Journal of Information Systems Engineering and Management
2025, 10(59s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Cooking Energy Transition in Nigeria: Adoption Rates and Influencing Factors of Clean Cooking Energy

Kashema Bahago[a], Benedict Akanegbu[b]
[a, b] *Department of Economics, Nile University of Nigeria, Plot 681, Cadastral Zone C, Jabi, Abuja, Nigeria*

ARTICLE INFO	ABSTRACT

Received: 29 Dec 2024
Revised: 15 Feb 2025
Accepted: 24 Feb 2025

This study examines the transition in cooking energy adoption rates and key determinants of clean cooking fuels in Nigeria, utilising general household survey (GHS) data collected over four waves from 2010 to 2019 by the National Bureau of Statistics (NBS): descriptive and summary statistics, ordinal logistic regression, and marginal effects analysis were deployed.

The findings indicate a positive, though limited, shift towards cleaner cooking fuels over the study period. Transitional fuels emerge as important interim options, helping to mitigate health and environmental risks while addressing economic and infrastructural challenges that hinder the direct adoption of clean energy. Key factors influencing the adoption of both transitional and clean fuels include gender, age, marital status, education, and informal savings. These variables are more strongly associated with the uptake of transitional fuels compared to traditional, unclean alternatives.

Keywords: Cooking Energy Transition; Cooking Fuels; Transitional Cooking Fuels; Energy Adoption; Air Pollution; Sustainable Development

1.0 Introduction

The study of household cooking energy transitions is crucial for evaluating the effectiveness of government and development partner interventions to reduce household dependence on traditional cooking fuels, such as charcoal, within specific periods. Three billion people in low- and lower-middle-income countries (LICs/LMICs) primarily depend on solid fuels for cooking; this trend is particularly prevalent in rural areas (Grabher et al., 2023; Aziz et al., 2022; Kumar & Igdalsky, 2019; Kumar et al., 2017). Household reliance on traditional cooking fuels poses significant health risks and contributes to environmental degradation. Previous studies estimate that traditional cooking methods contribute to over 3 million premature deaths annually (Li et al., 2024; Rybak & Pieśniewska, 2024; Qu et al., 2024; Neto-Bradley et al., 2020). In addition, economic constraints, gender and social dynamics, technological limitations, and infrastructural barriers further influence households' dependence on solid fuels for cooking.

The economic burden on households relying on traditional cooking fuels stems from the high costs of clean cooking fuels, placing financial strain on low-income families (Roy, 2024; Stritzke et al., 2023; Oyeniran & Isola, 2023; Ajayi, 2018). The time spent collecting firewood, particularly by women and children, limits their opportunities for education, income generation, and leisure, exacerbating time poverty (Parchure et al., 2024; Stoner et al., 2021; Aberilla et al., 2020). Gender and social challenges further perpetuate this dependence, as women and girls disproportionately bear the responsibility for collecting fuel and cooking, thereby restricting their economic and educational participation. Additionally, they face heightened safety risks, including violence and harassment, when traveling long distances to gather firewood in unsafe areas (Akter & Pratap, 2022).

Furthermore, technological and infrastructural constraints worsen these challenges, as many rural and low-income households lack access to cleaner cooking alternatives like liquefied petroleum gas (LPG), electricity, or improved cookstoves due to affordability issues and inadequate infrastructure (Adjei-Mantey & Takeuchi, 2023; Ali & Khan, 2022; Bakhsh et al., 2020). Even when modern options are available, socio-cultural preferences, a lack of awareness, and high initial costs hinder widespread adoption. These interconnected factors highlight the persistent structural barriers that sustain household dependence on traditional cooking fuels.

Journal of Information Systems Engineering and Management
2025, 10(59s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

This paper empirically assesses Nigeria's cooking energy transition over 10 years, analysing adoption rates and the factors influencing clean and transitional cooking energy uptake across four survey periods (waves). Unlike previous studies that relied on data from one or two survey periods, this study leverages a more extensive dataset to evaluate comprehensively. A key contribution is the disaggregation of the dependent variable cooking energy into clean, transitional, and unclean categories, providing a more nuanced understanding of household energy choices. This approach contrasts with prior research categorising cooking fuels as clean and unclean. By incorporating a transitional variable, the study facilitates a longitudinal assessment of households' adoption patterns, highlighting the pathways toward the sustainable adoption of clean cooking energy.

2.0 Literature Review

2.1 Household Cooking Energy Transition

Cooking energy transition refers to the shift from inefficient and polluting biomass fuels, such as firewood and charcoal, to cleaner alternatives like liquefied petroleum gas (LPG), biogas, and electricity (Rahut et al., 2024; Roy, 2024; Yang & Wang, 2023). This transition is often explained using energy transition theories, including the energy ladder hypothesis and the fuel stacking model. The energy ladder theory suggests that as household income increases, households switch from biomass to transitional fuels, such as kerosene, to cleaner energy sources (van der Kroon et al., 2013; Yadav et al., 2021). However, the fuel stacking model posits that households do not permanently abandon traditional fuels; instead, they use multiple fuel sources simultaneously (Gould et al., 2022; Ochieng et al., 2020; Parvizi et al., 2024; Yadav et al., 2021). The energy ladder theory and the fuel stacking theory form the basis for this study's contribution to knowledge on understanding the transition of cooking energy in Nigeria.

2.2 Factors Influencing the Adoption of Clean Cooking Fuels

The transition to clean cooking energy is influenced by socioeconomic, demographic, institutional, and behavioural factors. One of the critical determinants is income level and affordability, as households in low-income brackets often rely on traditional biomass fuels due to their low cost and widespread availability (Ma et al., 2022; Wassie et al., 2021; Ezeanyeji et al., 2020). Even when cleaner alternatives such as liquefied petroleum gas (LPG) and electricity are available, the high initial cost of acquiring equipment and the recurrent expense of fuel often deter adoption (van der Kroon et al., 2013). Government subsidies and credit facilities have improved adoption rates, especially in developing economies where financial constraints limit household energy transitions (Malla & Timilsina, 2014).

Another factor is education and awareness, as higher levels of education correlate with an increased likelihood of adopting clean cooking technologies (Adeyonu et al., 2022); Swain & Mishra, 2020; (Lewis & Pattanayak, 2012). Knowledge about the health hazards of indoor air pollution caused by biomass fuels, awareness campaigns, and improved access to cleaner alternatives have been instrumental in shifting household energy preferences (Bonjour et al., 2013). However, behavioural inertia and cultural attachment to traditional cooking practices often slow the transition process, even among educated households (Kelkar & Nathan, 2021).

The availability and accessibility of clean energy sources also play a crucial role. In rural and peri-urban areas, inadequate infrastructure for cleaner energy sources, such as LPG distribution and unreliable electricity supply, hinder adoption (Adjei-Mantey & Takeuchi, 2023; Ali & Khan, 2022). A stable fuel supply chain is a key determinant in ensuring the sustainability of clean cooking transitions (Mperejekumana et al., 2024; Nizami et al., 2023).

Furthermore, gender dynamics and intra-household decision-making shape energy choices, as women, who are the primary users of cooking energy, may lack the financial independence to switch to cleaner options (Flechtner et al., 2024; Kelkar & Nathan, 2021). Social norms and gender-based disparities in asset ownership often mean that male household heads, who may not prioritise cooking energy improvements, make the purchasing decisions (Yu, 2020). Interventions targeting women's empowerment and direct access to clean energy financing have effectively promoted clean fuel adoption (Okoli, 2024; Puzzolo et al., 2016).

Environmental concerns and health considerations have become increasingly important factors in adopting clean cooking energy, particularly in urban areas where air pollution is rising. (Pratiti et al., 2020; Rafaj et al., 2018; Rosenthal et al., 2018). Households suffering from respiratory illnesses due to biomass fuel exposure are more likely to switch to cleaner alternatives (Enyew et al., 2021; Kim et al., 2011). Climate change mitigation efforts and international commitments to sustainable energy access also drive policies that promote the global adoption of clean cooking energy (Adetomi Adewnmi et al., 2023; Karakosta et al., 2010).

3.0 Data and Methodology

3.1 Data

The paper utilised secondary data from the World Bank and the National Bureau of Statistics (NBS), spanning 10 years across four waves: Wave 1 (2010/2011), Wave 2 (2012/2013), Wave 3 (2015/2016), and Wave 4 (2018/2019). The General Household Survey (GHS) Panel consists of a nationally representative sample of 5,000 households, capturing the diversity of Nigeria's geopolitical zones in both urban and rural settings. The following variables were used for the economic analysis, as shown in the table below.

Table 1: Variables

Variable Acronyms	House Survey Question
Cooking Fuels	What are the fuels commonly used for this cookstove in the last 12 months (1st)?
Gender	What is the sex of the household head?
Age	Age in completed years?
Marital Status	What is the household head's marital status?
Highest Qualification	What is the household head's highest qualification attained?
Own Bank Account	Does the household head have a bank account?
Access to Credit	Did you try to borrow money during the last 6 months but were unable to?
Number of Meals Cooked Per Day	How many meals are taken per day in HH by adults 15 years and older?
Dwelling Ownership	Does HH own, rent or stay for free in the dwelling that HH currently occupies?
Health Consultation	During the past 4 weeks, have you consulted a health practitioner?
Formal Saving	Have you used a cooperative, savings association or micro-finance institution to save money?
Informal Saving	Has the household head used any informal savings groups to save money in the last 12 months?
Electricity Access	Do you have electricity from any source in your household?
Other Income	Have you received wages, salary, or other payments from this work?

3.2 Methodology

The study utilised descriptive statistics, ordinal logistic regression, and marginal effects, as it depends on the energy ladder theory (van der Kroon et al., 2013; Yadav et al., 2021). It introduced a transitional variable, making the dependent variable (cooking energy) categorical: clean, transitional, and unclean. This enables the ranking of households' preferences and adoption of cooking energy over the period under review.

3.3 Econometric model specifications

The ordinal model specification of the model for cooking energy includes the following:

$$logit(Y \leq jcf) = \beta_0 jcf + \beta_1 jcfX_1 + \beta_2 jcfX_2 + \beta_3 jcfX_3 + \beta_4 jcfX_4 + \beta_5 jcfX_5 + \beta_6 jcfX_6 + \beta_7 jcfX_7 + \beta_8 jcfX_8 + \beta_9 jcfX_9 + \beta_{10} jcfX_{10} \quad (3.1)$$

$$logit(Y \leq jtf) = \beta o jtf + \beta_1 jtfX_1 + \beta_2 jtfX_2 + \beta_3 jtfX_3 + \beta_4 jtfX_4 + \beta_5 jtfX_5 + \beta_6 jtfX_6 + \beta_7 jtfX_7 + \beta_8 jtfX_8 + \beta_9 jtfX_9 + \beta_{10} jtfX_{10} \quad (3.2)$$

$$logit(Y \leq juf) = \beta o juf + \beta_1 jufX_1 + \beta_2 jufX_2 + \beta_3 jufX_3 + \beta_4 jufX_4 + \beta_5 jufX_5 + \beta_6 jufX_6 + \beta_7 jufX_7 + \beta_8 jufX_8 + \beta_9 jufX_9 + \beta_{10} jufX_{10} \quad (3.3)$$

Where:

Y = the ordinal dependent variable.

Journal of Information Systems Engineering and Management
2025, 10(59s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Jcf = the ordinal dependent variable for clean cooking fuel

Jtf = the ordinal dependent variable for transitional cooking fuel

Juf = the ordinal dependent variable for unclean cooking fuel

$\beta_0 jcf$, $\beta_0 jtf$, $\beta_0 juf$ = the intercept for each model category of cooking fuels (Clean, Transition, and Unclean)

$B_1jcfX_1 + \beta_2jcfX_2 + \beta_3jcfX_3 + \beta_4jcfX_4 + \beta_5jcfX_5 + \beta_6jcfX_6 + \beta_7jcfX_7 + \beta_8jcfX_8 + \beta_9jcfX_9 + \beta_{10}jcfX_{10}$ = are the coefficients for the independent variables on the model for clean cooking fuels

$\beta_1jtfX_1 + \beta_2jtfX_2 + \beta_3jtfX_3 + \beta_4jtfX_4 + \beta_5jtfX_5 + \beta_6jtfX_6 + \beta_7jtfX_7 + \beta_8jtfX_8 + \beta_9jtfX_9 + \beta_{10}jtfX_{10}$ = are the coefficients for the independent variables on the model for transitional cooking fuels

$\beta_0 juf + \beta_1jufX_1 + \beta_2jufX_2 + \beta_3jufX_3 + \beta_4jufX_4 + \beta_5jufX_5 + \beta_6jufX_6 + \beta_7jufX_7 + \beta_8jufX_8 + \beta_9jufX_9 + \beta_{10}jufX_{10}$ = are the coefficients for the independent variables on the model for unclean cooking fuels

X1 = HH Gender

X2 = HH Age

X3 = HH Marital Status

X4 = HH Education Qualification

X5 = HH Own Bank Account

X6 = HH Access to Credit

X7 = HH Dwelling Ownership

X8 = HH Informal Savings

X9 = HH with Electricity

X10 = HH Other Income

4.0 Results and Discussion

4.1 Descriptive Statistics

Table 2: Household Cooking Fuel Consumption by Type in Wave 4

What are the fuels commonly used for this cookstove in the last 12 months (1st)	Freq.	Percent	Cum.
Kerosene	897	18.07	18.07
Coal/Lignite	3	0.06	18.13
Charcoal	156	3.14	21.27
Wood	3314	66.75	88.02
Animal Waste/Dung	7	0.14	88.16
Crop Residue/Plant Biomass	4	0.08	88.24
Saw Dust	3	0.06	88.30
Coal Briquette	1	0.02	88.32
Processed Biomass (Pellets)/Woodchips	1	0.02	88.34
Biogas	11	0.22	88.56
LPG/ Cooking Gas	511	10.29	98.85
Piped Natural Gas	4	0.08	98.93
Electric	40	0.81	99.74
Other	13	0.26	100.00

Journal of Information Systems Engineering and Management
2025, 10(59s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Total	4965	100.00

The household survey data from wave (period) 4 as shown in Table 2 indicates that wood is the most used energy source for cooking, with 66.75% of respondents reporting its use. Kerosene is the second most prevalent fuel at 18.07%, while LPG/cooking gas accounts for 10.29%. Charcoal is utilised by 3.14% of respondents. Less common fuels include biogas (0.22%), electricity (0.81%), and crop residue/plant biomass (0.08%). Other minor fuels, such as coal/lignite, animal waste/dung, sawdust, coal briquettes, processed biomass (pellets/woodchips), and piped natural gas, represent less than 0.2%. These fuels collectively contribute to the remaining 11.98% of total responses, with all categories summing to a cumulative total of 100%.

Table 3: Categorised Types of Cooking Fuels

Types of Cooking Fuels by Categories	Freq.	Percent	Cum.
Clean fuel	**566**	**11.43**	**11.43**
Transition fuel	**902**	**18.22**	**29.65**
Unclean fuel	**3483**	**70.35**	**100.00**
Total	**4951**	**100.00**	

The distribution of cooking fuel types indicates a significant reliance on unclean fuel, which make up the majority with 3,483 households, accounting for 70.35% of the total. Transition fuels follow, used by 902 households, representing 18.22%. Clean fuels, although the least used, are still adopted by 566 households, constituting 11.43% of the total sample. Altogether, these categories encompass the 4,951 households surveyed, highlighting the prevalence of unclean fuel use, despite some shifts toward cleaner or transitional energy sources.

Table 4: Categorisation of Cooking Fuels by Clean, Transitional, and Dirty

Clean Fuel	**Transition Fuel**	**Unclean Fuel**
Biogas	Kerosene	Coal ignite
LPG	Sawdust	Charcoal
Piped Natural Gas	Processed Biomass	Wood
Electricity	Coal Briquette	Animal waste
		Firewood
		Grass

Cooking fuels in Nigeria can be divided into three categories: clean, transitional, and unclean. This classification provides a framework for analyzing the country's fuel transition, with much of the research focusing on the dynamics of clean and unclean fuels. Clean fuels, such as biogas, liquefied petroleum gas (LPG), piped natural gas, and electricity, are sustainable and have minimal environmental and health impacts. Transitional fuels, like kerosene, sawdust, processed biomass, and coal briquettes, offer some improvements by reducing emissions through industrial refinement, although they still pose certain risks. Unclean fuels, such as firewood, animal waste, charcoal, and grass, are the most detrimental, contributing significantly to indoor air pollution and environmental degradation. Understanding these fuel categories enables a more nuanced exploration of the cooking-energy transition in Nigeria.

Journal of Information Systems Engineering and Management
2025, 10(59s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Table 4.1.4: Household Cooking Fuels Consumption by Waves

Categorised Cooking Fuels	Wave 4	Wave 3	Wave 2	Wave 1
Clean fuel	576	183	85	44
Transition fuel	937	979	970	1164
Unclean fuel	3523	3388	3522	3692
Total	5036	4550	4577	4900

Throughout four waves, the distribution of households by categorized cooking fuels reveals significant trends. In Wave 1, most households (3,692) relied on unclean fuels, while a smaller proportion used transition fuels (1,164) and clean fuels (44). As the waves progressed, there was a gradual increase in the adoption of clean fuels, rising from 44 households in Wave 1 to 576 households by Wave 4. Conversely, the use of transition fuels showed slight fluctuations, with 1,164 households in Wave 1, peaking at 979 in Wave 3, and slightly decreasing to 937 in Wave 4. However, unclean fuels remained the dominant energy source across all waves, with a marginal decrease from 3,692 households in Wave 1 to 3,523 in Wave 4. Overall, the total number of households surveyed increased, reaching 5,036 in Wave 4 compared to 4,900 in Wave 1. This indicates a slow yet noticeable shift towards cleaner fuel adoption, although unclean fuels still play a major role in energy consumption role.

Table 5.1.5: Household Cooking Fuels Consumption by Zones

Cooking Fuels	Zone code						
	1. North Central	2. North East	3. North West	4. South East	5. South South	6. South West	Total
Clean fuel	87	10	42	44	129	264	576
Transition fuel	106	16	49	237	255	274	937
Unclean fuel	658	801	761	550	444	309	3523
Total	851	827	852	831	828	847	5036

The analysis reveals a critical challenge in household energy consumption across the six geopolitical zones in Nigeria, with a dominant reliance on "unclean fuels" like wood and charcoal in all surveyed zones. This heavy dependence affects a substantial 3,523 households, compared to only 576 that use clean fuels. It has significant implications for public health due to indoor air pollution, environmental degradation from deforestation and emissions, and economic productivity related to the time spent on fuel collection. Addressing this widespread use of polluting fuels is paramount for the nation's sustainable development and the well-being of households.

A closer examination of the zonal distribution highlights significant regional disparities in fuel choices. The northern zones (North Central, North East, and North West) exhibit the highest prevalence of unclean fuel usage and notably lower adoption rates of cleaner alternatives. This trend reflects lower income levels, limited access to modern energy infrastructure, prevailing cultural practices, and potentially environmental constraints. Conversely, the southern zones (South East, South South, and South West) generally demonstrate a greater uptake of clean and transition fuels, possibly linked to higher urbanisation, better infrastructure access, increased income levels, and greater awareness of the adverse impacts of dirty fuels.

"Transition fuels" as a notable intermediary consumption pattern suggests a potential pathway for progress. These fuels indicate that some households are moving away from the most polluting options but have not yet fully adopted clean alternatives. Targeted interventions are crucial to accelerate the transition towards cleaner cooking solutions. These should focus on improving access to affordable clean fuel infrastructure, raising awareness about the benefits of clean fuels, implementing supportive policies and incentives, and addressing underlying issues of poverty that often hinder the adoption of cleaner energy sources across all zones in Nigeria.

Journal of Information Systems Engineering and Management
2025, 10(59s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

5.2: Ordinal Logic Regression

Table 5.2.1: Regression for Cooking Fuels and Wave

CookingFuels	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
: base 1	1	.	.	.	.	.	
2	1.036	.05	0.73	.464	.942	1.14	
3	.88	.042	-2.67	.007	.801	.966	***
4	.653	.03	-9.27	0	.597	.715	***
Mean dependent var			2.698	SD dependent var		0.552	
Pseudo r-squared			0.005	Number of obs		18776	
Chi-square			124.295	Prob > chi2		0.000	
Akaike crit. (AIC)			25789.184	Bayesian crit. (BIC)		25828.385	

**** p<.01, ** p<.05, * p<.1*

The ordinal logistic regression model analyses the transition to cleaner cooking fuels across four waves, with wave 1 as the reference (base) period. The results show that, compared to the base period, the log-odds of selecting wave 2 increase by 1.036, although this effect is not statistically significant (p = 0.464). In contrast, moving to wave 3 and wave 4 is associated with significant increases in log-odds, by 0.88 and 0.653, respectively (both p < 0.01). However, the decreasing magnitude of coefficients suggests that while transitioning to cleaner cooking fuels is possible, transitioning to clean cooking fuels becomes progressively more difficult due to higher fuel quality levels, likely because of economic or accessibility barriers.

The overall model is statistically significant (Chi-square = 124.295, p < 0.001) but explains a small portion of the variation in fuel choice (Pseudo R^2 = 0.005), indicating that other unmeasured factors may influence household decisions. The odds ratios further confirm that the likelihood of adopting higher-category fuels increases relative to the base, although the effect size diminishes for the highest fuel category. These results highlight both progress and persistent challenges in advancing clean cooking fuel adoption..

Table 5.2.2 Marginal Effect of Cooking Fuels and Wave

Conditional marginal effects Number of obs = 18,776

Model VCE: OIM

dy/dx wrt: 2. wave 3. wave 4. wave

1._predict: Pr(cooking Fuels==1), predict(pr outcome(1))

2._predict: Pr(cooking Fuels==2), predict(pr outcome(2))

3._predict: Pr(cooking Fuels==3), predict(pr outcome(3))

	dy/dx	std. err.	Z	P>z	[95% conf.	interval]
Wave 1	[Base	Category]				
Wave 2						
1	-0.001	0.002	-0.730	0.464	-0.005	0.002
2	-0.005	0.007	-0.730	0.464	-0.018	0.008
3	0.006	0.009	0.730	0.464	-0.010	0.023

Journal of Information Systems Engineering and Management
2025, 10(59s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/ **Research Article**

Wave 3						
1	0.005	0.002	2.660	0.008	0.001	0.009
2	0.018	0.007	2.670	0.008	0.005	0.031
3	-0.023	0.009	-2.670	0.008	-0.041	-0.006
Wave 4						
1	0.020	0.002	8.920	0.000	0.016	0.025
2	0.064	0.007	9.300	0.000	0.050	0.077
3	-0.084	0.009	-9.320	0.000	-0.101	-0.066

Note: dy/dx for factor levels is the discrete change from the base level.

The conditional marginal effects from the ordinal logit regression on cooking fuels across four survey waves demonstrate significant shifts in fuel adoption patterns over time. The results of the ordinal logit regression indicate that the findings for waves 3 and 4 are statistically significant. The regression results are categorized into three types of cooking fuels: clean, transitional, and unclean. Specifically, (outcome 1) represents clean cooking fuels (the base category), (outcome 2) denotes transitional fuels, and (outcome 3) refers to unclean fuels.

In Wave 2, compared to Wave 1 (the base), the marginal effects on the likelihood of using different types of cooking fuels are small and statistically insignificant. For example, the probability of using clean fuels (outcome 1) decreases slightly by -0.001(0.1%), while the probability for transitional fuels (outcome 2) decreases by -0.005(0.5%). The likelihood of using unclean fuels (outcome 3) shows a slight increase of 0.006(0.6%).

However, in Wave 3, a notable shift occurred. The probability of using clean fuels (outcome 1) rises significantly by 0.005(0.5%), while the probability of adopting transitional fuels (outcome 2) increases by 0.018 (1.8%). Meanwhile, the likelihood of relying on unclean fuels (outcome 3) decreases by -0.023 (2.3%). All these changes are statistically significant, with p-values below 0.01.

By Wave 4, these trends become even more pronounced. The probability of using clean fuels surges by 0.020(2%), and the use of transitional fuels increases significantly by 0.064(6.4%). Conversely, the likelihood of using unclean fuels drops sharply by -0.084 (8.4%). The p-values for all categories remain well below 0.01, underscoring the high statistical significance of these shifts and highlighting a clear trend toward cleaner energy options over time.

Table 5.2.3 Regression for Cooking Fuels and all variables

Cooking Fuels	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Gender:							
Base: male							
female	.68	.075	-3.51	0	.548	.843	***
age	.986	.002	-6.60	0	.982	.99	***
Marital status: Married mono							
married (polygamous)	1.827	.168	6.56	0	1.526	2.188	***
informal union	1.542	.791	0.85	.398	.565	4.212	
divorced	.515	.114	-2.99	.003	.333	.796	***
separated	.507	.082	-4.20	0	.369	.696	***
widowed	.9	.108	-0.87	.382	.711	1.14	
never married	.381	.046	-7.98	0	.301	.483	***
Highest Qualification:							
Base: No Education							

Journal of Information Systems Engineering and Management
2025, 10(59s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

SSCE or lower	.394	.028	-12.89	0	.342	.454	***
First Degree	.289	.028	-12.86	0	.24	.35	***
Master's and above	.065	.014	-12.33	0	.042	.101	***
Own Bank Account: Base: Yes							
no	2.183	.135	12.66	0	1.935	2.464	***
Access to Credit Base: yes							
no	.806	.068	-2.55	.011	.683	.951	**
Number of Meals cooked per Day	1.033	.035	0.95	.34	.967	1.104	
Dwelling Ownership base: owned							
employer provides	.56	.121	-2.68	.007	.366	.856	***
free, authorized	.444	.033	-11.00	0	.384	.513	***
free, not authorized	.331	.074	-4.92	0	.213	.515	***
rented	.176	.013	-24.25	0	.153	.203	***
Health Consultation base: yes							
no	1.044	.075	0.60	.549	.906	1.203	
Formal Savings base: Yes							
no	1.129	.109	1.26	.208	.935	1.363	
Informal Savings base: yes							
no	.856	.054	-2.45	.014	.756	.97	**
Electricity Access Base: yes							
No	4.846	.33	23.17	0	4.24	5.538	***
Other Income	1	0	-2.20	.028	1	1	**

Mean dependent var	2.737	SD dependent var	0.483
Pseudo r-squared	0.289	Number of obs	11247
Chi-square	4045.727	Prob > chi2	0.000
Akaike crit. (AIC)	10020.012	Bayesian crit. (BIC)	10203.209

*** *p<.01*, ** *p<.05*, * *p<.1*

The regression results reveal that gender, marital status, education level, and financial access significantly influence the choice of cooking fuels. Specifically, for gender, females increase the log-odds of choosing cleaner fuels by 0.68 units compared to males. In terms of marital status, households in polygamous marriages have higher log-odds (1.827 units) of adopting cleaner cooking fuels compared to those in monogamous marriages, while divorced, separated, and never married individuals show the likelihood of adopting clean cooking fuels. Higher educational attainment (SSCE, first degree, and master's and above) consistently decreases the log-odds of adopting cleaner cooking fuels relative to households with no formal education, suggesting that education is associated with a preference for cleaner cooking fuels.

Financial variables show a strong relationship with cooking fuel choices. Households without bank accounts exhibit lower log-odds in adopting clean cooking fuels compared to those with bank accounts. Similarly, lack of access to credit facilities reduces the log-odds by 0.806 units, highlighting the role of financial inclusion in enabling access to

Journal of Information Systems Engineering and Management
2025, 10(59s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

cleaner energy choices. Meanwhile, savings behaviour (formal or informal) does not show strong significance, except that the lack of informal savings slightly decreases the log-odds by 0.856 units in households adopting clean cooking fuels.

Housing conditions also play a crucial role. Compared to individuals who own their dwellings, households whose homes are provided by employers or occupied free of charge (whether authorised or not) or rented all experience significantly reduced log-odds of using cleaner fuels. Renting is associated with the greatest reduction, with a coefficient of 0.176. Moreover, individuals without access to electricity experience lower log-odds, suggesting that household access to electricity is positively associated with adopting cleaner energy sources.

Demographic factors such as age show a strong positive relationship (coef = 0.986, p < 0.001), suggesting that older households have higher log-odds of adopting cleaner cooking fuels more readily. Cooking behaviour, measured by the number of meals cooked daily, does not show a significant effect. Other income sources were statistically significant but did not change the log-odds meaningfully. The model demonstrates good explanatory power with a pseudo-R-squared of 0.289 and strong overall significance (p < 0.001), indicating that socio-demographic, financial, and infrastructural factors critically shape household energy choices.

Table 5.2.4: Marginal Effect of Regression for Cooking Fuels and All Variables

Average marginal effects Number of obs = 11,224

Model VCE: OIM

dy/dx wrt: gender, age, marital Status, Highest Qualification, Own Bank Account, Access to credit, Number of meals cooked per Day, Dwelling Ownership, Health Consultation, Formal Savings, Informal Savings, Electricity Access, other Income

1._predict: Pr(cooking Fuels==1), predict(pr outcome(1))

2._predict: Pr(cooking Fuels==2), predict(pr outcome(2))

3._predict: Pr(cooking Fuels==3), predict(pr outcome(3))

		dy/dx	**std.err**	**z**	**P>z**	**[95%conf.**	**interval]**
1. Gender (male)		**base**	**Category**				
2. Gender (female)							
	1	0.007	0.002	3.13	0.002	0.003	0.012
	2	0.041	0.012	3.47	0.001	0.018	0.063
	3	-0.048	0.014	-3.42	0.001	-0.075	-0.02
age							
	1	0	0	6.15	0	0	0
	2	0.001	0	6.62	0	0.001	0.002
	3	-0.002	0	-6.63	0	-0.002	-0.001
1. Marital Status Married (monogamous)		**base**	**Category**				

Journal of Information Systems Engineering and Management
2025, 10(59s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

2. Marital Status Married (polygamous)							
	1	-0.007	0.001	-7.11	0	-0.009	-0.005
	2	-0.061	0.009	-6.85	0	-0.078	-0.043
	3	0.068	0.01	6.97	0	0.049	0.087
3. Marital Status Informal union							
	1	-0.006	0.006	-1.02	0.306	-0.017	0.005
	2	-0.045	0.05	-0.89	0.372	-0.143	0.053
	3	0.05	0.056	0.91	0.365	-0.059	0.159
4. Marital Status Divorced							
	1	0.014	0.006	2.34	0.019	0.002	0.026
	2	0.075	0.026	2.9	0.004	0.024	0.126
	3	-0.089	0.032	-2.8	0.005	-0.151	-0.027
5. Marital Status Separated							
	1	0.014	0.004	3.3	0.001	0.006	0.023
	2	0.077	0.019	4.09	0	0.04	0.114
	3	-0.091	0.023	-3.96	0	-0.137	-0.046
6. Marital Status Widowed							
	1	0.002	0.002	0.85	0.396	-0.002	0.006
	2	0.011	0.013	0.87	0.384	-0.014	0.037
	3	-0.013	0.015	-0.87	0.385	-0.043	0.017

Journal of Information Systems Engineering and Management
2025, 10(59s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

7. Marital Status Never Married							
	1	0.023	0.004	5.79	0	0.015	0.031
	2	0.11	0.014	7.64	0	0.082	0.139
	3	-0.134	0.018	-7.36	0	-0.169	-0.098
1. Highest Qualification- No Education		**base**	**Category**				
2. Highest Qualification- SSCE or lower							
	1	0.011	0.001	10.82	0	0.009	0.013
	2	0.102	0.008	12.93	0	0.087	0.118
	3	-0.113	0.009	-13.21	0	-0.13	-0.097
3. Highest Qualification- First Degree							
	1	0.017	0.002	9.33	0	0.014	0.021
	2	0.141	0.012	11.94	0	0.118	0.164
	3	-0.159	0.013	-11.98	0	-0.185	-0.133
4. Highest Qualification- Masters and Above							
	1	0.08	0.014	5.72	0	0.053	0.107
	2	0.327	0.025	12.93	0	0.278	0.377
	3	-0.407	0.038	-10.74	0	-0.482	-0.333
1. Own Bank Account-Yes		**base**	**Category**				
2. Own Bank Account-No							
	1	-0.013	0.001	-10.24	0	-0.016	-0.011
	2	-0.09	0.008	-11.53	0	-0.106	-0.075
	3	0.103	0.009	11.76	0	0.086	0.121

Journal of Information Systems Engineering and Management
2025, 10(59s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

1. **Access to Credit-Yes**		**base**	**Category**				
2. Credit Access-No							
	1	0.003	0.001	2.71	0.007	0.001	0.006
	2	0.022	0.008	2.59	0.01	0.005	0.039
	3	-0.025	0.01	-2.61	0.009	-0.045	-0.006
Number of Meals Cooked per Day							
	1	-0.001	0.001	-0.95	0.34	-0.002	0.001
	2	-0.003	0.004	-0.95	0.34	-0.01	0.004
	3	0.004	0.004	0.95	0.34	-0.004	0.012
1. **Dwelling Ownership-Owned**		**base**	**Category**				
2. Dwelling Ownership-Employer provides							
	1	0.007	0.003	2.09	0.037	0	0.013
	2	0.068	0.027	2.49	0.013	0.015	0.121
	3	-0.075	0.03	-2.45	0.014	-0.134	-0.015
3. Dwelling Ownership- Free, Authorised							
	1	0.011	0.001	7.68	0	0.008	0.013
	2	0.098	0.009	10.42	0	0.079	0.116
	3	-0.108	0.011	-10.3	0	-0.129	-0.088
4. Dwelling Ownership- Free, not Authorised							
	1	0.017	0.005	3.14	0.002	0.006	0.027
	2	0.137	0.03	4.53	0	0.077	0.196
	3	-0.153	0.035	-4.34	0	-0.222	-0.084

Journal of Information Systems Engineering and Management
2025, 10(59s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/ **Research Article**

5. Dwelling Ownership- Rented							
	1	0.036	0.003	12.99	0	0.031	0.042
	2	0.221	0.011	20.84	0	0.201	0.242
	3	-0.257	0.012	-21.29	0	-0.281	-0.234
1. **Health Consultation-Yes**		**base**	**Category**				
2. Health Consult- No							
	1	-0.001	0.001	-0.59	0.554	-0.003	0.002
	2	-0.004	0.007	-0.6	0.549	-0.019	0.01
	3	0.005	0.009	0.6	0.55	-0.012	0.022
1. **Formal Savings-Yes**		**Base**	**Category**				
2. Savings with Financial Institutions- No							
	1	-0.002	0.002	-1.21	0.227	-0.006	0.001
	2	-0.013	0.01	-1.25	0.212	-0.033	0.007
	3	0.015	0.012	1.24	0.214	-0.009	0.038
1. **Informal Savings-Yes**		**base**	**Category**				
2.informal_Savings-No							
	1	0.003	0.001	2.51	0.012	0.001	0.005
	2	0.016	0.006	2.46	0.014	0.003	0.029
	3	-0.019	0.008	-2.47	0.013	-0.033	-0.004
1. **Electricity Access -Yes**		**base**	**Category**				
2. Has Electricity-No							

Journal of Information Systems Engineering and Management
2025, 10(59s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

	1	-0.018	0.001	-14.66	0	-0.02	-0.016
	2	-0.179	0.008	-23.72	0	-0.194	-0.164
	3	0.197	0.008	24.81	0	0.181	0.212
Other Income							
	1	0	0	2.18	0.029	0	0
	2	0	0	2.2	0.028	0	0
	3	0	0	-2.2	0.028	0	0

Analyzing the marginal effects of various demographic and socioeconomic factors on the adoption of different cooking fuels provides valuable insights into the cooking energy transition among the surveyed population of 11,224 individuals. The regression results categorize cooking fuels into three types: clean, transitional, and unclean, with outcome 1 representing clean cooking fuels, outcome 2 denoting transitional cooking fuels, and outcome 3 referring to unclean cooking fuels. Notably, gender significantly influences these adoption patterns; female respondents exhibit a higher propensity for adopting cleaner cooking fuels than their male counterparts, as evidenced by a positive marginal effect of 0.041 (4.1%) for transitional cooking fuels (outcome 2) and a positive marginal effect of 0.007 (0.7%) for clean cooking fuels (outcome 1). In contrast, unclean cooking fuels (outcome 3) demonstrate a negative marginal effect of -0.048 (4.8%). Age also impacts adoption rates, with each additional year correlating with a slight increase in the likelihood of adopting cleaner cooking fuels. However, this effect diminishes slightly in older age groups, as indicated by a positive marginal effect of 0.001 (0.1%) for transitional cooking fuels (outcome 2) and 0 (0%) for clean cooking fuels (outcome 1). In comparison, unclean cooking fuels (outcome 3) show a negative marginal effect of -0.002 (0.2%).

Marital status plays a significant role in influencing cooking fuel choices, particularly highlighting that households in formal or informal unions tend to experience a notable negative impact on adopting clean cooking fuels. In polygamous marriages, the marginal effects indicate a decrease of -0.061 (6.1%) for transitional cooking fuels and -0.007 (0.7%) for clean cooking fuels, while unclean cooking fuels demonstrate a positive marginal effect of 0.068 (6.8%). Similarly, those in informal unions show negative marginal effects of -0.045 (4.5%) for transitional cooking fuels and -0.006 (0.6%) for clean cooking fuels, with unclean cooking fuels again reflecting a positive marginal effect of 0.050 (5%).

In contrast, single individuals whether divorced, separated, widowed, or never married exhibit a substantial positive marginal effect on the adoption of clean cooking fuels. Divorced individuals show positive marginal effects of 0.075 (7.5%) for transitional cooking fuels and 0.014 (1.4%) for clean cooking fuels, while unclean cooking fuels present a negative marginal effect of -0.089 (8.9%). Those who are separated also indicate positive marginal effects of 0.077 (7.7%) for transitional cooking fuels and 0.014 (1.4%) for clean cooking fuels, with unclean cooking fuels showing a negative effect of -0.091 (9.1%). Similarly, widowed individuals reflect positive marginal effects of 0.011 (1.1%) and 0.002 (0.2%) for transitional and clean cooking fuels, respectively, while unclean cooking fuels reveal a negative effect of -0.013 (1.3%). Lastly, individuals who have never married show positive marginal effects of 0.011 (1.1%) for transitional cooking fuels and 0.023 (2.3%) for clean cooking fuels, with unclean cooking fuels indicating a notable negative marginal effect of -0.134 (13.4%).

Educational attainment is strongly correlated with the adoption of clean cooking fuel, indicating that all levels of education, and households have a positive marginal effect of adopting clean cooking fuels. Households that hold a senior secondary school certificate (SSCE) or lower married show positive marginal effects of 0.102(10.2%) for transitional cooking fuels and 0.011(1.1%) for clean cooking fuels, with unclean cooking fuels indicating a notable negative marginal effect of -0.113 (11.3%). Households who hold a first degree and above show positive marginal effects of 0.141 (14.1%) for transitional cooking fuels and 0.017 (1.7%) for clean cooking fuels, with unclean cooking fuels indicating a notable negative marginal effect of -0.159 (15.9%). Households that hold the highest education qualification of a master's degree and above show a positive marginal effect of 0.327 (32.7%) for transitional cooking fuels and 0.008 (0.8%) for clean cooking fuels, with unclean cooking fuels indicating a notable negative marginal effect of -0.407 (40.7%). This finding underscores the critical role of education in driving the transition to sustainable energy solutions.

Financial factors play a significant role in fuel adoption. Households without access to bank accounts or credit access facilities are less likely to adopt cleaner cooking fuels. Specifically, the absence of a bank account is associated with a negative marginal effect of -0.09 (0.9%) for transitional cooking fuels and -0.013 (1.3%) for clean cooking fuels, while it shows a notable positive marginal effect of 0.103 (10.3%) for unclean fuels. Similarly, households without access to credit facilities depict a positive marginal effect of 0.022 (2.2%) for transitional cooking fuels and 0.003 (0.3%) for clean cooking fuels, with a significant negative marginal effect of -0.025 (2.5%) for unclean fuels. As a result, households with no informal savings show a positive marginal effect of 0.016 (1.6%) for transitional cooking fuels and 0.003 (0.3%) for clean cooking fuels, with a significant negative marginal effect of -0.004 (0.4%) for unclean fuels

Interestingly, electricity access and dwelling types further reveal patterns in fuel adoption. Households with no access to electricity experience a low likelihood of adopting clean cooking energy, indicating a negative marginal effect of -0.179 (17.9%) for transitional cooking fuels and -0.018 (1.8%) for clean cooking fuels, with unclean cooking fuels reflecting a positive marginal effect of 0.197 (19.7%). Dwellings ownership showed a strong probability for adopting clean and transitional fuels for cooking.

The marginal effects highlight the complexity of the cooking energy transition, revealing the significant interplay of gender, age, marital status, education, and financial factors in influencing fuel choices. These findings emphasize the necessity for targeted interventions that consider these variables to promote the adoption of cleaner cooking fuels effectively. Also, evidence suggests that households are more likely to adopt transitional energy sources as part of the cooking energy transition towards cleaner alternatives.

Conclusion and Policy Implications

The household cooking energy transition in Nigeria has been positive over the past 10 years of the study period; however, the adoption rate remains slow, with a noticeable shift toward transitional fuels and away from unclean cooking fuels. Among the six geopolitical zones in Nigeria, the northern zones exhibit a higher utilisation of unclean cooking fuels, which is tied to factors such as lower income and limited infrastructure. In contrast, the southern zones show greater adoption of cleaner alternatives, indicating that targeted interventions are necessary to facilitate a nationwide transition to clean cooking solutions. The study found that demographic and socioeconomic factors significantly influence the choice of cooking fuel, with gender, age, marital status, education, and financial access showing significant marginal effects on household decisions regarding clean, transitional, and unclean fuels. These findings highlight the need for targeted interventions that consider these factors to promote the effective adoption of cleaner cooking solutions.

Limitations of the Study

The study's limitation hinges on its reliance on secondary data sources to evaluate the transition of cooking energy over 10 years across four different periods (waves). This household data limits the inclusion of relevant variables, particularly those related to health outcomes, such as health expenditures, which are essential for enriching the study. This limitation arises from the data's inability to capture such variables across the four period waves, noting that the study is a longitudinal study**.**

References

[1] Aberilla, J. M., Gallego-Schmid, A., Stamford, L., & Azapagic, A. (2020). Environmental sustainability of cooking fuels in remote communities: Life cycle and local impacts. *Science of The Total Environment*, *713*, 136445. https://doi.org/10.1016/j.scitotenv.2019.136445

[2] Adetomi Adewnmi, Kehinde Andrew Olu-lawal, Chinelo Emilia Okoli, Favour Oluwadamilare Usman, & Gloria Siwe Usiagu. (2023). Sustainable energy solutions and climate change: A policy review of emerging trends and

global responses. *World Journal of Advanced Research and Reviews*, *21*(2), 408–420. https://doi.org/10.30574/wjarr.2024.21.2.0474

[3] Adeyonu, A. G., Adams, S. O., Kehinde, M. O., Akerele, D., & Otekunrin, O. A. (2022). Spatial Profiles and Determinants of Multidimensional Energy Poverty in Rural Nigeria. *International Journal of Energy Economics and Policy*, *12*(3), 373–384. https://doi.org/10.32479/ijeep.13163

[4] Adjei-Mantey, K., & Takeuchi, K. (2023). Risk aversion and cleaner cooking fuel choice: An empirical study in Ghana. *Environment and Development Economics*, *28*(2), 130–148. https://doi.org/10.1017/S1355770X22000122

[5] Ajayi, P. I. (2018). Urban Household Energy Demand in Southwest Nigeria. *African Development Review*, *30*(4), 410–422. https://doi.org/10.1111/1467-8268.12348

[6] Akter, S., & Pratap, C. (2022). Impact of clean cooking fuel adoption on women's welfare in India: The mediating role of women's autonomy. *Sustainability Science*, *17*(1), 243–257. https://doi.org/10.1007/s11625-021-01069-9

[7] Ali, J., & Khan, W. (2022). Factors affecting access to clean cooking fuel among rural households in India during COVID-19 pandemic. *Energy for Sustainable Development*, *67*, 102–111. https://doi.org/10.1016/j.esd.2022.01.006

[8] Aziz, S., Barua, S., & Chowdhury, S. A. (2022). Cooking energy use in Bangladesh: Evidence from technology and fuel choice. *Energy*, *250*, 123696. https://doi.org/10.1016/j.energy.2022.123696

[9] Bakhsh, K., Sadiqa, A., Yasin, M. A., Haider, S., & Ali, R. (2020). Exploring the nexus between households' choice of cooking fuels, sanitation facilities and access to information in Pakistan. *Journal of Cleaner Production*, *257*, 120621. https://doi.org/10.1016/j.jclepro.2020.120621

[10] Bonjour, S., Adair-Rohani, H., Wolf, J., Bruce, N. G., Mehta, S., Prüss-Ustün, A., Lahiff, M., Rehfuess, E. A., Mishra, V., & Smith, K. R. (2013). Solid Fuel Use for Household Cooking: Country and Regional Estimates for 1980–2010. *Environmental Health Perspectives*. https://doi.org/10.1289/ehp.1205987

[11] Enyew, H. D., Mereta, S. T., & Hailu, A. B. (2021). Biomass fuel use and acute respiratory infection among children younger than 5 years in Ethiopia: A systematic review and meta-analysis. *Public Health*, *193*, 29–40. https://doi.org/10.1016/j.puhe.2020.12.016

[12] Ezeanyeji, C. I., Usifoh, K., Stanley, C. O. O., & Ejefobihi, U. F. (2020). *MICROFINANCING, POVERTY ALLEVIATION AND NIGERIA'S ECONOMIC GROWTH: THE NEXUS*. https://doi.org/10.5281/ZENODO.3732438

[13] Flechtner, S., Lich, U., & Pelz, S. (2024). Women's decision-making power, cooking fuel adoption and appliance ownership: Evidence from Rwanda, Nepal and Honduras. *Energy Research & Social Science*, *118*, 103780. https://doi.org/10.1016/j.erss.2024.103780

[14] Grabher, H. F., Rau, H., Ledermann, S. T., & Haberl, H. (2023). Beyond cooking: An energy services perspective on household energy use in low and middle income countries. *Energy Research & Social Science*, *97*, 102946. https://doi.org/10.1016/j.erss.2023.102946

[15] Karakosta, C., Doukas, H., & Psarras, J. (2010). Technology transfer through climate change: Setting a sustainable energy pattern. *Renewable and Sustainable Energy Reviews*, *14*(6), 1546–1557. https://doi.org/10.1016/j.rser.2010.02.001

[16] Kelkar, G., & Nathan, D. (2021). Cultural and Economic Barriers in Switching to Clean Cooking Energy: Does Women's Agency Make a Difference? *Energies*, *14*(21), 7242. https://doi.org/10.3390/en14217242

[17] Kim, K.-H., Jahan, S. A., & Kabir, E. (2011). A review of diseases associated with household air pollution due to the use of biomass fuels. *Journal of Hazardous Materials*, *192*(2), 425–431. https://doi.org/10.1016/j.jhazmat.2011.05.087

[18] Kumar, P., Dhand, A., Tabak, R. G., Brownson, R. C., & Yadama, G. N. (2017). Adoption and sustained use of cleaner cooking fuels in rural India: A case control study protocol to understand household, network, and organizational drivers. *Archives of Public Health*, *75*(1), 70. https://doi.org/10.1186/s13690-017-0244-2

[19] Kumar, P., & Igdalsky, L. (2019). Sustained uptake of clean cooking practices in poor communities: Role of social networks. *Energy Research & Social Science*, *48*, 189–193. https://doi.org/10.1016/j.erss.2018.10.008

[20] Lewis, J. J., & Pattanayak, S. K. (2012). Who Adopts Improved Fuels and Cookstoves? A Systematic Review. *Environmental Health Perspectives*, *120*(5), 637–645. https://doi.org/10.1289/ehp.1104194

[21] Li, H., Li, Y., Zheng, G., & Zhou, Y. (2024). Interaction between household energy consumption and health: A systematic review. *Renewable and Sustainable Energy Reviews*, *189*, 113859. https://doi.org/10.1016/j.rser.2023.113859

[22] Ma, W., Zheng, H., & Gong, B. (2022). Rural income growth, ethnic differences, and household cooking fuel choice: Evidence from China. *Energy Economics*, *107*, 105851. https://doi.org/10.1016/j.eneco.2022.105851

[23] Malla, S., & Timilsina, G. R. (2014). *Household Cooking Fuel Choice and Adoption of Improved Cookstoves in Developing Countries: A Review*. The World Bank. https://doi.org/10.1596/1813-9450-6903

[24] Mperejekumana, P., Shen, L., Gaballah, M. S., & Zhong, S. (2024). Exploring the potential and challenges of energy transition and household cooking sustainability in sub-sahara Africa. *Renewable and Sustainable Energy Reviews*, *199*, 114534. https://doi.org/10.1016/j.rser.2024.114534

[25] Neto-Bradley, A. P., Choudhary, R., & Bazaz, A. (2020). Slipping through the net: Can data science approaches help target clean cooking policy interventions? *Energy Policy*, *144*, 111650. https://doi.org/10.1016/j.enpol.2020.111650

[26] Nizami, M. A. F., Ahmad, M., & Latif, D. A. (2023). TOWARDS SUSTAINABLE ENERGY TRANSITION: ASSESSING ACCESS TO CLEAN FUELS AND COOKING TECHNOLOGIES. *Bulletin of Business and Economics (BBE)*, *12*(2), Article 2.

[27] Okoli, N. (2024). *Exploring the impact of conditional cash transfers on economic empowerment and clean energy use among poor women in urban Nigeria*. https://hdl.handle.net/10625/63214

[28] Oyeniran, I. W., & Isola, W. A. (2023). Patterns and determinants of household cooking fuel choice in Nigeria. *Energy*, *278*, 127753. https://doi.org/10.1016/j.energy.2023.127753

[29] Parchure, R., Chaudhary, E., Darak, S., Ghosh, S., Kumar, A., & Dey, S. (2024). High ambient air pollution erodes the benefits of using clean cooking fuel in preventing low birth weight in India. *Environmental Research Letters*, *19*(1), 014075. https://doi.org/10.1088/1748-9326/ad18e0

[30] Pratiti, R., Vadala, D., Kalynych, Z., & Sud, P. (2020). Health effects of household air pollution related to biomass cook stoves in resource limited countries and its mitigation by improved cookstoves. *Environmental Research*, *186*, 109574. https://doi.org/10.1016/j.envres.2020.109574

[31] Puzzolo, E., Pope, D., Stanistreet, D., Rehfuess, E. A., & Bruce, N. G. (2016). Clean fuels for resource-poor settings: A systematic review of barriers and enablers to adoption and sustained use. *Environmental Research*, *146*, 218–234. https://doi.org/10.1016/j.envres.2016.01.002

[32] Qu, X., Li, X., Bardgett, R. D., Kuzyakov, Y., Revillini, D., Sonne, C., Xia, C., Ruan, H., Liu, Y., Cao, F., Reich, P. B., & Delgado-Baquerizo, M. (2024). Deforestation impacts soil biodiversity and ecosystem services worldwide. *Proceedings of the National Academy of Sciences*, *121*(13), e2318475121. https://doi.org/10.1073/pnas.2318475121

[33] Rafaj, P., Kiesewetter, G., Gül, T., Schöpp, W., Cofala, J., Klimont, Z., Purohit, P., Heyes, C., Amann, M., Borken-Kleefeld, J., & Cozzi, L. (2018). Outlook for clean air in the context of sustainable development goals. *Global Environmental Change*, *53*, 1–11. https://doi.org/10.1016/j.gloenvcha.2018.08.008

[34] Rosenthal, J., Quinn, A., Grieshop, A. P., Pillarisetti, A., & Glass, R. I. (2018). Clean cooking and the SDGs: Integrated analytical approaches to guide energy interventions for health and environment goals. *Energy for Sustainable Development*, *42*, 152–159. https://doi.org/10.1016/j.esd.2017.11.003

[35] Roy, K. (2024). Transition to cooking with clean fuels in rural households of India: Studying the effect of policy and other factors. *Energy for Sustainable Development*, *80*, 101456. https://doi.org/10.1016/j.esd.2024.101456

[36] Rybak, J., & Pieśniewska, A. (2024). Chapter 2—Household air pollution and human health. In M. H. Dehghani, R. R. Karri, T. Vera, & S. K. M. Hassan (Eds.), *Health Effects of Indoor Air Pollution* (pp. 29–52). Academic Press. https://doi.org/10.1016/B978-0-443-16090-5.00005-2

[37] Stoner, O., Lewis, J., Martínez, I. L., Gumy, S., Economou, T., & Adair-Rohani, H. (2021). Household cooking fuel estimates at global and country level for 1990 to 2030. *Nature Communications*, *12*(1), 5793. https://doi.org/10.1038/s41467-021-26036-x

[38] Stritzke, S., Bricknell, M., Leach, M., Thapa, S., Khalifa, Y., & Brown, E. (2023). Impact Financing for Clean Cooking Energy Transitions: Reviews and Prospects. *Energies*, *16*(16), 5992. https://doi.org/10.3390/en16165992

[39] Swain, S. S., & Mishra, P. (2020). Determinants of adoption of cleaner cooking energy: Experience of the Pradhan Mantri Ujjwala Yojana in rural Odisha, India. *Journal of Cleaner Production*, *248*, 119223. https://doi.org/10.1016/j.jclepro.2019.119223

[40] van der Kroon, B., Brouwer, R., & van Beukering, P. J. H. (2013). The energy ladder: Theoretical myth or empirical truth? Results from a meta-analysis. *Renewable and Sustainable Energy Reviews*, *20*, 504–513. https://doi.org/10.1016/j.rser.2012.11.045

[41] Wassie, Y. T., Rannestad, M. M., & Adaramola, M. S. (2021). Determinants of household energy choices in rural sub-Saharan Africa: An example from southern Ethiopia. *Energy*, *221*, 119785. https://doi.org/10.1016/j.energy.2021.119785

[42] Yadav, P., Davies, P. J., & Asumadu-Sarkodie, S. (2021). Fuel choice and tradition: Why fuel stacking and the energy ladder are out of step? *Solar Energy*, *214*, 491–501. https://doi.org/10.1016/j.solener.2020.11.077

[43] Yu, S. (2020). *Rural Livelihoods, Gender Dynamics, and Intersectional Inequalities in South China* [Phd, University of Leeds]. https://etheses.whiterose.ac.uk/id/eprint/27195/