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Biomass Energy Dependence in South Africa: Are the Western Cape Province households descending the energy ladder after improvement in electricity access?

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Abstract

South Africa was considered to have attained universal access to modern energy from 1994 to 2012. This meant that the number of households that moved away from the use of dirty energy to clean energy for domestic activities has drastically increased "ascending the energy ladder". However, recent trends in household energy consumption in many developing countries are showing many households have either retained or are reversing to fuelwood use despite the modern energy access "descending the energy ladder". Against this backdrop, the present study evaluates whether or not South African households are still using fuelwood for domestic activities" descending the energy ladder" even after the rapid improvement in electricity access. Both theoretical and empirical literature suggests that households in developing countries often choose their energy type based on certain factors. We take this assumption to test in the Western Cape Province by employing a quantitative cross-sectional survey design involving a structured questionnaire from 1199 fuel-wood household consumers. The findings revealed that electricity access has made households to "move up the energy ladder" instead of "descending the energy ladder" for the reasons of household marital status, size of the household, household income, and employment status of the household. The study recommends more investment in human capital to enable households to have easy access to modern clean energy.

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Keywords: Biomass; Electricity; Energy ladder; Household; Western Cape Province

1. Introduction

Despite the improvement in awareness of the negative consequences associated with of the use of fuelwood, recent key development indices have indicated that the rate at which urban areas are growing and rate of population

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growth makes fuel wood a viable energy option for many households in the developing countries. The strong hike in the prices of modern clean energy had given many households little incentives to switch away from wood. Although the democratic government of South Africa had executed one of the most successful electrification projects whereby about six million households or 75% of South African population have accessed electricity [1,2], several empirical studies have shown that many of the households have retained their fuelwood consumption habits despite the improvement (descending the energy ladder). For example, [3] show that not fewer 68% of households in villages of Athol and Welverdiend in Bushbuckridge Municipality of Mpumalanga Province that have electricity access are still using fuel-wood as their primary energy source to meet their day to day household needs even when fuelwood had become more expensive in the areas. The main reason for retaining fuelwood is because it is primarily cost-saving energy for using electricity that gives the household the ability to invest in other economic activities that will generate other incomes to satisfy other necessities such as food, children's schooling, and clothing instead of spending on electricity. Also, [4] revealed that in Altein, Botsoleni, Makovha and Thenzenhi communities of Thulamela Municipality of Limpopo Province households use more fuelwood than electricity despite having access to electricity for the reason of socioeconomic factors such as household income, level of education, household size, employment and occupation. [5], argued that these factors played a significant role in influencing household to consume fuelwood instead of modern clean energy. To this end, the present study seeks to establish whether or not socioeconomic and demographic variables of the households influence their decision to descend the energy ladder despite the high electricity access in the Western Cape Province.

2. Statement of the problem

Majority of the South African households especially those in the lower-income category are energy poor due to the burden of electricity tariff making fuelwood and other biomass product an important energy source. However, to date, the biomass energy sector is not well developed in South Africa due to the concerns that increasing fuel-wood and other biomass product use might threaten South Africa's environment and domestic health. Therefore, studying household fuel-wood energy consumption is necessary since fuel-wood account for a large share of household energy source in some provinces. Most researches in the developing countries were mainly focused on negative environmental effects of fuel-wood consumption without actually evaluating the socioeconomic and demographic drivers of fuelwood consumption. Furthermore, understanding the demographic and socioeconomic drivers affecting the use of biomass product will provide insight to policymakers in promoting the use of modern energy among South African households.

3. Energy ladder hypothesis

The energy ladder hypothesis described the movement from dirty or traditional to conventional or modern energy services in the event of an increase in income or economic status of the households or vice versa. [6]. According to the model, as income increases, households will firstly move away from traditional fuels (fuelwood, crop residue, and dung) to transitional fuels (charcoal and kerosene) before finally moving to modern fuels (LPG and electricity) which are superior to traditional or transitional fuels "ascending the energy ladder". The main reason for the movement is because households prefer clean fuels for ease of use and efficiency.

4. Methodology

Western Cape is one of the affluent provinces in South Africa and higher GDP contributor. Electricity is used by more than 90% of the households for domestic activities [7]. Therefore, the study used a quantitative cross-sectional survey design and two-stage random sampling technique on 608 Enumeration Areas (EAs) demarcated for Western Cape Province during the 2011census to capture the respondents. Two (2) households (HHs) or sampling units were randomly selected from each of the Enumeration Area (EA). In each household (HH) in the housing unit, two respondents were identified and administered a questionnaire. A total of 1199 households (HH) responses were collected in the 608 enumeration areas (EAs).

5. Findings

5.1. Descriptive analysis

5.1.1. The dynamics of household fuelwood energy consumption

Frequency of using fuel-wood as a major energy source

The frequency Table 1 for consumer impact on energy source showed out of 1199 of the respondents, only 9.3% of respondents have indicated that they use fuelwood trice in a day. This is an indication that fuelwood is not frequently used by households.

Table 1. Frequency of using fuel-wood as major energy source.

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Once a day	292	24.4	24.4	24.4
	Twice a day	729	60.8	60.8	85.2
	Trice a day	112	9.3	9.3	94.5
	Other	48	4.0	4.0	98.5
	5	18	1.5	1.5	100.0
	Total	1199	100.0	100.0	

Reason for fuel-wood as a major energy source

Frequency Table 2 shows that 68.1% of the respondents have confirmed that the reason they use fuelwood as a major energy source is that it is relatively affordable. 8.7% said it is very affordable, 11.9% said it is a bit affordable while 11.3% said it is affordable. The difference between those that accepted using fuelwood is a bit affordable and those that said it is very affordable was only 0.3%, meaning that fuelwood is not the major energy for household activities.

Table 2. Reason for fuel-wood as major energy source.

		Frequency	Percent	Valid percent	Cumulative percent
Valid	A bit affordable	143	11.9	11.9	11.9
	Relatively affordable	817	68.1	68.1	80.1
	Affordable	135	11.3	11.3	91.3
	Very affordable	104	8.7	8.7	100.0
	Total	1199	100.0	100.0	

5.2. Logistic regression

Logit regression is used to test models that predict categorical outcomes with two or more categories. The predictor (independent) variables can be either categorical or continuous, or a mix of both in the one model. Therefore, Forced Entry Method, which is the default procedure available in SPSS was used being a family of logistic regression techniques available in SPSS that allow us to explore the predictive ability of sets or blocks of variables, and to specify the entry of variables. In this approach, all predictor variables are tested in one block to assess their predictive ability, while controlling for the effects of other predictors in the model.

5.2.1. The level of household fuelwood consumption

Table 3 shows that 950 (79.2%) cases or respondents were involved and there are missing cases of 249 (20.8%). Table 4, coding of dependent variables showed low fuel-wood energy is represented by 0 and high fuel-wood energy is represented by 1. The classification Table 5 predicted that 94.1% of respondents are low fuel-wood energy consumers.

Table 3. Case processing summary.

Unweighted cases[a]		N	Per cent
Selected cases	Included in analysis	950	79.2
	Missing cases	249	20.8
	Total	1199	100.0
Unselected cases		0	.0
Total		1199	100.0

[a]If weight is in effect, see classification table for the total number of cases.

Table 4. Dependent variable encoding.

Original value	Internal value
Low fuelwood energy	0
High fuelwood energy	1

Table 5. Classification table[a,b].

	Observed		Predicted		
			Energy source		Percentage correct
			Low fuel wood energy	High fuel wood energy	
Step 0	Energy source	Low fuel wood energy	894	0	100.0
		High fuel wood energy	56	0	0
	Overall percentage				94.1

[a]Constant is included in the model.
[b]The cut value is .500.

5.2.2. The impacts of socioeconomic and demographic variables on fuelwood consumption

Table 6 (categorical variable coding) shows the predictor variables (independent variables) which are demographic and socioeconomic. They include; employment status, age category, household size, marital status, educational level, monthly income, the structure of the house, and consumer gender.

Table 6. Categorical variables coding.

		Frequency	Parameter coding1
Employment status	Employed	280	.000
	Not employed	670	1.000
Age category	Young	769	.000
	Old	181	1.000
Marital category	Not married	628	.000
	Married	322	1.000
Education category	Secondary & Above	726	.000
	Primary	224	1.000
Household size	Small	824	.000
	Big	126	1.000
Monthly income	High income	225	.000
	Low income	725	1.000
Structure of house	Modern	832	.000
	Traditional	118	1.000
Consumer gender	Female	806	.000
	Male	144	1.000

To know how well the model in predicting the correct category for each variable is, the classification Table 7 in Block 0 is compared with that in Block 1, Table 8. In this analysis, it can be concluded that there is no improvement when the predictor variables are included in the model since the percentage remain the same (94.1%) in both tables.

Table 7. Block 0: Beginning block.

Iteration history[a,b,c]			
Iteration		−2Log likelihood	Coefficients constant
Step 0	1	498.044	−1.764
	2	431.154	−2.463
	3	425.789	−2.733
	4	425.716	−2.770
	5	425.716	−2.770

[a]Constant is included in the model.
[b]Initial -2 Log Likelihood: 425.716.
[c]Estimation terminated at iteration number 5 because parameter estimates changed by less than .001.

Table 8. Block 1: Method = Enter.

Iteration		−2 Log likelihood	Coefficients									
			Constant	Consumer gender(1)	Age category(1)	Marital Category(1)	Education category (1)		Household size(1)	Structure of house(1)	Monthly income(1)	Employment status(1)
Step 1	1		490.710	−2.004	.081	.056	−.092	.017	−.010	.040	.126	.205
	2		413.478	−3.133	.199	.139	−.233	.045	−.024	.093	.341	.545
	3		399.959	−4.091	.314	.228	−.384	.083	−.035	.133	.653	1.026
	4		397.697	−4.747	.352	.263	−.440	.103	−.036	.136	.903	1.419
	5		397.525	−4.995	.356	.269	−.444	.106	−.035	.134	.996	1.575
	6		397.524	−5.023	.356	.269	−.444	.106	−.035	.134	1.005	1.594
	7		397.524	−5.023	.356	.269	−.444	.106	−.035	.134	1.005	1.594
Iteration history[a,b,c,d]												

[a]Method: Enter.
[b]Constant is included in the model.
[c]Initial -2 Log Likelihood: 425.716.
[d]Estimation terminated at iteration number 7 because parameter estimates changed by less than .001.

The model summary in Table 9 shows a Cox & Snell R square and Negel kerke R square value of (0.129) and Negelkerke R square (0.231). These are pseudo R square statistics suggesting that between 12.9% and 23.1% of this variability is explained by the variables.

Table 9. Model summary.

Step	-2 Log likelihood	Cox & Snell R square	Nagelkerke R square
1	397.524[a]	.129	.231

[a]Estimation terminated at iteration number 7 because parameter estimates changed by less than .001.

Variable (s) entered on step 1: Consumer gender, Age Category, Marital status, Education Category, Household Size, Structure of House, Monthly Income, and Employment Status.

In Table 10, Wald test was carried out (variable in the equation table) to know the contribution of each predictor. The variable that contributes significantly to the predictive ability of the model is the marital status (.010), household size (.25), monthly income (.39), and employment status (.015). Other variables are consumer gender (.0439), education (.744) and structure of the house, these variables have no significant contribution to household fuel-wood consumption. The B value in Table 10 levelled variables in the equation shows that *marital status* has a negative and statistical relationship with the household probability of consuming fuelwood at a significant level (-.444) and (p=.016). This means that as the household marital status changes, the probability of consuming fuel-wood will decrease. The reason behind this could be that the single respondents participated more than the other respondents in the study. *Household size* was found to have a statistically significant negative relationship with fuel-wood energy

Table 10. Variables in the equation.

		B	*S.E.*	*Wald*	*df*	*Sig.*	*95% C.I.for EXP(B)*		
							Exp(B)	Lower	Upper
Step 1[a]	Consumer gender(1)	.356	.359	.984	1	.321	1.428	.706	2.888
	Age Category(1)	.269	.348	.600	1	.439	1.309	.662	2.588
	Marital Category(1)	-.444	.320	3.721	1	.016	4.641	1.442	18.202
	Education Category(1)	.106	.324	.107	1	.744	1.112	.589	2.099
	Household Size(1)	−.135	.423	3.007	1	.025	1.566	1.521	22.215
	Structure of House(1)	.134	.407	.108	1	.743	1.143	.515	2.538
	Monthly Income(1)	−1.005	.362	4.805	1	.039	3.733	1.346	13.004
	Employment Status(1)	−1.594	.353	5.958	1	.015	4.922	1.369	17.701
	Constant	−5.023	.727	47.736	1	.000	.007		

[a]Variable (s) entered on step 1.

Variable (s) entered on step 1: Consumer gender, Age Category, Marital status, Education Category, Household Size, Structure of House, Monthly Income, and Employment Status.

consumption. The result shows that there is less probability of household consuming fuel-wood energy in the study area. The negative relationship is statistically significant at (−.135) and (p=.025). This corroborates the findings of [8] in Nigeria. *Monthly income* has a negative relationship with fuelwood consumption at a significant value of (−1.005) and (p=.039). This result is in line with the study of [9] in Ghana. *Employment status* has a negative statistical relationship with the probability of consuming fuel-wood energy at (−1.594) and (p=.015) significant level. This relationship means that households with employment are more likely to consume modern clean energy like electricity due to income flow as confirmed by [10].

6. Conclusion

The results of the study indicated that fuel-wood is not the most frequently used energy source for household activities in the Western Cape Province. Only 9.3% of the households indicated that they use fuelwood three times a day. Also, the correlation analysis shows a highly negative significant relationship between fuel-wood consumption and *marital status, household size, monthly income, and household employment status*. Thus, a clear linkage exists between households' living circumstances and fuelwood consumption. This means that households in the Western Cape Province are not "descending the energy ladder" contrary to outcomes of many studies in the developing countries. Against the backdrop of our findings, South African policymakers should lay more emphasis on energy supply-driven factors by ensuring a sufficient and reliable supply of clean modern energy to the populace. Furthermore, economy-wide range policies should also be directed towards influencing the households to go for clean energy. However, one limitation noted in the study is that only Western Cape province was studied, the assumption is that if data of the rest of the provinces were used the outcome of the study may have changed.

CRediT authorship contribution statement

N.B. Muazu: Investigation, Formal analysis, Validation, Writing - original draft. **K. Ogujiuba:** Supervision, Writing - review & editing. **H.R. Tukur:** Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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