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Analysis of Household Energy Uses in Mubuga Informal Settlement, Gitega, Burundi

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ABSTRACT This paper presents an analysis of household energy uses in an informal settlement in Mubuga, Gitega, Burundi. At the time of the survey, the houses in Mubuga were not connected to the national electricity grid. Data were collected from a survey of 100 households through structured and open interviews. Of the interviewed households, 84 percent indicated that they used fuelwood as a primary energy source for cooking. About 94 percent used charcoal for commercial (barbecuing/grilling meat) purposes and 22 percent used it for domestic cooking. For lighting, kerosene accounted for 55 percent followed by candles (36%) and rechargeable lanterns (10%). Households in Mubuga used multiple energy carriers for cooking and heating needs. It is therefore recommended that intervention models that advocate for multiple fuel use should be promoted in the area. This allows indigent families to freely choose cooking fuels from a set of options.

INTRODUCTION

Lack of access to electricity continues to hamper the development of sub-Saharan Africa (SSA). According to Kimemia and Annegarn (2012), a country's level of socio-economic development is indicated by the level of access to clean and modern energy services or the lack thereof. It can be argued that lack of access to proper levels of energy services is responsible for the slow social-economic growth in the developing world (Kimemia et al. 2012; Panos et al 2015). In 2010, it was estimated that of the 860 million people inhabitant in SSA, 590 million lacked access to electricity (IEA 2010; Panos et al. 2015). In Burundi, the majority of households live in abject *energy poverty*. Lack of access to affordable electricity is a major determinant of *poverty* in the country. According to the Ministry of energy and minerals, about 97 percent of Burundians primarily rely on biomass fuels for cooking and heating purposes, while access to electricity remains low at 10 percent (République du Burundi 2011). The Urban population remains underserved by inefficient and unreliable energy systems, while many rural villagers have no access to electricity.

The Millennium Development Goals (MDG) cannot be realised without affordable, accessible and reliable energy services (UN Energy 2015). To meet these objectives, the government of Burundi has engaged in the development of policies and action plans for the energy sector. The policies aim to facilitate, in a sustainable manner, the supply and demand for energy in all sectors of the economy, including investing in renewable energy technologies.

Despite progressive pro-poor policies by the Burundi government, the majority of the population still live in poverty and inequality has deepened. Due to collapsed water and electricity infrastructure as a result of the civil war, the majority of Burundians, regardless of wealth status, heavily rely on forest resources for cooking and heating needs. The fuel is burned in an unsustainable manner using open fires and inefficient cookstoves, resulting in elevated levels of household and local ambient air pollution. The incomplete combustion of woody biomass leads to the release of particulate matter (PM) and noxious gases that have been shown to be damaging to human health in the household environment (Levin et al. 2016; Mitchell et al. 2016). Cooking over open fires causes severe burns, especially for children and women who spent a considerable time near cooking devices. Exposure to smoke results in eye infections and low birth weight can be a consequence of exposure to carbon monoxide during pregnancy (Chakraborty et al. 2014). The World Health Organization (WHO) has reported that on an annual basis, about 4.3 million premature deaths

are recorded and are directly attributable to household air pollution (HAP) from solid fuel use (SFU) (WHO 2014). More than half of these deaths occur in children under the age of five years. Household air pollution (HAP) is associated with increased morbidity making people susceptible to acute and chronic respiratory disorders, and pulmonary and systemic diseases (Gordon et al. 2014).

On the other hand, the continued use and reliance on fuelwood and charcoal is a major cause of deforestation in Burundi and other developing countries (Colombo et al. 2014; Marengo and Espinoza 2016). Although the collection of firewood and making of charcoal are not the only contributors to deforestation, in SSA the link is more evident (Colombo et al. 2014). Deforestation is exceptionally harmful to the natural environment, as it results in decreased biodiversity and increased rates of soil erosion. The clearing of trees for agricultural and energy purposes interrupts the natural hydrological cycle, as trees participate in the absorption of ground water and evaporation of water vapour (Bradford 2015). This leads to a drier climate and increases the potential risk of floods in areas situated downstream of rivers (De la Paix et al. 2013; Marengo and Espinoza 2016). There is clear evidence that deforestation results in increased levels of CO_2, by changing the carbon cycle (Smith et al. 2004; EPA 2015).

In light of the above, robust policies and strategies are needed to improve access to cleaner and efficient energy technologies as well as reducing the health burden associated with the use of traditional technologies and fuels. This can be achieved through the promotion of more efficient energy technologies and the sustainable use of traditional fuels. Through government and donor funded awareness campaigns, households should be encouraged to adopt modern energy carriers (*switch* from traditional fuels) and technologies. It is expected that the number of people who rely on forest resources will continue to increase if robust policies to expand access to modern fuels are not put in place. Despite the energy policies put in place by the government of Burundi to increase access to electricity, the majority of the households will remain without electricity connections into the foreseeable future, while some will not be able to afford the commodity. However, improving access to appropriate levels of modern energy services is required to improving public and environmental health, education, and reducing risks of burn injuries (Heltberg 2003; Makonese et al. 2016).

Realising the influence of household fuel use patterns on health and the environment, various studies have researched household fuel uses and choice determinants in various geographical locations and dwelling types. For example, various studies have been carried out in informal settlements (Wolpe and Reddy 2010; Lloyd 2014; Makonese et al. 2016) and in rural communities (Madubansi and Shackleton 2003; Masekoameng et al. 2005). Country and in-country studies on household energy uses and choice determinants have been carried out by Chen et al. (2016) for Sichuan, a rural village in China, Rahut et al. (2016) for Bhutan, van Gevelt et al. (2016) for an energy poor Rwandan village, Bamiro and Ogunjobi (2015) for Nigeria, Mwaura et al. (2015) for Kenya, Mensah and Adu (2013) for Ghana, Jan et al. (2012) for Pakistan and Heltberg (2003) for Guatemala, to mention a few. However, there are currently limited country- or in-country studies for Burundi focusing on household fuel use patterns or choice determinants.

This paper aims to investigate household fuel use scenarios in the Mubuga informal settlement, Gitega, Burundi. In carrying out the interviews, we were more interested in baseline access situations and any health related issues as a function of the continued use of traditional fuels. Strategies for improving access to modern forms of energy carriers and feasible ways of addressing the issue of fuel stacking/ multiple fuel use versus the *energy ladder* model are discussed and recommendations are given.

METHODOLOGY

Study Area

The surveys were carried out in an informal settlement in Mubuga, Gitega, Burundi. The area is situated about 100 km, north of the capital city of Bujumbura. Mubuga is located 2° 59' 12" S (Latitude) and 29° 36' 00" E (Longitude). The area is not connected to the national electricity grid, which is about 11 km from the informal settlement. There, however, have been efforts made by the Burundi government to generate solar electricity in that area. There is a 7, 5 MW solar

plant earmarked for the area. Residents of Mubuga are dependent on biomass fuels (firewood, charcoal, and agricultural waste), rechargeable electric lanterns, and candles to meet their basic cooking and lighting needs. The main dwelling houses are made of brick and mortar, with separate kitchen huts made from pole and clay. These are low-cost dwellings and they require less maintenance. The quality housing is poor in this informal settlement, as the buildings were not constructed following any set of housing standards. However, the walls of the houses are constructed using fired clay bricks, with the floors constructed from mud. Mud floors are hard, cheap, impervious, and easy to maintain. The roofing is mostly constructed with informal materials including dry grass or thatch, palm leaves, and corrugated iron sheets. The Meals are often cooked outdoors; the kitchens are outside of the main dwellings.

Questionnaire Surveys and Interviews

The questionnaire used herein was developed and employed in the case study area in December 2015, to collect information pertaining to energy use patterns. The following specific information was gathered:

- Fuel types and combustion technologies
- Socio-economic factors influencing stove and fuel choices;
- Fuel procurement;
- Quantity and cost of fuel used, primary for cooking, lighting, and meat grilling
- The cost of combustion devices.

The interviewers (administrators) were selected from the informal settlement and were trained to conduct the interviews using the developed questionnaire, first by testing the questionnaire on each other (Masekoameng et al. 2005; Scorgie et al. 2011; Kimemia and Annegarn 2012; Makonese et al. 2016). When the training exercise was over, the administrators took part in a pilot study to test the questionnaire on ten respondents who were not going to take part in the survey (Kitch et al. 2000). Similar to Makonese et al. (2016) and Kitch et al. (2000), the questionnaire instrument was designed with closed and opened ended questions and comprised twenty questions relating to the price of fuels, fuel use patterns, procurement and collection, and type and quantity of fuel used (Makonese et al. 2016). The researchers were advised by the University of Johannesburg that formal ethical clearance was not required as the study did not request any personal information.

The interview administrators randomly selected the houses to interview. Each dwelling in the informal settlement was given a number and the dwellings to be interviewed were drawn randomly from a pool of numbers corresponding to each dwelling. A consent form was included with the questionnaire at the start of each interview. The interview administrators had to explain to the respondents the purpose of the survey before the interview commenced. After which, the respondents were asked to sign the consent form. Interviews were not carried out on respondents who refused to sign the consent form. The interview administrators took a full day's work to conduct interviews to 100 randomly selected households. Of the 100 questionnaires administered, only 92 were received free of error.

The raw data were analysed for errors and quality through a summative evaluation process (Kimemia and Annegarn 2012). The quantitative data were analysed with a statistical software SPSS version 23.0, while content analysis was employed for qualitative data with the results reported in descriptive prose.

Limitations of the Study

Due to limitations in the time and budget, the energy used in performing various tasks related to household cooking and heating was not quantified, thus an energy balance will not be reported herein. The researchers could not perform probabilistic logit models to quantify determinants for household fuel choices, as the survey did not capture information on gender, education, and income levels of the respondents. The research was not designed to do an in-depth analysis of energy use patterns and choice determinants in the study area but it aimed to present a preliminary analysis of household fuel uses in an informal settlement in Burundi.

RESULTS AND DISCUSSION

Fuel Types and Combustion Technologies

Table 1 presents the frequency of fuel use for cooking and meat grilling (barbecuing). Generally, households in Mubuga cook two meals

Table 1: The fuel use frequency in Mubuga in sampled households (N = 92)

Type of fuel	*Cooking*	*Grilling meat*	*Lighting*
Wood	77 (84%)	14 (16%)	-
Kerosene	-	-	51 (55%)
Charcoal	20 (22%)	86 (94%)	-
Candle	-	-	33 (36%)
Rechargeable electric lanterns	-	-	9 (10%)
Combined frequency	97 (106%)	100 (110%)	84 (101%)

per day of beans, bananas, cassava and vegetables. Not many households can afford more than two meals per day, with a meaty dish reserved for special occasions or when the young boys kill small game from nearby forest resources. Results presented herein show that of the interviewed households 84 percent use firewood for cooking and beer brewing with open fire (three-stone stove) being the main cooking technology, while 16 percent reported using firewood for grilling (barbecuing) meat. In addition, 22 percent of the respondents reported using charcoal for cooking in a locally fabricated stove known as the *Imbabula*, while 78 percent use the fuel for meat grilling, especially in informal roadside restaurants.

The majority of households interviewed makes regular use of firewood and charcoal for cooking and grilling meat. The bulk of charcoal is used in commercial cooking activities. Firewood is the dominant fuel for cooking, with charcoal being the dominant fuel for grilling meat. Firewood is the principal fuel for economic activities like commercial cooking and beer brewing. About 12 percent of the interviewed households reported that they often brew a local beer called "Kanyanga" using firewood. This local brew has been banned for commercial sale in the formal market. Residents sell the beer among themselves (in Mubuga) as a money making business. Results also show that of the 92 households that reported using wood, 20 of them used the fuel for commercial cooking activities. This indicates that in the absence of formal employment, 21 percent of households are engaged in local biomass-powered business activities for income generation.

The penetration of electricity in this area is low because the area is yet to be connected to the national electricity grid, with the grid situated in Gitega about 11 km from the informal settlement. Kerosene is frequently used for lighting (55%) in self-fabricated wick lamps, followed by candles (33%) and rechargeable electric lanterns. Households who use rechargeable electric lanterns, have to cycle on bicycles or walk to Gitega town to get them recharged. A full recharge of the lantern would give the households approximately eight hours of light, and to get the lantern charged would cost them 1500 BIF[1] per lantern.

Respondents were aware of the harmful dangers of using solid fuels and inefficient kerosene wick lamps in the indoor environment. Of the interviewed households 88 percent reported that smoke from firewood caused them upper respiratory problems including coughs and chest infections, with some reporting that the smoke caused itchy and red eyes. One female householder commented on the dangers of using solid fuels and kerosene wick lamps indoors:

"Using firewood inside the house is not good for the health. The wood, especially when it is wet, produces a lot of smoke, which causes my children to cough, and have itchy and red eyes. Therefore, we have built a kitchen away from our main dwelling to avoid this problem. On the other hand, kerosene wick lamps remain a problem. We need the light in the night for the children to study. The lamps produce a lot of smoke which is not good for our health and cause everything in the house to smell of kerosene."

Socio-economic Aspect Affecting Fuel and Stove Choices

What Makes People in Mubuga Cook on Firewood

Based on affordability, availability, and socio-cultural aspects the households tend to prefer the firewood for preparing meals over kerosene, and charcoal. The majority of the respondents said that they collected firewood free of charge, while some indicated that they processed charcoal from firewood to sell in the nearby Gitega city. The traditional three- stone stoves are important cultural devices, where families sit around the fire to socialise. The stoves have multiple functions, which include space heat-

ing, cooking, lighting, and drying of vegetables and meat products. The smoke from the stove is used to repel insects including houseflies and mosquitoes. Asked whether the respondents would welcome improved single plate cookstoves that would save fuel and reduce smoke emissions, a male respondent commented that women preferred the three-stone fire to improved stoves because the three-stone fire serves multiple purposes simultaneously:

"Our women prefer the three-stone fire to any stove as the stove performs many functions simultaneously. These improved stoves are only suitable for smaller families as many of them are single-plate stoves. Again, some require you to cut wood into smaller pieces before you can use them. We do not have time to cut big logs of wood into kindling."

For meals that take longer to cook (for example, beans, cowpeas, samp), householders prefer to cook them on a three-stone fire stove. From the interviews, it also emerged that households preferred dishes cooked on a wood fire than on a charcoal fire, citing that the smoke tends to give flavour to the dish.

"I prefer dishes cooked over an open fire. They taste nice compared to dishes cooked over charcoal. The smoke of some tree species adds a good aroma and flavour to the dish...My wife once used a kerosene stove but she had to stop as the fumes from the stove added an unpleasant kerosene flavour to the food. So we stopped using it and have told our friends and family not to use these kerosene stoves." (Male householder respondent).

Cost of Combustion Technologies

The price of the cooking device can influence the choice the user makes on whether to buy the device (Makonese et al. 2016). All households interviewed used the three-stone fire for cooking and the respondents cited that the stove is manufactured free of charge anddoes not require skilled expertise to build it. The metal grill and the *Imbabula* stoves can be easily constructed from locally available scrap materials. From the surveys, it emerged there are two artisans in the area who manufacture these stoves upon request for a small fee (between 2000 BIF – 3000 BIF). Asked whether the respondents will be willing to adopt improved wood and charcoal stove, the survey indicated that the more than 60 percent of the respondents were interested in adopting an improved cookstove (ICS), with 40 percent raising concerns over the use of improved stoves. Of the 60 percent who agreed to buying ICS, when asked how much money they would be willing to spend on an improved stove, the majority (70%) chose the lower price option of less than 3 200 BIF, while 22 percent chose a higher price range of between 5 333 BIF and 8 533 BIF. Those who wish to use expensive stoves argued that the more expensive the stove is the better the quality and durability. Those who preferred cheaper ICS highlighted that due to increased levels of poverty, they could not afford the higher priced stove, although they wish they could own an expensive one. In fact, the main reason why householders wanted to use ICS was to save fuel and reduce household air pollution (HAP). The *Imbabula* stove, which is commonly used in the Mubuga informal settlement, is an example of an inefficient and aesthetically unpleasant cooking device. This further highlights the energy poverty and plight of the people in the area.

Comparative of Fuel Costs

Table 2 gives the average quantities of the fuels used per unit time and the corresponding cost of each of the four energy carriers used in the case study area. As most houses use more than one fuel source, the values are not indicative of the total household energy expenditure per period (Makonese et al. 2016). The survey showed that firewood (when purchased) is the least expensive fuel, while charcoal is the most expensive energy carrier. Candles have the least cost per unit compared to all other energy carriers. However, candles are used only for lighting purposes, and in some households, they are substituted with kerosene wick lamps.

Table 2 shows that the cost of lighting using candles and kerosene wick lamps is fairly high and forms a significant fraction of the overall household energy budget. In households who possess rechargeable electric lanterns, householders use ~ 6 000 BIF per week to have the lanterns recharged. This rate of expenditure is comparable to that of kerosene. However, the

Table 2: Quantities of fuels used and related cost – average over the 92 respondents

Type	*Unit of sale*	*Price/unit*	*Market*	*Weekly*	*Monthly*	*Yearly*
Wood	10 kg	535 BIF	local	3 735 BIF	14 930 BIF	179 185 BIF
Charcoal	5 kg	1600 BIF	local	11 200 BIF	47 995 BIF	575 950 BIF
Kerosene	1 L	960 BIF	local	5 760 BIF	23 038 BIF	276 455 BIF
Candles	each	160 BIF	local	1 120 BIF	4 480 BIF	5 3755 BIF

use of rechargeable electric lanterns has the added advantage of improving the general health of householders as they are exposed less to harmful emissions from kerosene wick lamps and possible fires from the use of candles. The electric lanterns are a status symbol in the community as they come with a high purchase price of 3800 BIF.

"I use a rechargeable electric lantern for illumination. The lanterns they burn brighter than 10 candles put together and they do not produce any smoke or smell like kerosene lamps. At least my children can study under some bright light. However, we only use the lanterns for less than 3 hrs per day as the batteries quickly drain out. They are expensive to recharge and I make a trip to Gitega every two days to get them recharged." (Female householder respondent).

Fuel Procurement

The respondents were asked how they obtained the fuels and more than 90 percent of the respondents confirmed that they buy the kerosene and candles from nearby shops. There is a Roman Catholic monastery in the area, with a shop that sells basic household goods. However, the monastery is not connected to the main electricity grid and relies on generator sets to power the church community. Concerning firewood, 92 percent of the respondents reported that they collected the wood free of charge and 5 percent indicated that they purchased it from firewood vendors, while 3 percent said that they both collected and purchased. Fuelwood in Mubuga is more often gathered from natural forests due to increased deforestation in the area. Charcoal is produced from forest resources in an unsustainable manner, from whence it is then ferried and sold to the nearest urban market. The unsustainable harvesting of forest resources for the production of charcoal, often in response to urban residential fuel demand, increases the burden on forest resources. Charcoal production often leads to localised deforestation and land degradation including soil erosion and siltation.

In most developing countries, especially in sub-Sahara Africa, women and children collect firewood from neighbouring forest resources. This exercise is strenuous and time-consuming. From the surveys, it was found that the average load was 20 kg of firewood per head load. Similar to findings by Porter et al. (2013), this study found that transport services are scarce or unaffordable for households in Mubuga. Transporting goods on a daily basis is achieved through head loading and on carts in a few households that can afford them. Domestic firewood load carrying (culturally regarded as a 'female' activity in most African societies) is a low-status activity and can be used as a poverty indicator. Carrying heavy firewood loads may have serious health implications for young girls, given their physical immaturity. Over time, the children may experience inflammation or damage to the head, neck, and the spine (Porter et al. 2013). The collection time plays a significant role in how else women and children spent their time. Longer firewood collection times often hinders women and children from engaging in other empowerment activities including education and running informal businesses. Often, the girl child is pulled out of school to spend time collecting firewood and other household chores, resulting in decreased levels of literacy and restricted economic opportunities.

Interrogating the Energy Ladder Model

From the evidence presented in this paper, households without access to modern forms of energy will continue to use a suite of energy carriers to meet their basic energy needs. Over the past two decades, there is increased body of evidence that suggests that "fuel switching" is not a straight path as suggested by the concept of an "energy ladder" or the "leapfrogging" concept (Madubansi and Shackleton 2003; Hiemstra-van der Horst and Hovorka 2008; Makonese et al. 2016). The high cost of connecting homes

to grid electricity, situated 11 km away from the village, is a major constraint towards complete substitution of other fuels with electricity. However, evidence has shown that even in homes that have been connected to the main electricity grid, households continue to use other forms of energy carriers (Madubansi and Shackleton 2003). High electricity tariffs may deter households from using electricity for energy intensive activities such as cooking and heating. Rather, households would use electricity for lighting, entertainment (radio and TV sets), and refrigeration. Other reasons for continued use of traditional fuels to others include socio-cultural preferences, where householders prefer a dish prepared on a wood fire to that prepared using other forms of energy. It is envisaged that, even when the Mubuga informal settlement will be electrified, households will continue to use firewood to meet some of their basic energy needs. This is because firewood is collected free of charge and is relatively cheaper than most advocated for modern energy carriers. It is also widely believed in Mubuga that firewood cooks faster than charcoal or kerosene fuels.

It can be argued in light of the above, that in impoverished societies, electricity is an additional fuel rather than a displacement fuel. As employment opportunities are still limited in Mubuga, activities from which households derive their incomes are equally limited. This has far-reaching implications on their purchasing power. Asked whether they would continue to use firewood when they receive electricity, one female householder had this to say:

"Having electricity in my home will be a good thing, and I pray for that to happen in my lifetime. However, no one in my family is working and we do not see ourselves affording to purchase those expensive electric gadgets, including electric stoves. Only the rich can afford them. That is why we will always use firewood for cooking until we also become rich."

There is a need for job creation around the area; without a higher purchasing power, it would be impossible for households to benefit from the introduction and use of modern and more costly energy carriers.

CONCLUSION

The survey focused on the domestic energy use scenarios in Mubuga informal settlement, Gitega, Burundi. This is the first survey of this nature in Burundi and has demonstrated energy challenges that informal communities in Burundi are facing to meet their basic cooking, heating, and lighting needs. Results showed that firewood is the primary energy source for low-income households. The fuel is harvested and collected by women and children from nearby forest resources. Longer firewood collection times often hinders the harvesters from engaging in other empowerment activities including education and running informal businesses. The efficient utilization of biomass resources reduces the collection times and this has the potential to improve the quality of life and livelihoods of both women and children. Kerosene and candles are widely used for lighting, while charcoal is used mostly for meat grilling than for cooking. Findings also showed that residents use multiple fuels (more than a single fuel source) to meet their energy needs. The choice of fuel use was found to be influenced by availability, cost, and cultural preferences. The respondents expressed that the continued use of solid fuels had an impact on their health and well-being. There is, therefore, a great need for the government and non-governmental organisations (NGOs) to pull resources together to address energy challenges facing the poor in informal settlements in Burundi.

RECOMMENDATIONS

Results presented in this paper have important policy implications and there is a need to include some of the findings into future energy policy designs for Burundi. For example, biomass fuels remain of significant economic value to informal settlements, rural communities and some low-income urban settlements in Burundi. This is because biomass is the single most used energy carrier in Mubuga informal settlement and across geographical locations in Burundi. There is, therefore, an urgent need for the government to recognise the value biomass resources play in the larger economy of Burundi, in order to develop energy and economic strategies and policies accordingly. Electrifying villages to replace the use of biomass fuels may not be financially feasible. For poor villages to be electrified, the government would need to subsidise heavily electricity connection fees to enable all households to be connected to the national grid.

Improved cooking technologies can play a significant role in Mubuga informal settlement. Energy efficient technologies provide improved energy services at low cost compared to conventional technologies, and they free up household time for women and children so that they can dedicate their time to education and other moneymaking initiatives. The government of Burundi could achieve this by reducing, subsiding or exempting tax or import duty on improved cookstove technologies, renewable energy technologies, and cleaner fuels. For this to be successful there is a need for the government to establish an independent agency with a mandate to plan and promote clean cooking and heating technologies. The agency will also coordinate the establishment and enforcement of technology standards, through testing, evaluation and monitoring exercises at national and subnational levels.

The provision of electricity alone may not replace traditional fuels such as wood and charcoal. In fact, switching completely to modern alternatives will not necessarily create a sustainable energy model for these marginalised communities. Thus, models and interventions that seek to address energy needs in informal settlements and rural communities in Burundi need to be less supply driven and should consider demand factors. This implies that such models should consider end user behaviour and preferences as a starting point. Any model or intervention that advocates for the use of multiple fuels should be promoted, as it allows households to choose freely energy sources from a suite of options.

This paper recommends, for future studies, an in-depth analysis of household energy use and cookstove preferences, willingness to purchase the technologies and shift to cleaner sources of energy. Such information is useful in directing investment and innovation in the cookstove sector in addressing energy poverty and access in marginalised communities

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