Assessment of Household Energy Poverty levels in Louiville, Mpumalanga, South Africa

Shalala Mgwambani, Kevin K. Kasangana, Daniel Masekameni, Tafadzwa Makonese, Mary Gulumian and Thokozani P. Mbonane

Abstract— In this paper, an assessment of the extent of household energy poverty and the implications of socio-economic status of the households in Louiville (a rural settlement in Mpumalanga province, South Africa) is made. In total 165 households were sampled over the course of two years. A survey was conducted from a sample of 165 households recording objective data of energy expenses and subjective data about households' satisfaction with current energy sources versus what they can afford vis-à-vis their income. Using the objective approach, the results showed a high prevalence, over 84% (*n*= 138), resulting from both the escalation of energy prices and low household income. Among the households under the poverty threshold, high dependence on traditional fuels including wood, coal and candles was noted for cooking, heating and illumination purposes. The subjective indicator analysis showed that, although the majority of households use traditional fuels for cooking and heating, over 91% of these households are not satisfied with their current energy share owing largely to energy affordability. In conclusion, the establishment of affordable energy tariffs for the poor can address several energy inequalities in the poor settlement.

***Index Terms*— energy poverty, energy use, households, Louiville**

1 INTRODUCTION

Residential clean basic energy access is essential to address many of today's global challenges including poverty, health and education [1], [2]. Increasing the share and use of modern energy is associated with a reduction of human morbidity; while at the same time promotes environmental sustainability [2], [4], [8]. Globally, countries have worked to decrease human dependence on energy sources associated with the burden of the environment and human disease including wood, coal, paraffin, and animal dung [3], [5], [6].

In South Africa, current interventions to reduce energy poverty are undergoing with emphasis on increasing access to grid electricity for all [9], [10]. However, despite efforts by the government to address energy inequalities within the republic, research has proven that majority of poor people are still energy deprived [11], [12]. Recent literature reports have established a high prevalence of energy poverty mostly in rural, informal and peri-urban households [13], [14], [15]. Furthermore, more than 95% of these households are economically poor and cannot afford modern energy services [16], [18].

Lack of access to clean energy such as electricity leads to increased dependence on coal, wood, paraffin in most South African households [13],15], [19]. These fuels are often burned using inefficient technologies, thus stove/fuel combination, which contributes to household air pollution (HAP) [20,21]. HAP is associated with several diseases, which increase the risk of acute mortality. It is evident that women and children carry most of energy inequalities burdens. Also, combustion of traditional fuels (solid and liquid fuels such as paraffin) brings along incidental burns and shack fires [22], [26]. But, despite all such incidences, it is anticipated that energy deprived households will continue to rely on "dirty fuels" due to access or high cost of electricity [7], [14].

The objective of this study was to investigate energy poverty in Louiville, Mpumalanga Province, South Africa. The study ends by identifying transitional barriers thus energy switch from traditional fuels to electrical energy.

2 ENERGY POVERTY

The specification of what constitutes the basis to define energy poverty has been debated in recent years. Variation in the definition of energy poverty exists between developed and developing countries, rural and urban areas. Briefly, though, energy poverty can be defined as the lack of access to energy services up to a socially and materially necessitated level for a household [33], [44]. Based on this definition, the concept of energy poverty can be further divided into accessibility and affordability. Accessibility and availability are used synonymously. There is a close relationship between energy poverty and availability. The measurement of energy poverty based on energy availability considers several indicators including a household share of modern energy services such as electricity and the consumption of traditional energy carriers if any [44], [45], [46].

Regarding energy availability, South Africa still faces unprecedented energy inequalities. Despite effort made by

* "This work was supported in part by the University of Johannesburg, the National Institute for Occupational Health, the University of the Witwatersrand and Ehlanzeni District Municipality."

Kevin K. Kasangana, University of the Witwatersrand, Parktown, 2193, Johannesburg, South Africa, Department of Toxicology and Biochemistry, National Institute of Occupational Health, National Health Laboratory Service, PO Box 4788, Johannesburg, South Africa, 2000. (kevinkas93@gmail.com)

Daniel Masekameni, School of Public Health, University of the Witwatersrand, Parktown, 2193, Johannesburg, South Africa (danielmasekameni@gmail.com)

Tafadzwa Makonese, SeTAR Centre, University of Johannesburg, Bunting Road Campus, P. Bag 524, Auckland Park 2006, Johannesburg, South Africa (taffywandi@gmail.com)

Thokozani P. Mbonane, Department of Environmental, University of Johannesburg (Doornfontein Campus P. bag 17011, Doornfontein 2028, Johannesburg, South Africa (tmbonane@uj.ac.za)

Mary Gulumian, Department of Toxicology and Biochemistry, National Institute of Occupational Health, National Health Laboratory Service, PO Box 4788, Johannesburg, South Africa, 2000. (Mary.Gulumian@nhls.nioh.ac.za)

the democratic government in the past two decades, over 9% of households' lack access to modern energy [9]. As such, measures to alleviate energy poverty in South Africa through energy availability are yet to be fully implemented [11].

The second focal point of energy poverty is affordability. This approach considers the fuel price as a defining aspect of fuel accessibility. Fuel prices have limited poor households to use modern energy services [48], [49]. Although the world has so much evolved with the production of clean energy, the inability of poor households to purchase and use such fuel could still aggravate fuel poverty [50], [51].

South African households living in rural and peri-urban areas are most affected by the challenge to afford prices of modern energy sources such as electricity. The underlying cause of that being limited income access and high rate of unemployment in these households [13], [15]. Therefore, in measuring the extent of energy poverty, it is important to consider first the poor individual.

Furthermore, South Africa's literature on energy has explored several approaches for quantifying household energy poverty. One such approach consistent with other countries' worldwide is the expenditure approach. In this approach, energy poverty is determined at the expenditure poverty line, and data is usually acquired from household energy surveys [11], [32], [45]. Although the expenditure model is considered to be the universal approach for measuring household energy poverty, it has been drawn with some setbacks in the past. For example, Hills [42], [43] explained that literature reports have often not distinguished between household energy overconsumption and energy poverty. Thus, the tendency to exaggerate the status quo of energy poverty.

Other approaches used in the measurements of energy poverty include the income approach and the subjective approach. The income approach is used to determine the share of household income utilised to cover household's basic energy needs [52]. It has been reported that low-income group households spend more money to acquire energy services than high-income households [50,51]. The subjective approach, on the other hand, is concerned specifically with the amount of energy a household consumes and the minimum energy demand for human survival and development [33], [53]. In contrast with all other existing approaches, the subjective approach further determines household's satisfaction with their share of energy [41].

In the context of this paper, the household expenditure approach consistent with the definition by the Department of Energy [39] is used. The paper also includes a new indicator to the subjective measurement.

3 DATA

3.1 Study area

The study was carried out in Louiville, a remote area located in Barberton town in Mpumalanga province. The area connects to the Lily gold mines and is sandwiched by the Makhonjwa Mountains. Louiville is comprised of more than ten villages, all characterised by a lack of access to roads infrastructure and basic household services including water and sanitation.

The primary source of drinking water for residents is a nearby canal, where effluent from gold mining activities is also discharged. This canal is used for agricultural and animal farming, which are among the activities practised by the households for a living. Also, the walls of the dwellings in Louiville are built with reeds, poles and mud. However, other dwellings are made from corrugated iron sheets or concrete blocks and roofed with iron sheets.

Moreover, for many residents in Louiville, the primary language of communication is SiSwati, although isiZulu is also spoken by some limited number of households. It is believed that a considerable proportion of residents in Louiville migrated from Swaziland in search of employment in the area.

3.2 Questionnaire development and administration

Preliminary surveys (minor pilot) were conducted using a questionnaire tool in three of Louiville villages from July to August 2016. The survey used a convenient sampling technique due to small population size and gathered information on energy practices focusing on types of cooking fuels and devices, as well as the costs of fuels used daily for cooking, heating, lighting and entertainment.

The survey conducted in 2017 was extended to six other villages in Louiville, adding to the initial three study sites. The questionnaire used in the survey was adapted from the World Bank comprehensive living standards surveys [24] ,[25] and the Sustainable Energy Technology and Research Centre (SeTAR) questionnaire on household energy practices in informal settlements [13]. The questionnaire was structured with both closed and open-ended questions [25]. The final questionnaire instrument comprised of twenty-five questions relating to types of households' energy and stoves, energy costs and consumption practices, and factors influencing household fuel choices. A total of 165 questionnaires were completed and reported in this study.

3.3 Quality control

Several quality assurance procedures were followed during both phases of the study. Interviewers were subjected to a day training on the administration of the questionnaire instrument. Interviewers then administered the questionnaire to each other during the training session. After the completion of the training, the study was initiated, and the interviewers went from house to house administering the questionnaire [15]. All questionnaires containing errors were excluded from the survey results analysis.

4 RESULTS AND DISCUSSION

4.1 Study population demographics

Table 1 presents the demographics and socio-economic characteristics of the study population. One hundred and sixty-five households participated in the survey. About 70% (n= 115) of the households had no employment at the time this study was conducted, and only 18% were employed. But this outcome could have resulted from the stoppage of gold mining activities in the area as more than 80% of households had reported having worked in the mines in the past two years. The difference between the two datasets could be attributed to the lack of industrial development in the area; the gold mine was the primary source of employment for most households.

Additionally, the types of households' dwellings and the trends in education amongst households are also discussed in Table 1. Most households lived in mud houses, with only 5% living in concrete block houses. Furthermore, regarding education, only 23% had reached secondary school, while the remaining had either reached primary school or had never attained any level of education.

Table I. Study population: Demographics and socioeconomic characteristics.

Household (*n*= 165)	*n* (%)
Type of dwelling	
Mudhouse	137 (83)
Concrete blocks	3 (2)
Reeds	0
Corrugated iron sheets	22 (13)
Poles	3 (2)
Education	
Primary	109 (66)
Secondary	38 (23)
Tertiary	3 (2)
Other (no formal education)	15 (9)
Occupation	
Employed	50 (30)
Unemployed	115 (70)

4.2 Household energy use scenarios

According to the findings presented in this section, households in Louiville rely on a variety of fuels to complete their basic household's activities. Wood is the most abundant household fuel as shown in Table 2. It was reported that 97% of households primarily relied on this fuel for cooking and heating. In addition to wood, the other types of fuels available at households in Louiville included gas (14%) and paraffin (38%).

Although Louiville is situated in the Lowveld, where fuel such as coal is rarely or not found, the findings of this study have outlined something different. About 45% of households in Louiville used, though occasionally, coal for household cooking and heating. Households reported on occasional merchandise of this fuel by local and transient merchants. These findings are comparable to the results from Kasangana *et al*. [27] where households in the Lowveld used coal in addition to other energy sources for cooking and heating.

Moreover, 70% of households (*n*=115) were connected to the electricity grid. Of those 115 households, 100% used electricity for illumination, while 4% and 7% of households used it for cooking and heating, respectively. The remaining proportion of household electricity is either used for entertainment, refrigeration and continuous maintenance of randomly reported electrical devices including computer and microwaves. This finding is similar to other studies [15], where the high price for electricity (See Table 2) limited its usage to illumination and entertainment at the household level. Currently, the electricity tariffs for indigent homes are set at R1.25 per kWh. With such tariffs, a household would spend R450 optimally (that is an additional R149 on top of what the householder can afford) on electricity if appliances such as heaters are not used for 24 hours [56].

Moreover, the limited use of electricity might have also been influenced by the distribution of electrical appliances/ devices per household as depicted in Table 3. Except for cell phones where the distribution rate was recorded at 92%, the remaining appliances were seldom found in most households.

"*Electricity is not easily affordable in this area. The promise by the government to provide free basic electricity for all has never been achieved. Consequently, having an electrical device means being able to use and maintain such device or replace especially when the older one is damaged*". Householder respondents.

Table II. Energy choices for cooking, heating and lightning.

Fuel type	Household tasks		
	Cooking	Heating	Lighting
Electricity	5 (4%)	8 (7%)	115 (100%)
Wood	160 (97%)	157 (95%)	0
Coal	75 (45%)	75 (45%)	0
Gas	23 (14%)	5 (3%)	0
Paraffin	63 (38%)	7 (4%)	3 (2%)
Candles	0	0	50 (100%)

Table III. Distribution of electrical appliances at the household level (***n***= 165).

Category	Status of availability	
	Yes	No
Electric stove	5 (3%)	160 (97%)
Water heater	8 (5%)	157 (95%)
Cellphone	152 (92%)	13 (8%)
TV	95 (58%)	70 (42%)
Computer	6 (4%)	159 (96%)
Microwave	28 (17%)	137 (83%)
Iron	3 (2%)	162 (98%)
Refrigerator	32 (19%)	133 (81%)
Radio	87 (53)	78 (47%)

4.3 Households energy expenses and energy poverty in Louiville

As Table 4 demonstrates, of the six types of household's fuels in Louiville, households spent the most money on electricity and coal. However, the price attached to each fuel type plays an important role in household's selection of energy carriers. Most households using wood for cooking and heating spent between R0 and R100 as the fuel is available for collection free of charge or a small fee at several sites in the area.

"*The dependence on wood fuel for daily cooking or heating is in part because the fuel is readily available in the whole area, mostly for free. However, in times when the fuel cannot be collected, we spend relatively little to acquire it*". Householder respondent.

"*To burn wood, one does not necessarily need stoves. We usually use a three-stone setup, although this practice is challenging during rainy seasons*". Female householder respondent.

Gas and paraffin had similar sale prices. However, the use of these fuels was not frequently reported. This could have

been influenced by the abundance of wood fuel and limitations in fuel merchandise at the site of the study. Moreover, candles which are used only for lightning had the lowest cost. But candles are included in Table 4 because the costs of energy for illumination by candles still forms an important aspect of the overall household energy budgets [13].

Table IV. Energy costs (Figures are averaged).

Fuel type	Fuel price	
	Month	Year
Electricity	R301	R4104
Paraffin	R289	R3468
Wood	R100	R1200
Candles	R66	R912
Coal	R281	R4056
Gas	R289	R3468

According to Papada & Kaliampakos [28], household energy poverty can be presented using both subjective and objective indicators. In Papada & Kaliampakos [28], the subjective indicators are limited to the household's inability to keep their house warm and structural formation of the house as well as house maintenance. In the context of this research, households were specifically questioned about their satisfaction with the energy supply present at home during the time of this research.

Furthermore, in contrast with subjective indicators, objective indicators are based on sets of conventionally prescribed methods. These methods use indicators such as household income and the allocation of fractions of such income to access modern energy services [28], [29], [30], [31]. The following two subsections present the findings of energy poverty in Louiville based on subjective and objective indicators.

4.3.1 Subjective indicator of energy poverty

In determining the subjective indicator of energy poverty, areas of utilities such as household's energy sources (clean versus dirty); household energy preferences and their energy selection during the time of the study were all computerised. Moreover, further aspects of energy poverty such as a switch from the current energy source to grid electricity or other clean fuel were also considered. The indicator of subjective energy poverty was then determined as follow:

$$Subjective = \frac{\text{House energy+preferences}}{\text{Study population}} \times 100 \qquad \text{Equation 1.}$$

According to the pooled cross-sectional results presented in Fig. 1, there only 9% of respondents were satisfied with their energy sources, while the others reported that they are dissatisfied with their energy share. Dissatisfied households believed the electricity prices are overexaggerated; consequently relying on electricity for their daily activities could probably mean increasing their monthly energy budget. Therefore, a switch to grid electricity or other clean energy sources would solely depend on affordability.

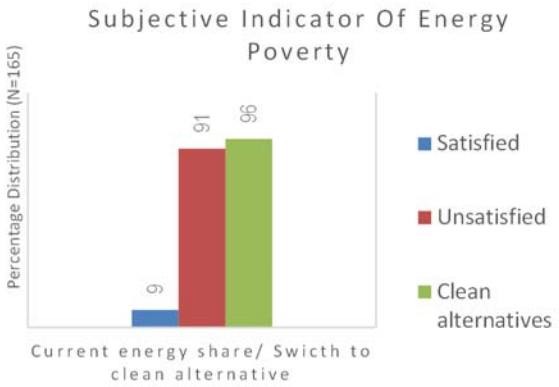

Fig. 1. Subjective indicator of energy poverty.

The issue of satisfaction with one's energy sources has not been extensively debated in the South African literature, especially regarding household energy poverty. In South Africa, as for most countries at a global scale, research on energy poverty places much weight parameters making the multidimensional energy poverty index [32], [33]. In this paper, subjective opinions are first considered to define influence on household's energy source preferences. This could represent a critical aspect of factors to be considered in remediating energy poverty in dissatisfied households.

4.3.2 Objective indicators of energy poverty

4.3.2.1. Characteristics of household income

The percentage distribution of households with formal employment in Louiville is 18%. The majority of households (85%, *n*= 98) with no formal employment are dependent on a single social grant or a combination of multiple grants including care dependency grant, social relief distress grant as well as foster child grant, for survival. Some households are supported financially by relatives who reside elsewhere and not in the case study area.

However, for both households without employment and those with employment or even those who depend on social grants, the median household income ranged between R1500 and R5000 per month. About half (55%, *n*= 85) of the sampled households earned a monthly income between R2000 and R2800, and R24000 and R33600 per annum. The highest monthly income recorded for a single household was R6000, while the lowest was R1200.

Table V. Characteristics of household income group.

Income group	Income distribution per household	
	Income (R)	*n*
Group 1	R0 - R1500	17
Group 2	R1501 - R3000	105
Group 3	R3001 - R5000	27
Group 4	≥ R5001	16

4.3.2.2. Energy expenditure patterns

The costs per month for each type of household energy source is presented in Table 4. In general, households used two or more sources of energy for completion of their activities. While wood was reported as the most used fuel for cooking and heating, the average monthly expenses on firewood are relatively lower in comparison to the other fuels. However, in most households, the energy share budget

increases with the addition of electricity and candles (See Table 4).

It was previously noted that electricity is not distributed throughout the entire Louiville community. There are other households, which are not connected to the main grid. Thus, households with no access to grid electricity would depend on multiple fuels to meet their monthly energy needs. The prevalence of electricity use for all the household activities was noted in the income group 4, where household earned up to R6000 per month.

Table VI. Energy expenses patterns and fuel uses per household (***n***= 165).

Total number of fuels used	*n* (Households)
1 (Electricity)	5
2 (Electricity + wood/ coal)	35
3 (Electricity+ wood/ coal + candles)	51
3 (Electricity+ paraffin/ gas +candles)	23
3 (Wood/ coal/+ paraffin/ gas +candles)	50

4.3.2.3. Determining the extent of energy poverty in Louiville using the objective approach

In determining the extent of energy poverty in Louiville, the paper first applies the expenditure model of the Department of Energy [32], [33]. This model based on the household expenses stipulates that a household is energy poor when 10 percent or more its income is spent on energy only. Hence, the need for the provision of data on household income and energy share budget. Therefore, to determine whether a household is energy poor, the summation of all energy expenditure was taken as a proportion of household income, and it is represented by the following equation:

$$Energy\ budget\ share\ = \frac{\text{Energy expenses}}{\text{Income after tax}} \times 100 \quad \text{Equation2.}$$

Based on the above model, all households whose energy budget was 10 percent or more of their income were regarded as energy poor. Consequently, those who were spending less than 10 percent of their income on energy were not considered to be energy poor.

The results of the survey on energy are first given according to income. Four income groups were identified in Table 5 with group one income category dependent on social grants, while income group (4) earned the highest income per month. All (*n*= 17) respondents in the first income group used wood and candles for cooking, heating and lightning, respectively. Over the course of a month, each household spent R66 on candles and R100 on wood. The combined monthly energy expenses equalled R166, which equated to 11% of the household income. This suggests that 17 out of 17 households in income group 1 can be considered energy poor.

According to Rahut *et al.* [35], the trends in the type of energy used for household activities varies according to income groups. A similar trend was found with income groups 2. This accounted for 105 households, and a single household earned an average amount of R2800 per month. Regarding energy sources, households relied on multiple fuels including electricity, which they mainly used for lightning. In households where electricity and wood were the main fuels, the median energy expense was R402, making 14.3% of household income. On the other hand, households that used coal instead of wood would spend R583, which equated to 20.8% of their income. Although household coal reserves were mostly carried over 30 days in some households, all households in income group 2 would still be considered energy poor as they spent above 10% of their income on the energy budget

Moreover, similar energy expenditure trends were also noted for the third income group; though, the energy share budget accounted for 8% of the household income. This finding could have been influenced by increasing household income as also noted in Barnes et al., [33], where increasing household income made households less energy poor.

All the households using electricity in income group 4 reported using it mostly for illumination, except for five households where electricity was used for all the household primary activities (Cooking, heating, illumination). In these households, the energy expenditure was R603, while the ones that added other fuels spent by average R528 on fuel budget. The proportion of energy share was 10.05% and 8.8 %. This suggests that five out of 16 households in income group 4 are energy poor. The five households are dependent on electricity for their daily energy.

4.3.3 Relationship between objective and subjective indicators of energy poverty and policy implications

An attempt was made to understand the association between the objective indicators of energy poverty and the subjective indicator. In the case of subjective indicators, it was reported that over 90% of households were not satisfied with their current energy share. Several households reported relying on raw energy because they were unable to afford the costs associated with grid electricity. Moreover, the strain of maintaining clean energy appliances/ devices as well as the ability to afford one, also played a role in the disinclination of households to switch to complete use of grid electricity.

Furthermore, reporting on the issue of affordability, high-income households were in a position for opting for electricity only or just one additional fuel as shown in Table 6. However, households who were dependent on electricity only were found to be energy poor in comparison to those who used electricity with wood or another fuel. This finding is in line with other similar studies, where households' dependence or one fuel type (electricity) did not reduce the likelihood of energy poverty. Households traditional fuels are usually purchased at a lower price and have implications for household's energy budget [28], [30], [37], [38]. In households where electricity was the only source of energy, electrical appliances used for household's activities were found, whereas the ones that used multiple fuels did not have some of these appliances.

There was also the relationship between household energy poverty and categories of income groups. Income group 2 households spent a higher share of their income on energy services relative to the rest of the groups. Several scientific investigations had reported similar findings. For instance, Pachauri and Jiang [40], as well as Pachauri et al. [53], reported that low-income households spend more money to acquire energy services than high-income households based

on their income rates. Therefore, a limited income will continue to aggravate poverty.

Furthermore, energy poverty has been at the centre of political debates in South Africa. Recent energy debates have led to the removal of the value-added tax on all liquid fuels as well as the dissemination of grid electricity subsidy especially for the poor. It is clear from this assessment that households largely depend on other energy sources (e.g. Candles) rather than the liquid fuels from which the value-added tax has been offset [7], [34], [54]. This aspect could be considered in future energy policy interventions in areas such as Louiville. Finally, the establishment of affordable energy tariffs for the poor can address several energy inequalities in poor settlements. Strategies could include reducing the costs per unit for grid electricity and disseminating other clean energy sources including LPG and solar energy. The transport and sale opportunities of these energy sources in the local community could also create business opportunities for local people, thus bridging the gap between fuel access and poverty in the long run.

The above findings should be regarded with caution, as there been other important variables that have not been presented in this paper. For instance, the unit cost for fuels consumed at the household level and, the cost of cooking appliances, the relationship between education variables, number of people in a household, fuel choices and amount of fuels consumed have not been studied. These factors could shed light on household fuel selection, thus better understanding of energy poverty in Louiville.

5 CONCLUSION

The focus of this study was to shed light on trends in household energy poverty in Louiville. The results showed that energy poverty is widespread throughout the entire Louiville community. The paper also explained using the expenditure model that both income and energy cost are positive factors in worsening energy poverty. As such, households in Louiville will continue burning traditional fuels including coal, wood, paraffin and candles to complement their energy needs.

This observation has got policy implications on energy poverty alleviation and increased access to clean energy primarily for cooking and heating. Poor households can be made less energy poor by making all energy sources affordable. However, in the long run, energy interventions in this area need to consider eradicating continuous household dependence on polluting fuels as this has both direct and indirect implications for human health and the environment at a larger extent.

ACKNOWLEDGEMENTS

This research was supported by the University of Johannesburg, Department of Environmental Health, Ehlanzeni District Municipality, University of the Witwatersrand and the National Institute for Occupational Health. The authors thank the colleagues and students for assistance with data collection and Mr Shalala Leonel Mgwambani for help with data capturing.

REFERENCES

[1] United Nations Development Programme. (2016). Sustainable Development Goals. Available from http://www.undp.org/content/undp/en/home/sustainable-development-goals.html

[2] S. O. Oyedepo, (2012, June). On energy for sustainable development in Nigeria. *Renewable and Sustainable Energy Reviews, 16(5),* pp. 2583-2598.

[3] F. S. Javadi, B. Rismanchi, M. Sarraf, O. Afshar, R. Saidur, H. W. Ping, N. A. Rahim. (2013, March). Global policy of rural electrification. *Renewable and Sustainable Energy Reviews*, *19*, pp. 402-416.

[4] M. Barron, M. Torero. (2017, Nov). Household electrification and indoor air pollution. *Journal of Environmental Economics and Management*, *86*, pp. 81-92.

[5] L. Bretschger, A. Schaefer. (2017, Oct). Dirty history versus clean expectations: Can energy policies provide momentum for growth? *European Economic Review*, *99*, pp. 170-190.

[6] S. Griffiths. (2017, March). A review and assessment of energy policy in the Middle East and North Africa region. *Energy Policy*, *102*, pp. 249-269.

[7] B. Bekker, A. Eberhard, T. Gauntand, A. Marquard. (2008). South Africa's rapid electrification programme: Policy, institutional, planning, financing and technical innovations. *Energy Policy, 36(8),* pp. 3115 – 3127.

[8] T. Bernard, M. Torero, (2009). Impact of Rural Electrification on Poorer Households in Ethiopia. Report for the World Bank, Washington, DC.

[9] Department of Energy, (2013). Integrated Resource Plan for Electricity (IRP) 2010-2030. Update Report 2013. Pretoria: Department of Energy.

[10] W. Barnard, (2011). Background to SA Electrification Program [Presentation], Department of Energy, Republic of South Africa. 11 November. Available at: http://siteresources.worldbank.org/EXTAFRREGTOPENERGY/Resources/717305- 1327690230600/8397692-1327691245128/WolseyBarnard_AEI_Presentation1 1Nov11.pdf

[11] Z. Ismail. (2015). An Empirical Estimation of Energy Poverty in Poor South African Households. *Journal of Economics and Sustainable Development*, *6(13)*, pp. 184-192.

[12] Department of Energy, (2012). A Survey of Energy-related Behaviour and Perceptions in South Africa: The Residential Sector. Pretoria: Department of Energy.

[13] T. Makonese, M.D. Masekameni, H.J. Annegarn, "Energy use scenarios in an informal urban settlement in Johannesburg, South Africa", in *Proceedings of the 24th Domestic Use of Energy Conference (DUE)*, 2016, pp. 1-6.

[14] M. Balmer. (2007, August). Household coal use in an urban township in South Africa. *Journal of Energy in Southern Africa, 18(3),* pp. 27-32.

[15] P. Lloyd. (2014, Aug.). The energy profile of a low-income urban community. *Journal of Energy in Southern Africa, 25(3),* pp. 80 – 85.

[16] University of South Africa, (2012). Income and Expenditure of Households in South Africa, Bureau of Market Research. Information Blurb, University of South Africa. Available at: http://www.unisa.ac.za/contents/faculties/ems/docs/Pr ess429.pdf

[17] D. K. Kimemia, A. van Niekerk, (2017). Energy poverty, shack fires and childhood burns *South African Medical Journal, 107(4*), pp. 289-291.

[18] Department of Energy, (2013) Integrated Energy Planning Report-2012 Department of Energy, Republic of South Africa. Available at: http://www.energy.gov.za/files/IEP/IEP_Publications/D raft-2012-Integrated-Energy-Plan.pdf

[19] Department of Energy, (2012). A Survey of Energy-related Behaviour and Perceptions in South Africa: The Residential Sector. Pretoria: Department of Energy.

[20] T. Makonese, D. M. Masekameni, P. Forbes, H. J. Annegarn. (2015, November). Influence of fire-ignition methods and stove ventilation rates on gaseous and particle emissions from residential coal braziers, *Journal of Energy in Southern Africa, 26(4),* pp. 16-28.

[21] M.D. Masekameni, T. Makonese, H.J. Annegarn, "Performance Evaluation of Three Charcoal Stoves", in *Proceedings of the 24th Domestic Use of Energy Conference (DUE)*, 2016, pp. 36-43.

[22] L. Masondo, M.D. Masekameni, T. Makonese, H. J. Annegarn, K. Mohapi. (2016). Influence of coal-particle size on emissions using the top-lit updraft ignition method. *The Clean Air Journal*, *26(1),* pp. 16-20.

[23] D. Kimemia, C. Vermaak, S. Pachauri and B, Rhodes. (2014, February). Burns, scalds and poisonings from household energy use in South Africa: Are the energy poor at greater risk. *Energy for Sustainable Development*, *18*, pp. 1-8.

[24] A. Deaton, M. Grosh, "Consumption" in Designing Household Survey Questionnaires for Developing Countries: Lessons from 15 Years of

the Living Standards Measurement Study Surveys. The World Bank, Washington, D.C, 2000.
[25] R. Kitchin & N.J. Tate, "Conducting Research in Human Geography: Theory, Methodology and Practices". Harlow: Prentice Hall, 2000.
[26] S. B. Gordon, N. G. Bruce, J. Grigg, et al. (2014). Respiratory risks from household air pollution in low and middle-income countries. *The Lancet Respiratory Medicine Commission, 2(10),* pp. 832-860.
[27] K. K. Kasangana, M. D. Masekameni, S. S. Saliwa, "Exploring access to clean energy for various domestic uses in Mpumalanga province, South Africa", in *Proceedings of the 25th Domestic Use of Energy Conference (DUE),* 2017, pp. 116-120.
[28] L. Papada & D. Kaliampakos. (2016, July). Measuring energy poverty in Greece. *Energy Policy, 94,* pp. 157–165.
[29] H. Thomson and C. Snell. (2013, Jan). Quantifying the prevalence of fuel poverty across the European Union. *Energy Policy, 52,* pp. 563–572.
[30] S. Okushima. (2016, Nov). Measuring energy poverty in Japan, 2004–2013. *Energy Policy 98,* pp. 557–564.
[31] P. Nussbaumer, M. Bazilian, V. Modic. (2012). Measuring energy poverty: Focusing on what matters. *Renewable and Sustainable Energy Reviews, 16(1),* pp. 231– 243.
[32] Z. Ismail and P. Khembo. (2015). Determinants of energy poverty in South Africa. *Journal of Energy in Southern Africa, 26(3),* pp. 66-78.
[33] D. F. Barnes, R. K. Shahidur, A. S. Hussain. (2011, Feb). Energy poverty in rural Bangladesh. *Energy Policy, 39(2),* pp. 894-904.
[34] Department of Energy (2009). Socio-Economic Impact of Electrification: Household Perspective 2009.
[35] D. B. Rahut, S. Das, H. De Groote and B. Behera, (2014, May). Determinants of household energy use in Bhutan. *Energy, 69,* pp. 661-672.
[36] C. Vermaak. (2014). Developing an Energy-Based Poverty Line for South Africa. *Journal of Interdisciplinary Economics, 7(1),* pp. 127-144.
[37] N. M. Rao and B. S. Reddy. (2007). Variations in energy use by Indian households: an analysis of micro-level data. *Energy, 32(2),* pp. 143-153.
[38] M. Farsi, M. Filippini, S. Pachauri. (2007, Dec). Fuel choices in urban Indian households. *Environmental and Development Economics, 12(6),* pp.757.
[39] S. R. Khandker, D. F, Barnes, & H. A. Samad. (2012). Are the energy poor also income poor? Evidence from India. *Energy Policy, 47,* pp. 1-12.
[40] S. Pachauri, L. Jiang. (2008). The household energy transition in India and China. *Energy Policy, 36(11),* pp. 4022-4035.
[41] K. Wang, Y. Wang, K. Li, and Y. Wei. (2015, July). Energy poverty in China: An index based comprehensive evaluation. *Renewable and Sustainable Energy Reviews,* 47, pp. 308–323.
[42] J. Hills. (2011). Fuel Poverty: The Problem and its Measurement. Department of Energy and Climate Change, Government of UK, London.
[43] J. Hills. (2012). Getting the Measure of Fuel Poverty. Department of Energy and Climate Change, Government of UK, London.
[44] M. G. Pereira, M. A. V. Freitas, & N. F. da Silva, (2011, Jan). The challenge of Energy Poverty: Brazilian case study. *Energy Policy 39,* pp. 167–175.
[45] R. Mould & K. J. Baker. (2017). Documenting fuel poverty from the householders' perspective. *Energy Research & Social Science, 31,* pp. 21–31
[46] M.G. Pereira, M.A.V. Freitas, N.F. da Silva. (2010). Rural electrification and energy poverty: empirical evidences from Brazil. *Renewable and Sustainable Energy Reviews, 14 (4),* pp. 1229-1240.
[47] N. Jamal. (2015). Options for the supply of electricity to rural homes in South Africa. *Journal of Energy in Southern Africa, 26(3),* pp. 58-65.
[48] Z. Jiang and J. Tan, (2013, December). How the removal of energy subsidy affects general price in China: A study based on input-output model. *Energy Policy, 63,* pp. 599-606.
[49] M. Bazilian, P. Nussbaumer, H.-H. Rogner, A. Brew-Hammond, V. Foster., et al. (2012). Energy access scenarios to 2030 for the power sector in sub-Saharan Africa. *Utilities Policy, 20,* pp. 1–16. doi:10.1016/j.jup.2011.11.002.
[50] C. Sun and X. Ouyang. (2016, Jan). Price and expenditure elasticities of residential energy demand during urbanization: An empirical analysis based on the household-level survey data in China. *Energy Policy, 88,* pp. 56-63.
[51] Z. Jiang, X. Ouyang, G. Huang. (2015,). The distributional impacts of removing energy subsidies in China. *China Economic Review, 33,* pp. 111-122.
[52] E. Fahmy. (2011). The definition and measurement of fuel poverty. A briefing paper to inform consumer focus's submission to the Hills fuel poverty review, University of Bristol.
[53] S. Pachauri, A. Mueller, A. Kemmler. (2004). On measuring energy poverty in Indian households. *World Development, 32(12),* pp. 2083–104.
[54] F. Adam. (2010, Feb). Free Basic Electricity: A Better Life for All, Earthlife Africa, Johannesburg.
[55] Department of Mineral and Energy, (2004, May). Free basic energy policy guidelines (low-income household energy support programme, Department of Mineral and Energy: South Africa.
[56] Eskom (2016). Tariffs and charges booklet 2016/2017. Accessed on [2018-01-22] from www.eskom.co.za/tariffs

AUTHORS BIOS AND PHOTOGRAPHS

Kevin K. Kasangana is a medical scientist and researcher at the National Institute for Occupational Health. He holds a bachelor's degree in environmental health, and he is currently enrolled for the degree of Master of Public Health in Occupational Hygiene at the University of Witwatersrand. His current research interests are in toxicological behaviours of nanoparticles emissions from synthetic laboratories and household combustion technologies. kevinkas93@gmail.com

Tafadzwa Makonese is an energy and air quality specialist with the SeTAR Centre, University of Johannesburg. He holds a PhD in Energy Studies from the University of Johannesburg. His current research interests are in air pollution and related health effects. He has researched the development of culturally appropriate stove performance testing protocols, and their usefulness in wider stove dissemination programmes funded the World Bank, the Global Alliance for Clean Cookstoves (GACC) and others. taffywandi@gmail.com

Thokozani P. Mbonane is a Lecturer in Environmental Health at the University of Johannesburg. He completed his MTech Degree at the University of Johannesburg and currently doing doctoral studies focusing on lifetime lead exposure and antisocial behaviour (aggression). His current interests are on the health impact from environmental exposure to heavy metals (lead, mercury, cadmium). tmbonane@uj.ac.za