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The impact of energy fuel choice determinants on sustainable energy consumption of selected South African households

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Abstract

The erratic nature of electricity supply in South Africa combines with other factors continuous to affect household electricity demand, leading to increasing reliance on other fuels. This dependence is characterised by the use of traditional fuels by mostly low-income households, contributing significantly to environmentally harmful emissions. This study assessed the primary determinants of energy fuel choice in selected South African households, to alert policymakers to important energy consumption behavioural tendencies that can inform policies and that can assist sustainable energy growth and reduction of biomass use in households. The investigation was primarily based on energy consumption models and used a quantitative research design. Gauteng and North West were considered for data collection. Households, in general, tended to practice energy stacking. The results suggest policy measures that could promote sustainable energy use by households.

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1. Introduction

Andrew (2015:1) asserted that the most important need in life is the availability of energy to drive social development and industrial competitiveness. Elias and Victor (2005:4) argued that human behaviour has been changing constantly towards the utilisation of energy because of the influence of technological developments. However, despite the need for improved access to sustainable energy, Ellingsen (2010:3) stated that there is still a constant growth in energy inequality, as most rural households across the world continue to struggle to access modern energy services, leading to increasing reliance on traditional biofuels. Pachauri and Rao (2014:1) highlighted that energy inequality was commonly analysed on the following bases:

- income or some related monetary measure, as prevailing disparities in income would closely mirror inequalities in energy accessed and consumed; and
- disparities in energy quantities consumed and types of energy sources predominantly used.

The authors argued that the distribution of modern energy sources remained highly unequal, with a much higher dependence on environmentally unfriendly energy fuels by most people, especially in developing countries. A massive study conducted by the International Energy Agency (IEA) (2006:40) on households' use of biofuels, reflected the following findings;

- over 2.5 billion people around the world still primarily rely on traditional energy sources such as fuelwood, charcoal, agricultural and animal waste to meet their daily energy demand for cooking and heating yearly. A total of 1.6 billion people are still without complete electricity access;
- in developing countries over 90% of most household daily energy consumption comes from biofuels; and
- one-third of the world's population (2.7 billion people) will still primarily depend on biofuels in 2030.

Oparinde (2010:3) found that biomass fuels could be regarded as combustible renewables such as vegetable materials that can be converted into vegetable oil, landfill gas and bio-additives. Biomass can also be traditional energy fuels such as wood and animal waste, and intermediate biomass sources such as charcoal and coal. Biomass use in the present study was taken to refer to traditional energy fuels. Gallachóir (2007) recommended that energy research was primary for developing robust policies and initiating a change towards increased energy sustainability. Such empirical research significantly contributes to understanding energy poverty in South Africa. The IEA (2002:376) found that

only 23% of the sub-Saharan population is electrified, with about 500 million people still unconnected to an electricity source, making the least electrified region in the world. Winkler (2006:34) cited recent estimates showing that a significant proportion of South Africa's households would remain unelectrified. Treiber *et al.* (2015) noted that improvement towards the consumption of cleaner fuels would reduce energy poverty. Linear model investigations such as that of Ismail and Khembo (2015) predict a positive relationship between socio-economic development and energy fuels transition in South Africa. Howells *et al.* (2005) noted that a primary hindrance to facilitating energy transition in the country is the knowledge deficit in policymaking on factors that govern energy choices by households.

2. Conceptual framework development

This study, following the models discussed in the supplementary file,[1] took into consideration both the energy ladder and the energy stacking hypotheses. Concerns on biomass fuels use and its effect on clean energy use have not been adequately analysed in the South African context (Howells *et al.*, 2005), with very little empirical research exploring the appropriateness of energy choice models in the country's household sector. It is, however, noteworthy much empirical research has been conducted here with regard to the energy ladder (Alberts *et al.*, 1997; Davis, 1998; Howells *et al.*, 2006; Louw *et al.*, 2008). There is limited research advancing the applicability of the energy stacking hypothesis, despite the work of Madubansi and Shackleton (2006); and Musango (2014), with objectives related to this hypothesis. The present study, therefore, comprehensively explored both the energy ladder and the energy stacking guidelines in the South African context. Uhunamure *et al.* (2017) can be recognised as one of the first researchers to consider both models for such a study. Households' fuel choice classification criteria of endogenous factors (household characteristics) and exogenous factors (external conditions) in Kowsari and Zerriffi (2011) guided the development of the conceptual framework for the empirical research (see Table 1).

The present study considered only the endogenous category. Two factors were considered from the economic characteristics and four factors from the non-economic characteristics.

2.1 Economic characteristics

The economic category was generally considered to be a primary influence on households' energy choice. The income and expenditure factor were sampled in the empirical research. Overemphasising income or expenditure as a measurement of wealth in determining a household's fuel choice is unclear, as in countries such as South Africa, a sig-

Table 1: Household fuel choice factors (Kowsari and Zerriffi, 2011).

Categories	Factors	Measuring aspect
Endogenous factors		
Economic characteristics	Income, expenditure and landholding	Endogenous characteristics reflect the capabilities of households, behavioural attitudes, preferences and experiences of households
Non-economic characteristics	Household size, gender, age, household composition, education, labour and information	
Behavioural and cultural characteristics	Preferences(e.g food taste), practices, lifestyle, social status and ethnicity	
Exogenous factors		
Physical environment	Geographic location and climatic condition	Exogenous factors influence household decisions about their energy system by affecting available choices and incentives to choose one energy technology or fuel over another.
Policies	Energy policy, subsidies and market and trade policies.	
Energy supply element	Affordability, availability, accessibility and reliability of energy supplies	
Energy device characteristics	Conversion efficiency, cost and payment method and complexity of operation	

nificant proportion of households depend on free, government-subsidised energy. Research can choose to use either income or expenditure as a measurement of wealth, but appplication should be relative to its context (Elias *et al.*, 2005).

2.1.1 Income and setting
Income was the first factor studied in as a significant determinant of energy fuel choice, through the energy ladder model. Early findings concurred that there is a significant association between income and households energy choice (Barnes *et al.*, 1994, 1996; Pachauri & Spreng, 2004; Wuyuan *et al.*, 2008). Even though new findings emerged exploring more comprehensive approaches to factors influencing household fuel choice pattern, Whitfield (2006:143) pointed out the shortcomings in energy research to advance the understanding of household fuel choice significantly beyond the influence of incomes. Van der Kroon *et al.* (2013) found that the placement of a household in the environment would typically determine the level of opportunity and possible income level.

2.1.2 Expenditure
Davis (1998) and Heltberg (2005) used expenditure instead of income in measuring economic influence on households' energy fuel choice. Low- and high-income households differ in energy spending as:
- the price of modern fuels, as well as their transaction cost, is usually high;
- income for low-income households is typically too low to accommodate payments associated with modern energy systems; and
- low-income households have an uncertain income source to accommodate regular spending required by modern energy sources.

A household's expenditure of fuel will depend on the unit price of the fuel demanded (Schlag & Zuzarte, 2008:10). As a rise in a household income will enable its capacity to switch to more sustainable fuels, primary and useful energy consumption will also increase as well (Mestl & Eskeland, 2009). Link *et al.* (2012) highlighted that minimum wages influence reliance on biomass energy fuels. Rao and Reddy (2013) maintained that household incomes derived from wages or salaries had a positive impact on the probability of using cleaner fuels. Van der Kroon (2013) found that a household's capital determined the fuel type relied on.

2.2 Non-economic characteristics
In early household fuel choice studies, the economic factor was the only one used to capture patterns of household fuel-switching through the aid of the energy ladder. However, non-economic elements later gained momentum, based on the concept of energy transition. Campbell *et al.* (2003) determined that income continued to be the most recommended determinant of fuel choice and the world is gradually heading to a dichotomy in which norms such as wealthier households being able to adopt modern fuels while poorer oness are increasingly forced to choose biomass will be irrelevant. The present empirical study considered the following household categories: size, education and gender.

2.2.1 Household size

Kowsari and Zerriffi (2011) pointed out that household size determined the amount of energy consumed by a household. Household size indirectly influences households to practise both energy switching and energy stacking behaviours. Ado (2016) articulates household size to significantly affect the use of energy fuel types. The size of a household will influence fuel transition because large ones tend to practise energy stacking more than smaller ones.

2.2.2 Education

Link *et al.* (2012) asserted that education influenced energy fuel transition in two ways. Firstly, schooling limits the labour force for fuel acquisition activities such as wood collection, possibly leading to a tendency to adopt fuels requiring no acquisition efforts, such as paraffin and gas. Secondly, education can initiate change by providing knowledge about the dangers that biomass energy pose to health and the environment. Schlag and Zuzarte (2008:14) highlight that a large proportion of the global population, especially sub-Saharan Africans, lack significant tutelage on consumers fuel choice theory. Thus, some informal education on fuels will greatly impact on households' fuel preferences. Prasad (2008) highlighted the need for people to be well informed, and thus empowered, at household level about the advantages of cleaner energy and the shortcomings of biomass fuels. According to the theory of cognitive dissonance, individuals strive for consistency between their knowledge and behavioural attitudes (Kowsari & Zerriffi, 2011). Whitfield (2006:143) mentioned that information education and social learning could be used to influence households energy fuels adoption significantly. Educational level will affect households' disposition to adopt modern fuels (Musango, 2014).

2.2.3 Gender

Patriarchal societies generally expect women to perform the majority of household tasks, such as cooking and washing. Gender can immensely influence fuel choice. A household where a male is the primary income earner and the main decision-maker might neglect the importance of the costs and benefit of clean cooking fuels (Schlag & Zuzarte, 2008:13-15). Treiber (2015) concurred that culture and tradition can influence women ignoring modern energy technologies. It was found that women preferred preparing chapattis using charcoal and fuelwood as this was less time consuming, given constant and controllable heat. The cooking process involved traditional pots and biomass fuel, which influenced the taste (Treiber, 2015). Van der Kroon *et al*. (2013) found that women and children are most involved in collecting wood in most South East Asian countries. Balmer (2007) maintained

that gender roles referred to the different tasks individuals performed; in households it means a division of labour in which different obligations are assigned to men and women.

2.3 Household activities and energy use in the South African context

The empirical research considered that certain fuels are mostly utilised for a particular household activity in the South African context. Electricity was the only energy type that households universally used for various activities such as cooking, lighting and heating. Use of LPG is mainly limited to cooking, solar energy to water heating. Direct utilisation of biomass fuel types (coal, wood and charcoal) by households includes for heating and cooking (Musango, 2014). Research on energy transition shows that most households' basic energy demand is for heating, cooking and lighting and fuel choice mostly relates to these (IEA, 2006:369). It is necessary to address these together for a realistic approach to household energy analysis (Kowsari & Zerriffi, 2011) and they were what the present study focused on.

3. Methodology

The study considered households in the North West and Gauteng provinces of South Africa. Gauteng because of its level of urban growth and being the country's nucleus of social development. North West province was selected as a developing province, to represent the country's spatial geography. Pretoria and Johannesburg were the target sample cities in Gauteng, and Mafikeng and Potchefstroom in the North West.

A purposive-convenience sampling technique was used. Actual data gathering utilised the quota sampling guidelines. Purposive-convenience sampling involves targeting participants at random. Purposive targeting was employed to find mostly income earners considered to be the financial nucleus in providing households' day-to-day needs. Convenience sampling meant gathering data from households based on their availability and willingness to participate in the study. The quota sampling guideline was used to target households from identified zones from sample cities. The demographics are mostly in clusters where an urban city has an outskirt settlement – usually referred to as a township. These townships reflect underdeveloped characteristics as compared with central city settlements with more sustainable development tendencies. The aim was to identify low-income and high-income residential groups, ensuring that enough participants from both groups were considered. Table 2 presents a description of sampled groups, Table 3 shows the income brackets.

This paper is part of a larger project aimed at developing a framework for sustainable energy

Table 2: A description of sampled groups.

City	Quotas	Income rank status
Mafikeng quota (A)	Riviera Park	High
Mafikeng quota (B)	Extension 36	Low
Potchefstroom quota (A)	Potchefstroom	High
Potchefstroom quota (B)	Ikageng	Low
Pretoria (A)	Pretoria North	High
Pretoria (B)	Soshanguve	Low
Johannesburg (A)	Auckland Park	High
Johannesburg (B)	Soweto	Low

development in South Africa. The data collection employed closed-ended questionnaires with defined categories for examining the effect of electricity supply and consumption in the domestic sector and related electricity consumer behaviours. Questions were strictly dichotomous, with participants ticking "yes" or "no" on the options that relate to their practised fuel choice behaviours. In total, 400 households were given questionnaires, but just 323 responded.

4. Data analysis and results

The International Business Machines (IBM) Statistical Package for Social Sciences (SPSS) statistics version 24.0.0 was used in analysing data (IBM SPSS, 2016). A test for reliability was conducted on the data by estimating the Cronbach Alpha, which measures the internal consistency of responses and indicates the level to which participants' opinions are relative on scale. For an exploratory study, reliability measured by Cronbach's Alpha of >0.5 and <0.7 is good, and >0.7 gives excellent reliability. The Cronbach Alpha obtained was 0.74, implying that there was a sufficient internal consistency from acquired data. The Chi-square test was used to identify if an association existed between sampled groups through the Cramer's V. The aim was to determine the existence of equality between the two categorical (groups). A Cramer value >0.1 <0.3 indicates small, >0.3<0.5 medium and >0.5 large associations between groups. The p values are also presented to confirm the validity of results. It is,

however, not relevant for this paper as the research aimed at establishing practical significant differences among sample groups, rather than statistical differences.

4.1 Influence of income on energy fuel choice

The criteria used in this factor determinant involved sampling participants based on quotas within the target sample demographics. The investigation also reflected that groups' income status was relative to sampled income brackets similar to Makonese *et al.* (2018). The income profile of sampled groups is shown in Table 3.

The results indicate that sampled areas from townships on average comprised households with lower income brackets compared with those from main town zones. Analysis considered grouping all settlements with similar income status to perform a general analysis based on each of the classified income ranks (high- and low-income groups).

Table 4 shows the results for income groups' use of electricity for lighting, cooking and heating. The Cramer's V differs only marginally within income groups in the use of electricity for cooking of 0.13 and heating of 0.21. Results indicate that 95.8% of households from the high-income group and 94.3% of low-income group used electricity for lighting in general. Furthermore, results indicate that income influences household's use of electricity for cooking and heating. Most high-income earners use electricity for cooking at 95.8% and heating at 79.1%. Low-income earners use electricity less for cooking at 77.6% and heating at 71.5%.

Table 5 reflects the results for income groups' use of LPG. The Cramer's V of 0.21 indicates a zero difference within income groups for the use of LPG for cooking and heating. Results reveal that high-income households tended to use gas at 35.2% as an alternative cooking fuel compared with 16.5% of low-income groups. Low-income groups tend to use paraffin for cooking at 15.2% compared with high-income households at 3%.

Table 6 presents results for solar water heating. High-income households tended to utilise solar

Table 3: A description of the income profile of sampled groups.

Groups	Total participants	Brackets (ZAR/month)				
		>15 000	15 001–25 000	25 001–34 000	34 001–46 000	>46 000
Soweto	49	38	5	6	0	0
Extension 36	50	43	7	0	0	0
Ikageng	9	7	3	0	0	0
Soshanguve	50	33	8	9	0	0
Rivira Park	49	0	11	33	5	0
Potcheftroom	15	0	3	6	6	0
Auckland Park	50	0	0	8	24	18
Pretoria North	51	0	0	14	29	8

Table 4: Use of electricity by income (ZAR/month).

Description	High-income		Low-income		Cramer's V	
	Yes	No	Yes	No	P values	Effect
			Electricity use for lighting			
Frequency	158	7	149	9	0.05	0.03
Percentage	95.8	4.2	94.3	5.7		
			Electricity use for cooking			
Frequency	139	19	128	37	0.01	0.13
Percentage	95.8	5.7	77.6	22.4		
			Electricity use for heating			
Frequency	125	33	118	47	0.05	0.21
Percentage	79.1	20.9	71.5	28.5		

Table 5: Use of liquefied petroleum gas and paraffin by income.

Description	High-income		Low-income		Cramer's V	
	Yes	No	Yes	No	P values	Effect
			Gas use for cooking			
Frequency	58	107	26	132	<0.001	0.21
Percentage	35.2	64.8	16.5	83.5		
			Paraffin use for cooking			
Frequency	5	160	24	134	<0.001	0.21
Percentage	3	97	15.2	84.4		

Table 6: The use of solar water heater by income.

Description	High-income		Low-income		Cramer's V	
	Yes	No	Yes	No	P values	Effect
Frequency	40	125	16	142	0.001	0.26
Percentage	24.2	75.8	10.1	89.9		

Table 7: Use of traditional fuels (biomass) by income.

Description	High-income		Low-income		Cramer's V	
	Yes	No	Yes	No	P values	Effect
			Use of wood for cooking			
Frequency	9	156	65	93	0.001	0.34
Percentage	5.5	94.5	42	58		
			Use of wood for heating			
Frequency	20	145	28	130	0.05	0.07
Percentage	12.1	87.9	17.7	82.3		
			Use of coal for cooking			
Frequency	6	152	118	47	0.05	0.53
Percentage	4	96	72	28		
			Use of coal for heating			
Frequency	12	146	15	150	0.05	0.02
Percentage	7.6	92.4	9.1	90.9		

water heaters at 24.2% as an alternative energy source for heating compared with 10.1% of low-income groups. The use of solar within the income groups had an effect size of 0.26 tending towards medium. Cramer's V indicate that there is a small association between income and the use of solar water heaters.

Table 7 presents results on households' use of energy fuels with biomass. In general, Cramer's V reflect that there were medium differences within income groups for the use of wood for cooking at 0.34 and large differences for the use of coal for cooking at 0.53. The results reflect that low-income households tended to use wood more for cooking at

42% compared with high-income households at 5.5%. Low-income groups also used coal significantly for cooking at 72%. High-income groups tended to not use coal for cooking, at only 4%.

4.2 Expenditure

Expenditure on energy was also tested to determine the influence of spending power on households' energy choice. Participating households from the two sampled groups had to indicate their monthly spending on electricity on a scale ranging from below ZAR 200 to above ZAR 300. The aim was to determine the spending disparity on electricity within the sampled household groups. Table 8 presents the results for households spending on electricity, showing that high-income households spent most, with a larger proportion of them at 81.1% spending above ZAR 300 for electricity monthly. Low-income households at 27.8% spent less than ZAR 300, while 52.5% spent less than ZAR 200. This implies that the proportion of income devoted for electricity spending was small for low income households compared with high-income households.

4.3 Household size

Household size was a significant influence on energy choice. Table 9 presents results for household size effect on electricity for lighting, cooking and heating. Cramer's V reflect small differences for household size and use of electricity for cooking (0.15) and heating (0.18) but not lighting (0.08).

Table 8: Expenditure per income groups in rands.

Description	<200	<300	>300	Total
High income group				
Frequency	11	20	133	164
Percentage	6.7	12.2	81.1	100
Low income group				
Frequency	83	31	44	158
Percentage	52.5	19.6	27.9	100

Table 10 presents the influence of household size on the use of LPG for cooking. Households with more members tended to utilise LPG for cooking. Cramer's V reflected small differences between household size and household use of paraffin (0.14); and gas fuel (0.13) for cooking. Families with 1 to 3 members used paraffin less for cooking (4.5%), compared with households with 4 to 6 members (13.1%), and 7 and more members (11.8%). Households with 1 to 3 members also used less gas fuel for cooking (22.3%) compared with households with 4 to 6 members (26.3%) and at least 7 members (41.8%).

Table 11 presents results for household size influence on the use of coal and wood for cooking and heating, indicating that household size was not significant here. For instance, the use of wood for heating when the frequency of participants and percentages obtained are compared reflected that household size with 1 to 3 members (14.1%) and 4

Table 9: Household size influence on the use of electricity for lighting, cooking and heating.

No. of members	Measurements	Yes	No	Total	P value	Effect size
Use of electricity for lighting						
1 – 3	Frequency	128	2	130	0.05	0.18
	Percentage	98.5	1.5	100		
4 – 6	Frequency	148	8	156		
	Percentage	94.9	5.1	100		
>7	Frequency	29	5	34		
	Percentage	85.3	14.7	100		
Use of electricity for cooking						
1 – 3	Frequency	47	78	125	0.021	0.15
	Percentage	37.6	62.4	10		
4 – 6	Frequency	61	94	155		
	Percentage	39.4	60.6	100		
>7	Frequency	19	12	31		
	Percentage	61.3	38.70	100		
Use of electricity for heating						
1 – 3	Frequency	102	28	130	0.03	0.08
	Percentage	78.5	21.5	100		
4 – 6	Frequency	116	40	156		
	Percentage	74.40	25.60	100		
>7	Frequency	23	11	34		
	Percentage	67.60	32.40	100		

Table 10: Household size influence on the use of liquefied petroleum gas and paraffin for cooking.

No. of members	Measurements	Yes	No	Total	P value	Effect size
		Use of paraffin for cooking				
1 – 3	Frequency	7	149	130	0.03	0.14
	Percentage	4.5	95.5	100		
4 – 6	Frequency	17	113	156		
	Percentage	13.1	86.9	100		
>7	Frequency	4	30	34		
	Percentage	11.8	88.2	100		
		Use of gas for cooking				
1 – 3	Frequency	29	101	130	0.06	0.13
	Percentage	22.3	77.7	100		
4 – 6	Frequency	41	115	156		
	Percentage	26.3	73.7	100		
>7	Frequency	14	20	34		
	Percentage	41.2	58.8	100		

Table 11: Household size influence on the use of biomass for cooking and heating.

No. of members	Measurements	Yes	No	Total	P value	Effect size
		Use of wood for cooking				
1 – 3	Frequency	22	134	156	0.05	0.09
	Percentage	14.1	85.9	100		
4 – 6	Frequency	17	113	130		
	Percentage	13.1	86.9	10		
7	Frequency	8	26	34		
	Percentage	23.50	76.50	100		
		Use of coal for cooking				
1 – 3	Frequency	6	150	156	0.29	0.09
	Percentage	3.80	96.20	100		
4 – 6	Frequency	8	122	130		
	Percentage	6.20	93.80	100		
>7	Frequency	2	32	34		
	Percentage	5.90	94.10	100		
		Use of wood for heating				
1 – 3	Frequency	22	134	156	0.13	0.11
	Percentage	14.10	85.90	100		
4 – 6	Frequency	17	113	130		
	Percentage	13.10	86.90	100		
>7	Frequency	9	25	34		
	Percentage	26.50	73.50	100		
		Use of coal for heating				
1 – 3	Frequency	10	146	156	0.26	0.09
	Percentage	6.4	93.6	100		
4 – 6	Frequency	12	118	130		
	Percentage	9.2	90.8	100		
>7	Frequency	5	29	43		
	Percentage	14.7	85.3	100		

to 6 (13.1%) displayed a similar pattern of wood use for heating.

Table 12 presents results for solar water heating.

Cramer's V indicate that there is no association between household size and the use of solar water heaters.

Table 12: Household size influence on the use of solar water heating.

No. of members	Measurements	Yes	No	Total	P value	Effect size
1 – 3	Frequency	12	118	130	0.26	0.09
	Percentage	9.20	90.8	100		
4 – 6	Frequency	10	146	156		
	Percentage	6.40	93.6	100		
>7	Frequency	5	29	34		
	Percentage	14.7	85.3	320		

Table 13: Education's influence on the use of electricity for lighting, cooking and heating.

Qualification level	Measurements	Yes	No	Total	P value	Effect size
		Use of electricity for lighting				
Grade 12 and below	Frequency	52	2	54	0.5	0.07
	Percentage	96.3	3.7	100		
Diploma	Frequency	57	1	58		
	Percentage	98.3	1.7	100		
Degree	Frequency	86	5	91		
	Percentage	95.5	5.5	100		
Postgraduate	Frequency	106	7	113		
	Percentage	93.8	6.2	100		
		Use of electricity for cooking				
Grade 12 and below	Frequency	37	17	34	0.18	0.12
	Percentage	68.5	31.5	100		
Diploma	Frequency	48	10	58		
	Percentage	82.8	17.2	100		
Degree	Frequency	81	10	91		
	Percentage	89	11	100		
Postgraduate	Frequency	96	17	113		
	Percentage	85	15	100		
		Use of electricity for heating				
Grade 12 and below	Frequency	37	17	54	0.03	0.15
	Percentage	68.50	31.50	100		
Diploma	Frequency	48	10	58		
	Percentage	82.8	17.2	100		
Degree	Frequency	86	5	91		
	Percentage	95.5	5.5	100		
Postgraduate	Frequency	96	17	113		
	Percentage	85	15	100		

4.4 Education

The opinions of participants were assessed by evaluating the influence of primary income earners' educational levels on the household's fuel choice. Table 13 presents results for electricity use for lighting, cooking and heating. Cramer's V reflected small differences for cooking (0.12) and heating (0.15). Participants with higher qualifications such as postgraduates (85%) and degrees (89%) used electricity mostly for cooking in comparison with participants who possessed a diploma (82.8%) and grade 12 and below (68.5%). Participants with higher qualifications, postgraduates (85%) and

degrees (95%) used electricity mostly for heating compared with participants in possession of a diploma (82.8%) and grade 12 and below (68.5%).

Table 14 reflects results on the influence of educational level on the use of LPG and paraffin for cooking. It was found that there was an influence. Cramer's V indicated small-to-medium differences for the use of paraffin (0.19) and of gas (0.18). Participants with lower educational levels such as grade 12 and below (15.9%) and diploma (11.1%) used paraffin mostly for cooking compared with participants at higher educational levels: degree (3.3%) and postgraduate (3.4%). Participants with

Table 14: Education's influence on the use of liquefied petroleum gas and paraffin for cooking.

Qualification level	Measurements	Yes	No	Total	P value	Effect size
		Use of paraffin for cooking				
Grade 12 and below	Frequency	18	95	113	0.01	0.19
	Percentage	15.9	84.10	100		
Diploma	Frequency	6	48	54		
	Percentage	11.1	88.80	100		
Degree	Frequency	3	88	91		
	Percentage	3.3	96.7	100		
Post-graduate	Frequency	2	56	58		
	Percentage	3.4	96.6	100		
		Use of gas for cooking				
Grade 12 and below	Frequency	19	94	113	0.02	0.18
	Percentage	16.8	83.2	100		
Diploma	Frequency	15	43	58		
	Percentage	25.9	74.1	100		
Degree	Frequency	25	66	91		
	Percentage	27.5	72.5	100		
Post-graduate	Frequency	21	33	54		
	Percentage	38.9	61.10	100		

higher qualifications postgraduate (38.9%) and degrees (27.5%), used gas more than those with lower qualifications: diploma (25.9%) and grade 12 and below (16.8%).

Table 15 reflects results on the influence of educational level on the use of biomass for cooking and heating. The Cramer's V reflect that medium differences existed for educational level and household use of wood for cooking (0.29) and heating (0.20). Participants with lower qualifications: grade 12 and below (27.4%) and diploma (7.4%), used wood for cooking than participants with higher qualifications: degree (7.7%) and post-graduate (3.4%). Results also reflect that participants with lower qualifications: grade 12 and below (23.9%) and diploma (14.8%), used wood for heating more than participants with higher qualifications: degree (8.8%) and postgraduates (6.9%).

These tendencies might follow these patterns because higher educational levels will tend to deter-

Table 15: Education's influence on biomass use for cooking and heating.

Qualification level	Measurements	Yes	No	Total	P value	Effect size
		Use of wood for cooking				
Grade 12 and below	Frequency	31	82	113	<0.001	0.29
	Percentage	27.4	72.6	100		
Diploma	Frequency	4	50	54		
	Percentage	7.40	92.60	100		
Degree	Frequency	7	84	91		\
	Percentage	7.7	92.3	100		
Post-graduate	Frequency	2	56	58		
	Percentage	3.4	96.6	100		
		Use of coal for cooking				
Grade 12 and below	Frequency	6	107	113	0.52	0.08
	Percentage	5.3	94.7	100		
Diploma	Frequency	4	50	54		
	Percentage	7.4	92.6	100		
Degree	Frequency	3	55	58		
	Percentage	5.2	94.8	100		
Post-graduate	Frequency	2	89	91		
	Percentage	2.2	97.8	100		

Continued on next page

Table 15: Education's influence on biomass use for cooking and heating.

Qualification level	Measurements	Yes	No	Total	P value	Effect size
		Use of wood for heating				
Grade 12 and below	Frequency	27	86	113	<0.001	0.20
	Percentage	23.9	76.1	100		
Diploma	Frequency	8	46	54		
	Percentage	14.8	85.2	100		
Degree	Frequency	8	83	92		
	Percentage	8.8	91.2	100		
Post-graduate	Frequency	4	54	58		
	Percentage	6.9	93.1	100		
		Use of coal for heating				
Grade 12 and below	Frequency	6	102	108	0.31	0.09
	Percentage	5.3	90.1	100		
Diploma	Frequency	9	82	101		
	Percentage	9.9	90.1	100		
Degree	Frequency	6	48	50		
	Percentage	11.1	88.9	100		
Post-graduate	Frequency	3	55	58		
	Percentage	5.2	94.8	100		
		Use of coal for heating				
Grade 12 and below	Frequency	6	102	108	0.31	0.09
	Percentage	5.3	90.1	100		
Diploma	Frequency	9	82	101		
	Percentage	9.9	90.1	100		
Degree	Frequency	6	48	50		
	Percentage	11.1	88.9	100		
Post-graduate	Frequency	3	55	58		
	Percentage	5.2	94.8	100		

Table 16: Education's influence on solar water heating.

Qualification level	Measurements	Yes	No	Total	P value	Effect size
Grade 12 and below	Frequency	2	111	113	0.05	0.16
	Percentage	1.8	98.2	100		
Diploma	Frequency	1	90	100		
	Percentage	1.1	98.9	100		
Degree	Frequency	3	51	54		
	Percentage	5.6	94.4	100		
Post-graduate	Frequency	5	53	58		
	Percentage	8.6	91.40	100		

mine income, levels of comfort, and lifestyle.

The relationship between educational qualifications and the use of solar water heaters is presented in Table 16. The Cramer's V confirmed small differences for educational level and household use of solar water heaters (0.16). Participants with higher qualification: postgraduate (8.6%) and degree (5.6%) used more solar energy than those with lower qualifications: diploma (1.1%) and grade 12 and below (1.8%).

4.5 Gender

Gender assessment was made of the male and female participants' usage of different energy sources for domestic activities. Table 17 presents the results for lighting, cooking and heating. The Cramer's V reflects small differences for gender and the use of electricity for lighting (0.14) and cooking (0.16). Results indicate that male participants use electricity mostly for lighting (98.1%), compared to females (92.2). Results also reflect that male partic-

Table 17: The influence of gender on electricity use for lighting, cooking and heating.

Gender	Measurements	Yes	No	Total	P value	Effect size
		Use of electricity for lighting				
Male	Frequency	153	3	156	0.01	0.14
	Percentage	98.10%	1.90%	100%		
Female	Frequency	154	13	167		
	Percentage	92.20%	7.80%	100%		
		Use of electricity for cooking				
Male	Frequency	65	91	156	0.01	0.16
	Percentage	41.60%	58.40%	100%		
Female	Frequency	63	104	167		
	Percentage	37.70%	62.3%%	100		
		Use of electricity for heating				
Male	Frequency	121	35	156	0.34	0.05
	Percentage	77.60%	22.40%	100%		
Female	Frequency	122	45	167		
	Percentage	73.10%	26.90%	100%		

Table 18: The influence of gender on liquefied petroleum gas and paraffin use for cooking.

Gender	Measurements	Yes	No	Total	P value	Effect size
		Use of paraffin for cooking				
Male	Frequency	39	117	156	0.27	0.1
	Percentage	25	75	100		
Female	Frequency	47	120	167		
	Percentage	28.1	71.9	100		
Use of gas for cooking						
Male	Frequency	45	111	156	0.26	0.11
	Percentage	28.8	71.2	100		
Female	Frequency	39	128	167		
	Percentage	23.4	76.6	100		

ipants' use electricity most for cooking (41.6%), compared to females (37.7%).

Table 18 reflects the influence of gender on the use of LPG. The Cramer's V showed small differences for gender and the use of paraffin for cooking (0.1) and gas for cooking (0.1). Paraffin was more used for cooking by females (28.1%) than males (25%). Gas was used for cooking mostly by men (28.8%) than by females (23.4%). Inconsequential effect sizes were, however, reflected for gender influence on LPG use.

Table 19 presents the influence of gender on the use of biomass for cooking and heating. The Cramer's V indicated small differences for gender and the use of wood for cooking (0.14) and coal for cooking (0.12). Wood was used more for cooking by females (30.5%) than by males (12.2%). A noteworthy difference was recorded in the use of coal for cooking for female (10.8%) and male (5.8%).

Table 20 reflects results on the influence of gender on renewable energy use for heating. The Cramer's V reflect no significant differences for gender and the use of solar water heaters.

6. Conclusions

The research aimed to assess determinants of energy fuel choice in the South African household context by utilising the guidelines of the energy ladder and energy stacking hypotheses. Results were consistent with those of some previous studies, but some are unique to the South African context.

Findings reflected that high-income households tend to use more advanced energy sources of energy fuels than low-income ones in general. High-income groups used more electricity for cooking and heating. However, electricity is used by all income groups primarily for lighting. Low-income households tend to use paraffin for cooking, compared with high-income households that tend to use more LP gas. Solar water heaters are more used by high-income households for heating. Low-income households tend to use wood fuel significantly for cooking and heating. Coal tends to be used by low-income groups for cooking. Findings also reflect that monthly electricity expenditure above ZAR 300 is commoner with high-income households (81.1%) than low-income ones (27.8%).

Table 19: The influence of gender on biomass use for cooking and heating.

Gender	Measurements	Yes	No	Total	P value	Effect size
		Use of wood for cooking				
Male	Frequency	19	137	156	0.06	0.14
	Percentage	12.2	87.8	100		
Female	Frequency	51	116	167		
	Percentage	30.50	69.50	100		
		Use of coal for cooking				
Male	Frequency	6	161	167	0.26	0.12
	Percentage	3.60	96.4	100		
Female	Frequency	56	100	156		
	Percentage	36.	64	100		
		Use of wood for heating				
Male	Frequency	23	144	167	0.05	0.03
	Percentage	13.8	86.2	100		
Female	Frequency	25	131	156		
	Percentage	16	84	100		
		Use of coal for heating				
Male	Frequency	9	147	156	0.10	0.09
	Percentage	5.8	94.2	100		
Female	Frequency	18	149	167		
	Percentage	10.8	89.2	100		

Table 20: The influence of gender on solar water heating.

Gender	Measurements	Yes	No	Total	P value	Effect size
Male	Frequency	19	137	156	0.42	0.07
	Percentage	12.1	87.9	100		
Female	Frequency	4	120	167		
	Percentage	2.6	97.4	100		

Results reflect that household size will influence the use of energy for lighting, cooking and heating. Larger households tend to use LPG for cooking more than smaller ones. Household size has a limited influence on biomass use, except for wood for heating, and no influence on the use of solar energy for water heating. Results reflect that educational level correlate to household energy fuel choice. Household participants with higher educational qualification levels (postgraduates and degreed) have a greater tendency to use electricity for lighting, cooking and heating. Participants with lower academic qualifications (Diploma and grade 12 and below) use more paraffin for cooking while participants with higher qualifications tend more to use gas. For biomass, education greatly influences the use of woodfuel for both heating and cooking. Education has little impact on the use of solar energy for water heating.

As regards the influence of gender on energy choice, more male participants use electricity for lighting, cooking and heating than female ones. Males use gas fuel more for cooking while females use more paraffin. There were insignificant differences in biomass use between females and men, except for wood in cooking. The results also showed that more male participants utilise solar energy for heating than female participants.

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