, this shift does not always follow a linear path. Many households combine multiple fuels, using both traditional and modern clean energy sources depending on cost, availability, and cooking needs. This pattern shows that income alone does not guarantee a complete transition. Based on this scenario, awareness becomes very important. Understanding the health and efficiency shortcomings of traditional cooking fuels can encourage transition towards cleaner alternatives. At the same time, awareness of potential cost savings and health benefits may motivate adoption even where income growth is modest.

Generally, the Energy Ladder Theory complements the Theory of Planned Behavior by linking structural

conditions with behavioural readiness. Collectively, these contexts provide a basis for examining both the decision-making process and the socio-economic factors involved in adopting alternative cooking energy sources.

Empirical Review and Hypotheses Development

The persistent reliance on traditional cooking fuels remains widespread in developing countries, as access to cleaner alternatives alone does not guarantee complete transition (Alananga, 2024; Ibe & Kollur, 2024). Many households adopt a mixed energy pattern, sustaining biomass use alongside modern fuels due to income constraints, cultural practices, and familiarity with traditional methods (Alananga, 2024; Ibe & Kollur, 2024). Ndunguru (2024) reports that continued biomass use contributes to environmental degradation, highlighting the importance of household awareness and behavioural attitudes. Using the Push–Pull–Mooring model, Emmanuel and Say (2024) found that perceived advantages of modern fuels particularly affordability and accessibility exert stronger effects on switching intentions than dissatisfaction with traditional fuels alone, with social norms and habits either facilitating or hindering transitions. Zandamela and Kim (2024) similarly argue that energy decisions reflect social influence and household perceptions rather than technology availability alone. Collectively, these findings indicate that successful energy transitions depend not merely on economic conditions but critically on awareness and behavioural considerations that shape household choices

Households' awareness and adoption of alternative cooking energies

Household awareness is commonly examined in studies of energy behaviour. Gajdzik et al. (2024) argue that households with stronger financial awareness are more likely to adopt energy-saving practices. While their study focused on electricity use in Poland, it indicates a broader tendency. When households are aware of tariffs, consumption patterns, and efficiency, they are better positioned to make informed energy choices. In the case of clean cooking energies, such awareness influences how households evaluate costs, health risks, and environmental implications related to different fuel options.

Findings from developing countries suggest that awareness on its own does not always result in adoption. Bappah et al. (2024) observe that firewoods and charcoal remain widely used because they are affordable and readily available. At the same time, exposure to reliable information through media, non-governmental organisations, and schools tends to increase interest in alternative cooking fuels. A similar pattern was found by Rasel et al. (2024) in rural Bangladesh, where reliance on solid cooking fuels is linked to respiratory and cardiovascular conditions. In spite of this, many households continue to depend on such fuels due to financial constraints. This reflects a gap between what households know and what they are able to do in practice.

Moreover, empirical results from Sub-Saharan Africa indicate that both knowledge and economic conditions shape household cooking energy decisions. Little understanding of health and environmental consequences can delay change, while high costs and unreliable supply systems hamper adoption even where awareness exists. Combined, these studies reveal that awareness can encourage households to reevaluate traditional cooking practices, but a transition to cleaner energy depends on their capacity to act on that knowledge. On this basis, the study proposes the following hypothesis:

H1: Households' awareness positively influences the adoption of alternative cooking energies.

Perceived Behavioral Control and the adoption of alternative cooking energies

Perceived behavioural control is another factor that influences household energy adoption decisions. Anchored on the Theory of Planned Behavior, Zandamela and Kim (2024) examined clean energy use in Maputo, Mozambique. Their conclusions displayed that perceived behavioural control influences both intention and actual behaviour. Households are more inclined to adopt clean clean energy when they believe they have the resources and ability required. These findings support the view advanced by Ajzen (1991) that individuals are more likely to act when they feel capable of performing a given behaviour.

Related studies point to similar constraints. Alananga (2024) and Ibe and Kollur (2024) link low adoption of clean cooking energy with income limitations, entrenched cultural practices, and continued dependence on traditional cooking energies. These conditions sometimes weaken confidence in switching to modern energy, even where alternatives are available. In this setting, affordability, access, and ease of use become key in shaping whether households consider cleaner fuels a practical option.

Overall, the literature suggests a consistent pattern: when households feel able to afford, obtain, and use cleaner cooking energies, adoption is more likely. Awareness and perceived behavioural control therefore operate together in shaping household decisions. Based on this reasoning, the study proposes the following hypothesis:

H2: Perceived Behavioral Control positively influences the adoption of alternative cooking energies.

Conceptual Framework

Figure 1 displays the conceptual framework for this study. It is informed by the Theory of Planned Behavior, the Energy Ladder Theory, and insights from prior empirical studies. In this framework, household awareness and perceived behavioural control are considered as the key independent variables, each expected to exert a direct influence on the adoption of alternative cooking energy.

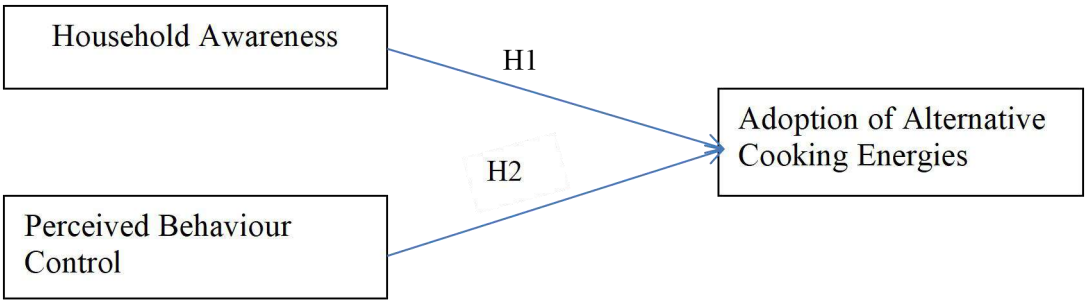


Figure 1: Conceptual framework: Source: Synthesized from literature Review (2025)

Methodology

Research design and procedures

The current study adopted a quantitative approach and a cross-sectional research design, which is appropriate for examining relationships among latent variables and testing theory-driven hypotheses at a specific point in time. This design offered a clear and efficient snapshot of how particular constructs are related in the study context, allowing for strong analysis of patterns and relationships. While the data reflect conditions at a single stage, the approach provides understanding on the dynamics between variables and supports, theory-informed interpretation of the findings.

The analysis was focused on the relationship between household awareness, perceived behavioural control, and the adoption of cleaner cooking energy sources, including solar energy, liquefied petroleum gas (LPG), and biogas. Household awareness was kept as the primary independent variable and measured across several dimensions informed by earlier studies. These included awareness of health risks associated with traditional fuels, understanding of environmental effects, knowledge of cost implications, and familiarity with the availability of cleaner cooking energy options in the local context.

On the other hand, Perceived behavioural control was introduced to capture how households consider their ability to afford, access and use alternative clean energy technologies, in line with the Theory of Planned Behaviour. The dependent variable, adoption of alternative cooking energies, comprised both intention and actual use of cleaner cooking energy options (Ajzen, 2020; Li et al., 2023;). Data collection and analysis followed systematic procedures to ensure consistency and to support testing of the hypothesized relationships.

Data and sample

The study population comprised 2,092,985 households in Dar es Salaam and Pwani Regions, selected due to their large populations, diverse socio-economic conditions, and the coexistence of traditional and modern cooking energy sources. According to the 2022 Population and Housing Census, Dar es Salaam accounted for 1,550,066 households, while Pwani had 542,919, providing a suitable context for examining household energy choices. Simple random sampling was employed to give each household an equal chance of inclusion, reducing selection bias and supporting broader generalisation of findings. Sample size determination followed best practices for Structural Equation Modelling (SEM), which requires at least ten observations per estimated path to ensure stable and reliable estimates. Based on this guideline, the study targeted 400 households to satisfy SEM requirements while allowing for potential non-response.

A total of 397 completed questionnaires were returned, yielding a 99.25% response rate. This high participation was achieved through hand delivery of questionnaires, clear explanation of the study's purpose, and follow-up where necessary. To assess non-response bias, early and late responses were compared, with no notable differences observed in key characteristics, indicating minimal bias. The final sample was adequate for analysis using SmartPLS 4. Additionally, a power analysis conducted with G*Power confirmed that the sample size was adequate to detect medium effect sizes at the 0.05 level of significance. The achieved sample of 397 households thus provided sufficient statistical power for the SEM analysis, ensuring that the study's findings on household awareness and perceived behavioural control in relation to alternative cooking energy adoption would be reliable and generalisable within the study context.

Data Screening and Preliminary Analysis

Prior to the main analysis, the dataset was reviewed to identify missing values and assess general distribution patterns. Only a small proportion of responses was missing and thee were replaced using linear interpolation to retain a complete dataset. This approach was appropriate given the ordinal nature of the Likert scales items, and the low level of missing data.

The distribution of data was also assessed. Although few variables showed minor departure from normality, this did not affect the analysis method. The study deployed Partial Least Squares Structural Equation Modelling (PLS-SEM) was used, which does not require strict normality and is particularly well suited for models with latent variables. As the data were collected using a single self-report questionnaire, the possibility of common method bias was taken into account. To minimise this risk, the questionnaire was organised so that independent and dependent variables appeared in separate sections, and respondents were assured that their answers would remain anonymous. Additionally, the use of PLS-SEM which is generally less sensitive to common method variance compared with covariance-based SEM, provided an added mitigation. These measures together helped ensure the reliability of the findings.

Research Instrument

Research data were collected using a structured, closed-ended questionnaire designed to capture household awareness, perceived behavioural control, and adoption of alternative cooking energy. The measurement items were drawn from established scales used in previous studies and were adjusted to reflect local cooking practices and energy options in Tanzania. Responses were measured on a seven-point Likert scale, ranging from 1, strongly disagree, to 7, strongly agree (Rezaei & Ghofranfarid, 2018). This format provided a sufficient range to capture variations respondent's views, enhancing measurement sensitivity. The development of the Instrument followed the standard procedures outlined by Churchill and Iacobucci (2004), including defining constructs, generating items, evaluating content validity, and refining the scale. These steps ensured consistency, clarity, and reliability in measurement.

Techniques of Data Analysis

After completion of data collection, all responses were coded and entered into SPSS Version 27 software for preliminary screening. The data were then checked for entry errors, cleaning involved checking for entry errors, missing values, and outliers. Missing values were few and showed no clear pattern indicating that they were randomly distributed. Linear interpolation was applied, following Hair et al. (2010). Box plots showed no extreme outliers. The main analysis used PLS-SEM in SmartPLS Version 4. This method allowed the examination of relationships between latent variables and supported prediction of outcomes. Both the measurement model and the structural model were assessed, with attention to reliability, validity, and hypothesis testing.

Outer Model

The outer model tested the relationship between each indicator and its associated latent variable. In the PLS model, two types of outer measurements exist: reflective and formative indicators. According to Hair et al. (2022), reflective indicators were assessed for convergent validity and internal consistency. Convergent validity was measured using the factor loading, which should exceed 0.7. Discriminant validity was evaluated using the Average Variance Extracted (AVE), with a value greater than 0.5 considered acceptable. Construct reliability was checked by means of Cronbach's alpha and composite reliability, all of which exceeded 0.7. Formative indicators were assessed for multicollinearity using the Variance Inflation Factor (VIF). A VIF value below 5 indicated no multicollinearity. If multicollinearity was detected, indicators with high VIF could be removed (Hair et al., 2014). In this study, all constructs were measured using reflective indicators. Thus, the assessment followed the reflective measurement model criteria.

Inner Model

The inner model tested the relationships between latent constructs. Before assessing the significance of the relationships, multicollinearity in the structural model was checked. VIF values below 5 indicated no multicollinearity (Hair et al., 2022). The extent to which the model explains the outcome was measured using the Variance explained, R^2 (Duryadi, 2021). R^2 values of 0.19, 0.33, and 0.67 were interpreted as weak, moderate, and strong explanatory power, respectively. These benchmarks were used to assess how well household awareness and perceived behavioural control explained the adoption of alternative cooking energies.

Hypothesis Testing

Hypothesis testing was conducted using path coefficients and significance levels generated in Smart PLS4 through bootstrapping procedures in PLS-SEM. All hypotheses were tested at a 5 percent significance level. A hypothesis was accepted if the path coefficient was positive and the p-value was less than 0.05. Conversely, hypotheses with negative path coefficients or p-values greater than 0.05 were rejected. This approach ensures objective and statistically valid decision-making.

Ethical Consideration

Ethical principles were followed throughout the study. Participation was voluntary. Respondents were briefed of the study's objectives before data gathering. Informed consent was obtained from all participants. Responses were anonymised, and data access was restricted to the researcher. No personal identifiable data was collected. All data were used only for academic purposes, in line with standard research ethics.

Empirical Results

Instrument Validity and Demographic Characteristics

Instrument validity was established as questionnaire items were adapted from previously validated scales tested in prior empirical research, demonstrating acceptable validity and reliability. Reliability and validity tests performed using study data confirmed all item–total correlations exceeded 0.30, while Cronbach's alpha and composite reliability values for all constructs were above 0.70, confirming measurement items were valid and reliable for analysis.

Table 1 summarises household head characteristics by gender, age, and education. The sample is fairly distributed across these groups, offering broad perspectives on energy adoption. Most households fall in middle-income and medium-size categories, reflecting common economic and living conditions shaping energy choices. Differences in household awareness and perceived behavioural control indicate varying levels of readiness to adopt alternative cooking energy, providing a basis for further analysis of how these factors relate to adoption behaviour.

Table 1: Demographic Characteristics of Respondents (n = 397)

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender of Household Head	Female	238	59.9
	Male	159	40.1
Age of Household Head (Years)	18–30	74	18.6
	31–40	121	30.5
	41–50	104	26.2
	Above 50	98	24.7
Education Level	No formal education	42	10.6
	Primary education	146	36.8
	Secondary education	132	33.2
	Tertiary education	77	19.4
Monthly Household Income (TZS)	Below 300,000	128	32.2
	300,001–600,000	149	37.5
	600,001–1,000,000	83	20.9
	Above 1,000,000	37	9.3
Household Size	1–3 members	96	24.2
	4–6 members	201	50.6
	Above 6 members	100	25.2
Primary Cooking Energy Used	Firewood	164	41.3
	Charcoal	154	38.8
	LPG	61	15.4
	Electricity / Other	18	4.5
Awareness of Alternative Cooking Energies	Low	103	25.9
	Moderate	179	45.1
	High	115	29
Perceived Behavioral Control	Low	112	28.2
	Moderate	167	42.1
	High	118	29.7

Source: Field data (2024)

Assessment of measurement (Outer) Model

Factor Loading

In reflective measurement models, outer loadings indicate how strongly each indicator relates to its underlying latent construct. These relationships are typically represented by arrows from the construct to the observed items. The outer model was evaluated to determine how well each construct was captured by its indicators. The indicators with loadings below 0.50 were treated as weak and were removed, as they did not adequately represent the intended construct (Hair et al., 2017). Higher loadings suggest a closer alignment with the underlying construct, supporting convergent validity and ensuring the consistency of the instrument.

Table 2 reports the indicator loadings estimated using Partial Least Squares (PLS). All items showed strong links with their respective constructs. The loadings ranged from 0.614 to 0.882, which are above the commended threshold of 0.50 (Henseler & Chin, 2010; Hair et al., 2013). These results show that the items are suitable for measuring the constructs and can be retained for the next stage of analysis.

Table 2: Factor loading

Construct	Indicator	Statements	Loadings
AACE	AACE1	I plan to switch to an alternative cooking energy within few days	0.855
	AACE2	I intend to rely on alternative fuels (LPG, biogas, ethanol) as my primary cooking method.	0.614
	AACE3	I will encourage friends or neighbors to adopt clean cookstoves.	0.884
	AACE4	I would participate in a community program promoting alternative cooking energy.	0.686
	AACE5	I am willing to allocate part of my household budget toward purchasing a clean cookstove	0.858
	AACE6	I have discussed the possibility of switching fuels with other household members.	0.796
PBC	PBC1	I feel confident in my ability to switch to alternative cooking energy sources.	0.836
	PBC2	I believe I have the resources (financial, time, etc.) to adopt alternative cooking energy sources.	0.855
	PBC3	Local services centers are readily available if I need after sales support.	0.843
	PBC4	I can handle minor maintenance on an alternative stove without outside help.	0.736
	PBC5	I am capable of learning how to use alternative cooking energy technologies.	0.795
	PBC6	I feel that adopting alternative cooking energy sources is not too complicated for me.	0.819
	PBC7	Accessing a steady supply of alternative fuel in my locality is easy.	0.793
HA	HA1	I am awareness that using wood or charcoal for cooking poses serious health risks to the family	0.614
	HA2	I understand the environmental damage caused by deforestation and smoke emissions.	0.711
	HA3	I know that switching to alternative fuels (LPG, biogas, ethanol) can lower monthly cooking costs.	0.712
	HA4	I know where to find reliable, information on alternative cooking technologies	0.820
	HA5	I I am aware of the different types of alternative cooking energies	0.779
	HA6	I am informed of the differences in price various cooking energy sources.	0.706

Source: Research data (2024)

Notes: *PBC: Perceived Behavioral Control; HA: Households' awareness; Adoption of Alternative Cooking Energy (AACE)*

Adoption of Alternative Cooking Energy (AACE)

Table 2 shows how the indicators for Adoption of Alternative Cooking Energy (AACE) performed. AACE1, AACE3, and AACE5 recorded the highest loadings. These items relate to personal commitment, social influence, and financial readiness. Households that agreed with these statements were more likely to intend to adopt alternative cooking energy.

AACE2 and AACE4 had lower loadings. This points to differences in how households view reliance on traditional fuels and their level of community involvement. AACE6 reflects household discussion, which suggests that conversations among family members can shape adoption decisions. Taken together, the results support the reflective structure of the AACE construct. They also point to possible groupings linked to personal, social, and participatory aspects. This may help refine future measurement and policy efforts.

Perceived Behavioural Control (PBC)

Perceived Behavioural Control formed a consistent construct, with all items meeting the required threshold. PBC2 and PBC3 had the highest loadings. These items relate to financial capacity, time, and access to support. PBC4, which refers to the ability to manage or maintain technology, had a slightly lower loading. It still adds value by capturing practical confidence in using energy systems. The pattern shows that both personal ability and external support shape households' readiness to adopt cleaner cooking energy. The consistency across items suggests that no indicators need to be removed. Future work may examine whether these factors vary across different groups.

Household Awareness (HA)

From the results, Household Awareness (HA) varied across the individual items. Items HA1 and HA2, which addressed health and environmental risks, showed moderate loadings. HA4 and HA5, which captured practical knowledge and access to information, recorded stronger loadings. HA3, which focuses on cost savings, also had a moderate loading, suggesting that connecting environmental concerns with economic benefits can make the message more relevant to households. HA6, which describes awareness of price differences, highlights the importance of providing clear and practical information. Overall, these results indicate that awareness is not uniform; information that is specific and applicable to daily decision-making appears more effective than general messages about risk.

Validity and reliability

In Table 3, reports on reliability and validity values for each construct are displayed, including Cronbach's alpha, rho_A, composite reliability (rho_C), and AVE. Cronbach's alpha values were from 0.820 to 0.913, indicating strong internal consistency and confirming that the items effectively capture the same underlying concept. Rho_A values were similarly high, ranging from 0.839 to 0.917, further supporting the reliability of the constructs. Composite reliability (rho_C), which accounts for both internal consistency and item correlations, ranged from 0.869 to 0.931, confirming the robustness of the constructs. AVE values ranged from 0.528 to 0.622, exceeding the recommended threshold of 0.50 indicating that each construct explains more than half of the variance in its indicators. Taken together, these outcomes demonstrate that the constructs were measured consistently and accurately, confirming that the measurement model is reliable and suitable for the next stage of structural analysis.

Table 3: Validity and Reliability of Constructs

Construct	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	AVE
AACE	0.878	0.913	0.907	0.622
PBC	0.913	0.917	0.931	0.659
HA	0.820	0.839	0.869	0.528

Source: Research data (2024)

Discriminant validity

Table 4 shows the outcomes of the discriminant validity assessment. Generally, the diagonal values (shown in bold) are higher than the correlations between constructs, showing that each construct is different from the others. This pattern demonstrates that items are more strongly related with their own construct than with other constructs, confirming that the measures capture separate concepts without significant overlap. These findings satisfy the Fornell and Larcker (1981) condition, which wants that the square root of the AVE for every construct exceeded its correlations with all other constructs.

Table 4: Discriminant validity: Fornell-Larcker criterion

Construct	AACE	PBC	HA
AACE	**0.788**		
PBC	0.512	**0.812**	
HA	0.611	0.597	**0.726**

Source: Research data (2024)

Measurement Model Diagnostics

Partial Least Squares Structural Equation Modelling (PLS-SEM) was employed. to examine the effects of Household Awareness (HA) and Perceived Behavioural Control (PBC) on the use of Alternative clean Cooking Energies (AACE). The guiding principle from Hair et al. (2017) was used to gauge the measurement model and ensured that each construct was measured accurately and consistently. Diagnostic tests assessed indicator reliability, internal consistency, convergent validity, and discriminant validity. These evaluations confirmed that the constructs were clearly defined and distinct, giving a concrete basis for subsequent analysis of the structural model (Table 5).

Table 5: Indicator Reliability and Multicollinearity

Construct	Indicator	Loading	Inner model – VIF
AACE	AACE1–AACE6	0.614–0.884	
PBC	PBC1–PBC7	0.736–0.855	1.554
HA	HA1–HA6	0.614–0.820	1.554

Source: Research data (2024)

Structural Model Results estimation

Figure. 1 shows the hypothesized/ predicted structural outcome for the current study variables. It shows the direct effect model as presented in Figure 1.

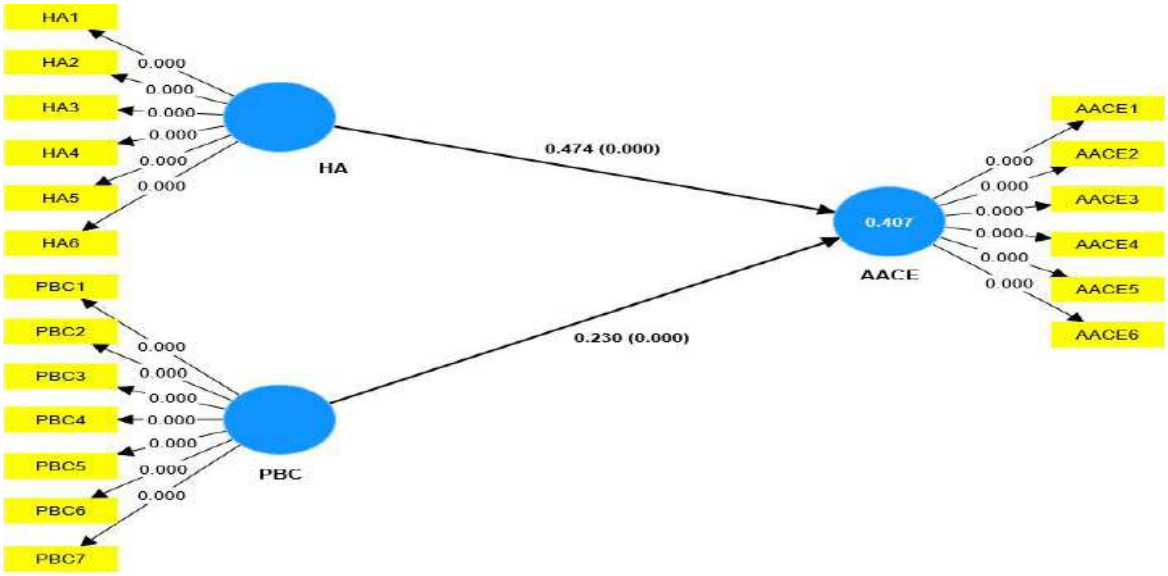


Figure 1: Hypothesized relationships

Both Figure 1 and Table 6 indicate the results of the SEM analysis. Household Awareness (HA) indicates a strong positive influence on the Adoption of Alternative Cooking Energy (AACE). The coefficient is positive and statistically significant, showing that households with better awareness of alternative energy sources are more likely to adopt cleaner cooking methods. These findings highlight the role of awareness initiatives in supporting sustainable household energy practices.

Similarly Perceived Behavioural Control (PBC) indicates a positive and significant effect on AACE. Households that perceive themselves as capable of affording, accessing, and using alternative energy technologies are more inclined to adopt cleaner cooking options. This suggests that interventions aimed at improving both confidence and accessibility can further support adoption.

Overall, these results are in line with prior studies. Kizilcec et al. (2022) argue that uptake of LPG, solar home systems, and electric cooking in Sub-Saharan Africa is influenced by household awareness, cost, and access. Likewise, Asante et al. (2022) reported that technical, economic, and social barriers affect renewable energy adoption in developing countries, while education and supportive policies can help overcome these challenges.

Table 6: SEM Estimation Results

Hypotheses	Path coefficient	Sample mean	Std deviation	T statistics	P values	f^2	R^2	Q^2
HA -> AACE	0.474	0.474	0.059	8.076	0.000	0.244	0.407	0.234
PBC -> AACE	0.230	0.232	0.056	4.116	0.000	0.057		

Source: Research data (2024)

On the other hand, the explained variance (coefficient of determination- R^2) shows the proportion of variance in a dependent variable explained by its predictors (Hair et al., 2017). As presented in Table 4, the R^2 for the Adoption of Alternative Cooking Energy (AACE) was 0.407. This indicates that Household Awareness (HA) and Perceived Behavioural Control (PBC) together explain 40.7% of the variation in adoption. Household awareness reflects the extent to which households understand alternative cooking energy options, whereas perceived behavioural control captures their perceived ability to overcome barriers such as cost, accessibility, and usability. These findings suggest that both increasing awareness and addressing practical constraints are crucial for supporting the adoption of cleaner cooking energies. The blindfolding procedure was used to gauge the model's predictive relevance to calculate Stone-Geisser's Q^2 (Geisser, 1974). A Q^2 value above zero indicates that the model can predict the outcome. In this study, the cross-validated redundancy method produced a Q^2 of 0.234 for AACE (Table 4), confirming that the model has predictive relevance for this outcome.

The effect size (f^2) measures the contribution of each predictor to explaining the dependent variable. Household awareness had an effect size of $f^2 = 0.244$, which is considered moderate (small = 0.02, moderate = 0.15, large = 0.35). This indicates that awareness makes a meaningful contribution to explaining adoption of alternative cooking energy. Perceived behavioural control had an effect size of $f^2 = 0.057$, which is small. Although statistically significant, it contributed less to the explained variance than awareness. This shows that awareness had a stronger influence on adoption decisions than perceived behavioural control.

Importance Performance Map Analysis

The Importance-Performance Map Analysis (IPMA) suggested by Martilla and James (1977) is meant to identify areas of priorities for intervention. For the current study (Figure 2), Household Awareness (HA) is positioned in Quadrant 2 ("possible overkill"), while Perceived Behavioural Control (PBC) falls in Quadrant 3 ("concentrate here"). HA's placement in Quadrant 2 shows that the current awareness efforts are performing well, but households consider it somewhat less critical for their adoption decisions. This suggests that additional investment in awareness campaigns may yield limited further behavioural change.

In contrast, PBC's location in Quadrant 3 highlights a key area for intervention. Households appreciate the importance of perceived control in adopting cleaner energy, but current support is not enough. Many are aware of alternative energy options but face financial, technical, or infrastructural barriers that limit their ability to act. Targeted interventions for example subsidies, improved access to energy infrastructure, and capacity-building initiatives should be prioritised to enhance households' perceived control and encourage a shift away from traditional fuels.

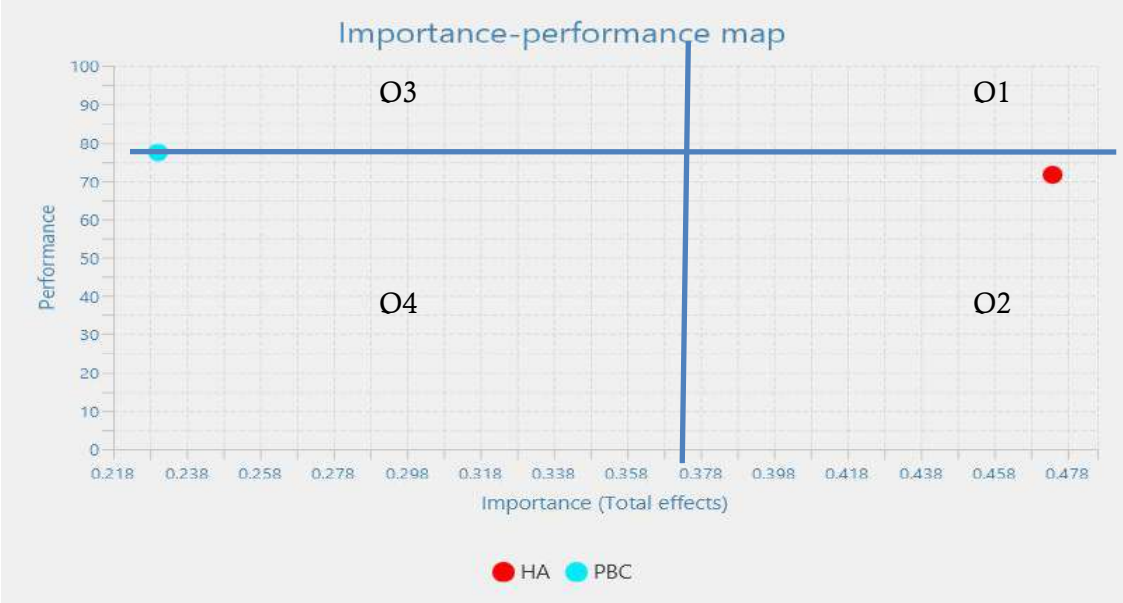


Figure 2: Importance performance map analysis graph

Discussions of Findings

The current study examined the influence of household awareness and perceived behavioural control on the adoption of alternative cooking energy in Tanzania. The results show that both factors have a positive effect on households' use of cleaner cooking technologies.Households with higher awareness of alternative cooking options were more likely to consider and adopt them. When households understood the health risks related with firewoods and charcoal and were familiar with alternatives such as LPG, solar energy, or biogas, they viewed these options more positively. Similar evidence was reported by Bappah et al. (2024), who revealed that media exposure and educational programs increased households' willingness to adopt alternative fuels. Rasel et al. (2024) also observed that households knowledgeable about the health impacts of solid fuels were more inclined to consider cleaner energy options.However, awareness by itself does not always result to adoption. Rasel et al. (2024) observed that households with low income or poor access to cleaner fuels often continue using traditional options despite being informed. Similarly, Alananga (2024) noted that knowledge of modern alternatives does not automatically translate into behaviour change. These findings suggest that while awareness can generate interest, practical barriers such as cost, availability, and convenience often slow the transition from traditional fuels.

Practically, Perceived behavioural control also plays a key role. Households are more likely to adopt alternative cooking energy when they feel capable of affording, accessing, and using these fuels. This is consistent with the Theory of Planned Behavior, which suggests that people act when they believe they have the resources and ability to do so. Zandamela and Kim (2024) reported similar results in Mozambique, where households confident in using modern fuels demonstrated stronger adoption intentions. Nevertheless, perceived ability alone may not be sufficient; cultural habits and long-standing cooking routines can limit adoption, as observed by Ibe and Kollur (2024). Traditional fuels remain widespread because they are familiar, readily available, and fit established household routines.

In Tanzania, both awareness and perceived ability shape household energy decisions. Many households still rely on charcoal and firewood because they are readily available and fit easily into daily routine. Raising public awareness about the health and environmental risks of traditional fuels can encourage consideration of alternatives. Simultaneously, improving the affordability and accessibility of cleaner fuels strengthens households' confidence to adopt them. Together, these factors support a gradual shift

toward cleaner cooking energy.

Conclusion, Limitation, and Recommendation for further studies

The outer loadings for perceived behavioural control indicate that access to financial resources, time, and after-sales support strongly influence households' intentions to adopt clean cooking technologies, aligning with the Theory of Planned Behavior by narrowing the gap between intention and action. Household Awareness findings revealed a varied pattern, with knowledge-based items showing higher loadings than risk-focused items, suggesting that actionable, localized knowledge motivates adoption more effectively than general awareness of risks. The interaction between awareness and perceived control is imperative, as practical information increases households' confidence while stronger control beliefs encourage information-seeking, making interventions combining information with support mechanisms most effective. Strategically, delivering information campaigns immediately before support programs may enhance outcomes. However, the study did not fully explore broader socio-economic conditions, cultural norms, and policy environments that may influence adoption. Future research should incorporate these dimensions using mixed-methods or longitudinal designs. Practically, interventions should be tailored to local conditions to support successful adoption of cleaner cooking energy.

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