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Patterns of Household Cooking Energy and Associated Factors: Experience from Kilimanjaro Region, Tanzania

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Abstract

Traditional biomass is a major source of cooking and heating energy in Tanzania. Although Tanzanian energy policy insists on the need to diversify energy sources, the level of diversification at a household level is not well known. This study identified energy use patterns and their associated factors in Kilimanjaro Region of Tanzania. Specifically, the study identified the types of cooking fuels and stoves available and used by households, as well as how and why households combined various cooking fuels. The household survey was conducted in 294 randomly selected households in the districts of Rombo and Hai. We found that although biomass is becoming scarce, it is still a major source of cooking energy, combined with the traditional cooking stove. Only 10.2% of the households reported full-time use of improved biomass cookstoves (ICS). The rest combined ICS with the traditional stove, threatening the sustainability of the biomass resource. It was found that 15% of ICS used by households were abandoned due to various technical flaws. Factors like woodlot ownership, kitchen location, electric grid connection, quality of living, and sources of firewood were associated with partial switching of households to either transition fuels or cleaner fuels. We conclude that energy use patterns in this region demonstrate a partial switching of fuel source, because some households use transition fuels or cleaner fuels combined with firewood. Fuel diversification focused more on cooking with biomass than moving to cleaner fuels. This implies that biomass will continue to be a major source of cooking fuels for Tanzanian households and, hence, ICS remains the best solution. For ICS to have a broad impact and achieve more widespread use, it is necessary to address some technical problems associated with ICS. The government of Tanzania should revisit the cost of alternative energy sources like LPG to improve their affordability for the masses.

Key words: biomass, energy mix, energy use pattern, transition fuel, ICS, partial switching

1. Introduction

Despite global efforts to promote universal access to modern energy services, 1.3 billion people have no access to electricity and 2.6 billion have no access to a clean cooking facility (World Energy Outlook, 2012). It is projected that developing countries will continue to face energy problems, as they are characterised by an uneven distribution of modern energy supplies coupled with the use of inefficient end use technologies (Jan *et al.*, 2012). It has been argued that lack of access for the poor to efficient and affordable energy sources limits their socio-economic prospects and, consequently, development (Lambrou and Piana, 2006). It is alarming to see that this energy situation is set to change very slowly over the next 20 years (Kaygusuz, 2012) a situation that sets back efforts to achieve the Millennium Development Goals (MDGs).

Though households require energy for various uses, cooking is one area that has received less attention by international and local communities (Kees and Feldmann, 2011). Cooking could be a less energy-consuming activity: 2.6 billion people rely on traditional fuels and technologies to cook. In addition, shifting cooking fuels and technologies has significant potential to improve the sustainability of development and the welfare of individuals by addressing multiple problems, ranging from gender to health and the environment (Foell *et al.*, 2011).

Although biomass is a renewable resource, it is becoming increasingly scarce due to the growing demand for biomass in parts of many developing countries. Mbwambo *et al*. (2012) point out population growth, economic development, poverty, inadequate institutional arrangements, and insecure land tenure as contributing factors to growing demand. In addition, the current rate of wood fuel consumption often compromises the forest's rate of regrowth (Lusambo, 2009). This is caused by a decrease in forest area, the main source of wood fuel for the majority of people in most developing countries. There is therefore a need to switch to alternative energy sources that ensure sustainability.

Tanzanian energy resources include biomass, hydropower, natural gas, wind, nuclear, solar and thermal energy (Research and Analysis Working Group, 2012). Despite the diversity of these energy resources, biomass (in the form of firewood) and charcoal is the main source of energy in Tanzania, accounting for more than 96% of households (Global Alliance for Clean Cookstoves, 2014). Only 14% of the total population is connected to the national electric grid, of which the majority resides in urban centers, leaving rural households to account for only 2.5% of the connected population (National Bureau of Statics (NBS) and ICF Macro, 2011). This heavy reliance on wood-based biomass and the use of inefficient wood energy conversion technologies are among the leading causes of deforestation and poor indoor air quality in Tanzania (Lusambo, 2009; Lyimo, 2005/2006). The effect of biomass on acute respiratory infections is the same for households using transition fuels, like kerosene and charcoal (Kilabuko and Nakai, 2007). These factors are important for moving to cleaner fuels to reduce the health and other risks associated with the use of unclean fuels.

2. Conceptualization of the Problem

To address the negative consequences associated with the use of solid fuels in developing countries, we need to strengthen efforts to ensure universal access to clean cooking energy and technologies. Without strengthening these efforts, most people will continue to be negatively affected by the use of biomass. Maes and Verbist (2012) proposed two policy options, with this view in mind. The first option is to improve incrementally by switching from solid fuels to fossil fuels—Liquefied Petroleum Gas (LPG or kerosene), biogas, or electricity—while the second option is to increase the sustainability of the current traditional biomass system. The first option is well supported by energy ladder models, which conceptualize this process of fuel switching as following three distinct phases. The first phase is characterized by dependence on biomass, while in the second phase, the households are expected to move to modern or transition fuels such kerosene, coal and charcoal. Finally, in the third phase, households are expected to move to cleaner cooking fuels like LPG or electricity (Heltberg, 2004). The energy ladder model suggests that as a household moves from low income to higher income level, it uses more modern and efficient energy sources. This is also well-supported by the model of fuel switching, which assumes that with the introduction of superior fuels, households will abandon inferior fuels (traditional solid biomass) for superior ones.

The second sustainability component for traditional biomass calls for an implementation of fuel efficiency interventions that allow the same amount of energy to be produced with less fuel and fewer emissions (Larson and Rosen, 2002**.** The option is more feasible in developing countries, and various energy stakeholders have worked extensively on it by promoting various biomass-energy-efficient end-use technologies. Though the possibility of complete switching as proposed by the energy ladder model has failed, other scholars proposed the multiple fuel model, or “fuel stacking strategy,” where the household does not completely switch: rather, they combine various types of fuel based on various conditions (Masera *et al*., 2000).

Although the energy ladder model suggests that the transition from traditional to modern fuels and devices can be explained by increasing income (Masera *et al*., 2000, 2005, Helbert 2004), scholars have criticized the model’s scant inclusion of other factors (Jebaraj and Iniyan, 2006). Some argue that household-level energy use patterns depend on three simultaneous energy system decisions: energy services, energy carriers, and energy conversion devices (Kowsari and Zerriffi, 2011). This implies that the type of fuel used depends on the cooking device owned by the household, the type of fuel available, the food being cooked, and the cooking process. It is important to note that in each energy system there are distinct factors influencing the selection of a particular cooking method, fuel and stove type. In some instances these factors act in isolation, while in others, they interact.

Energy dynamics aside, the process of fuel switching is very complex and context-specific. Though Mekonnen and Köhlin (2009) argued that better availability is essential for switching to alternative fuels, in developing countries, it is often argued the choice to switch is in itself complicated. A study in rural Haryana, India found that food like chapatti was preferred to be cooked with a *chulah* stove (traditional stove with no chimney), as it becomes crispy and tasty with this cooking method (Joon *et al*., 2009). While this preference is related to the stove type and food taste, it implies that the cook is forced to use biomass in its traditional form (firewood) as the main cooking fuel to achieve the desired taste. Miah *et al*. (2011) found that—for both rural and semi-urban areas—factors like monthly household energy expenditure, monthly income, family size, dwelling type, and dwelling size, total land ownership and educational status play an important role in determining the fuels used. Similarly, Gupta and Köhlin (2006) identified factors like age, education, fuel price, religion, and caste as influences on fuel preferences.

The situation is the same for African countries. For example, a study by Lee (2013) in Uganda found that the vast majority of households in urban and rural areas rely on a mix of solid and non-solid fuels. Apart from income factors (like household size), education and access to private or public water sources were found to be significant for solid-fuel dependence in the rural cohort. In Kenya, it was revealed that a woman's education level, whether or not the household owned the dwelling unit, and whether the main dwelling unit is traditional or modern influence the type of energy used for household cooking (Pundo and Fraser, 2006). Looking at these factors, it is logical to conclude that income is not the only factor influencing the choice of fuel at the household level.

Despite the existence of studies explaining household energy consumption patterns and the factors that influence these patterns, household energy use patterns and their associated variables remain understudied in developing countries (Kowsari and Zerriffi, 2011). In addition, Smeets *et al.* (2012) argue that the successful implementation of improved traditional biomass systems depends on local conditions and the socioeconomic impact on these systems. Given these arguments, it is important to explore household cooking energy patterns in Tanzania and to explore the reasons behind this pattern.

Tanzania's energy policy identifies the importance of diversifying country energy sources, with the goal of contributing to national economic growth and improving the standard of living in a sustainable and environmentally sound manner (United Republic of Tanzania (URT), 2003). The policy hopes to reduce the demand for wood fuels and to create opportunities for citizens to switch to more modern types of fuels. Despite the Tanzanian energy policy's insistence on the need to diversify energy sources, 96% of the households in Tanzania still use traditional biomass (Global Alliance for Clean Cookstoves, 2014). This indicates a lack of progress towards meeting the development initiative of ensuring access to clean energy. As such, this paper attempts to determine patterns in household cooking energy and associated factors. Specifically, the study answered the following questions:

i. What types of cooking fuels are available and used by households?
ii. What types of cooking stoves are available and used by households for cooking and heating service in their study areas?
iii. How frequently are improved cookstoves used by household for cooking services?
iv. What factors are associated with the ways in which households combine different types of fuels?

The study results contribute to the body of knowledge on cooking energy patterns at the household level and, more specifically, to the understanding of how and why households mix various fuel sources. The results will contribute to further implementation of the Tanzanian energy policy by providing information on progress so far in achieving its goal of energy diversification.

3. Methodology

3.1. Study area

This study was conducted in the Kilimanjaro because of its wood fuel deficits (Mwihava, 2002). Apart from being a fuel deficit region, some interventions for promoting and disseminating alternative energy sources and improved cookstoves are being implemented in this area. The Tanzania Traditional Energy Development Organization (TaTEDO), a Non-Governmental Organization (NGO), has promoted and disseminated various alternative energy sources and different prototypes of improved stoves in several districts of Kilimanjaro Region.

The region is located in the northeastern part of Tanzania, and borders Kenya to the north. It has seven administrative districts: Hai, Rombo, Same, Mwanga Moshi Rural, Moshi Urban, and Siha. According to the 2012 Population and Housing Census (PHC), the region had a total of 1,640,087 people, with a population density of 124 people per square kilometre. The region is among the most densely populated regions in Tanzania. It is characterised by mountains, plateaus, and lowlands, and generally experiences a warm, equatorial climate (Mkiramweni, 2012). The focus of the study was in two districts of Rombo and Hai, involving a total of six villages.

3.2. Research design, sampling procedures, data collection and analysis

A cross-sectional research design was employed, where data were collected once from each of the studied households. Multistage sampling was used to select districts, wards, and villages. The selection criterion for each stage was the availability of the energy serving stoves intervention.

In each district, three villages were selected, to make a total of six study villages. In Rombo District, the selected villages were Shimbikati, Manda Juu, and Mamsera Juu, while the Foo, Nkuu Sinde, and Nshara Villages represented Hai District. A simple random sampling technique was used to select households to be included in the interview. The household sampling frames were constructed from the village registers. In the event that the hamlets' (sub-village) registers were not updated, the Village Executive Officers (VEO) and Villages Chairpersons (VC) provided the information required to construct the sample frames.

The study applied both qualitative and quantitative approaches for data collection. A total of 294 pretested structured questionnaires were administered to the households. During the administration of the questionnaire, both husbands and wives and some other elder members in the households were encouraged to be present, as some questions were easier if answered in groups. The questionnaires were used to collect information on different types of household fuel and cooking appliances, the availability of alternative fuels other than biomass, and factors associated with the way households mixed energy sources for cooking purposes. Qualitative data was collected through Focus Group Discussions (FGDs) and interviews with key informants, which were guided by a checklist of questions. The FGDs were conducted in each village by formulating groups of 8-10 people such that there was equal representation by age and sex. Key informants were intentionally selected based on predetermined characteristics like age, experience and role played in the village.

The descriptive analysis was employed to analyse different types of cooking energy and appliances, the existence of alternative fuels, and how household mix various fuels and stoves in cooking activities. A chi square test (cross tabulation) was employed to find association between various factors with the adopted energy mix category at household. The households were categorized into three groups based on their mix of cooking fuels: the first group included households using firewood exclusively, the second category was comprised of households using firewood and transition fuels (charcoal and kerosene), and the third group included households that combine firewood with either transition or clean fuels. To assess the strength of association between the variables, we used Cramer's V value, which, according to Healey (2005), demonstrates associations between 0.00–0.1 (weak), 0.11–0.3 (moderate), and above 0.3 (high).

Qualitative information was organised and categorized into various themes based on each specific objective. The interpretation of these qualitative results was used in the discussion to support quantitative results. The qualitative data was useful to give an in-depth explanation of some issues that could not be captured through a structured questionnaire.

4. Results and Discussion

4.1. Main cooking fuels available in the study area

The study identified the main cooking energy available in the study area where, as shown in Table 1, the use of biomass in the form of firewood was reported by 81.8% of respondents. The availability of other biomass sources like saw dust and charcoal were reported by 3.9% of the households, respectively. Biogas has been promoted by different stakeholders, including theTanzania Traditional Energy Development Organization (TaTEDO), in various villages in Kilimanjaro Region. Regardless of this promotion, only 0.8% of respondents reported this as their main source of cooking energy. Use of other renewable energy sources, such as solar energy, was reported by only 0.3% of respondents. Despite the availability of various sources of energy in the study area, these results imply that biomass is still a major source of cooking energy in the region. A failure to use other energy sources to supply cooking energy might be either due to lack of awareness or to high costs.

Type of fuel	**Frequency**	**Percentage of cases**
Firewood	292	81.8
Sawdust	14	3.9
Charcoal	14	3.9
Kerosene	12	3.4
Electricity	11	3.1
Gas- LPG	10	2.8
Biogas	3	0.8
Solar energy	1	0.3
Total	357	**100**

TABLE 1. Main cooking fuels available in the study area (n = 294).

Because firewood was reported as a main source of cooking energy, it was important to identify how households access the resource in their study area. The availability of fuelwood could be among the factors that influence households to switch to alternative cooking fuels or to use efficient cooking stoves in order to reduce household energy stress. As indicated in Figure 1, the study revealed that 34% of households depend exclusively on buying cooking fuel wood (firewood), and 31% depend on collection from household farms or woodlots, while the rest combine buying and collection. The region has also experienced rapid land use changes, where land cultivation has expanded to marginal land, bush land is disappearing, and settlements are expanding (Soini, 2005). The land use changes have decreased the land available for firewood collection (woodlots) and decreased the land available for tree planting, due to expanding settlements. These results imply that firewood is no longer easily available. Fuel wood resources are scarce: households can no longer depend much on collection.

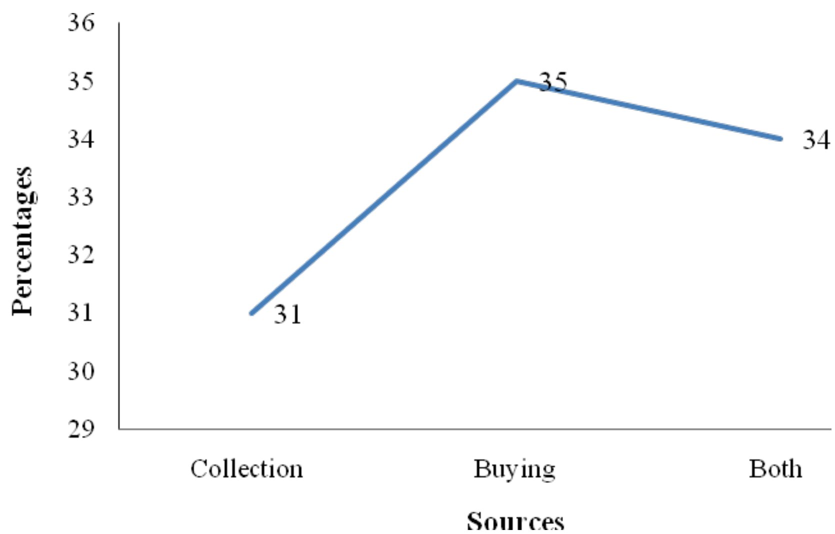

FIGURE 1. Access to firewood by households.

The results (Fig. 1) show approximately equal percentage use of firewood sources. Regardless of these patterns, it was important to explore the availability of the two major sources (collection and buying). It is commonly assumed that firewood is abundantly available in rural areas and, hence, we expected a majority of the households to be collecting the resources rather than buying them. This study marked a shift in access to firewood, from collection to buying, or to combining the two sources. The households reported collecting firewood around their homestead and their woodlot. It was further observed that the availability of firewood from these sources had been diminishing. This increasing scarcity was among the reasons for shifting from collection to buying. During the focus group discussions, several factors were reported as contributing to fuel wood scarcity and, hence, the shift from collection to purchase.

The conservation measures around Mount Kilimanjaro National Park were listed among the reasons for fuel wood scarcity in the region. When women from Mamsera Juu Village were asked what were the reasons for fuel wood scarcity, their response was as follows:

> In the past we were accessing firewood from the national park…Nowadays the Authority is very strict; they have full time guards throughout the park,,,women cannot go to the forest anymore. Even if you collect the dried dead wood you will be punished. (Female FGD - Mamsera Juu Village)

The above response implies that one of the major reasons for the decrease in fuelwood collection was that it the wood is no longer readily available to the community members.

In addition to strengthened conservation regulations, an increased population has also contributed to increased fuelwood scarcity. The increased population adds to the demand for residential land and also to the demand for building materials. This was reported by the key informant from Shimbikati Village:

> When we were few in our village, we could even go to our neighbours or relatives to ask for trees to get firewood…also, we had a small woodlots where we could collect firewood for the whole year. Our children have grown, hence increases demand for land and building materials... once you allocate land (kihamba[1]) for building a house, then the trees under that plot are gone and you remain with a very small size of land…we are no longer having trees and also not having land to plant new trees.

Households access firewood through collection, purchase, or a combination of the two. If the scarcity is the factor causing shifts from collection to buying, then where do sellers get their firewood? It was important to explore the availability of firewood as described by individuals who depend on buying firewood. When a firewood dealer from Shimbikati Village was asked where they acquired firewood to sell, the informant responded:

> It is becoming hard even for ourselves to get firewood for selling...trees are very expensive and we compete with timber dealers who offer good prices than us... What we normally do is either to buy a live tree or wait for the timber business dealers to sell some few remaining branches...It is become hard with this chain saw technology where nothing remains. (KI- Shimbikati Village)

Firewood is not readily available, even when one has money to buy it. The resource is becoming very expensive, and finding quality firewood is increasingly difficult. When asked their opinion on the availability of firewood, women from Nkuu Sinde Village reported:

> Sometime you find that you have cash money but no firewood to buy…the sellers does not get them easily. They are within the community where both we don't have forest in which we can collect firewood. They depend only on few people who want to sell their trees. This makes the firewood to be expensive and sometime selling non-dried wood. (Female FGD discussant, Nkuu Sinde)

The discussion above implies that the firewood resource is becoming scarce and adding stress to households. It was revealed from various group discussions that, in the past, most of the households never expected that

[1] A piece of land where the family make a homestead. Normally in the *chaga* tribe, parents have the responsibility of allocating land to the male children so they can establish their homestead through inheritance.

they would one day be budgeting for cooking fuel and, more specifically, for inferior quality fuel (firewood). The access to fuelwood for cooking was reported to be very stressful not only for women, but also for men (household heads), as obtaining the commodity now has serious financial implications.

4.2. Patterns in fuel and stoves mix at household level

The results in Table 2 show that regardless of the existence of alternative energy sources, biomass was reported by 89.8% of households as the only major source of energy for cooking, while the rest combine biomass with either transition or clean cooking fuels. The result follows a pattern in most developing countries, where use of multiple energy sources for household cooking and heating services is common (Liu *et al*., 2013). The results in Table 2 imply that no household has switched completely to transition or cleaner fuels.

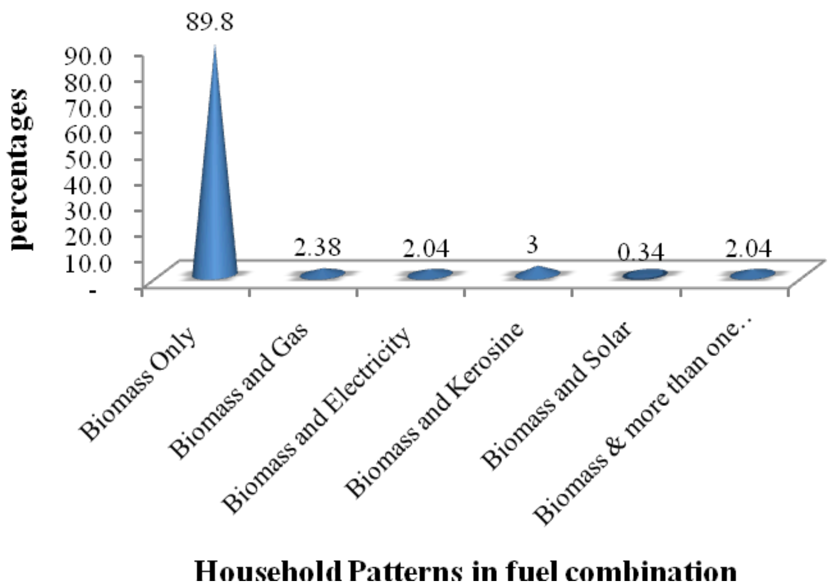

FIGURE 2. Combinations of cooking fuels used by households.

The practice of partial switching is clear here, as biomass remains in each category of energy mix sampled. Although charcoal was included as biomass (charcoal, saw dust, and firewood), it is categorized as a transition fuel in the energy ladder model.

It was important to identify households depending on their use of firewood or the combination of firewood and transition fuels (charcoal and kerosene). This categorization, shown in Table 2, reveals that only 13.3% of households combine firewood and transition fuels, while 77.6% use firewood only. Therefore, these households can be categorized as not switching at all. Very few households even partially switched.

A study in Pakistan showed that energy mixes used by households range from a minimum of 1 energy source to a maximum of 6 different energy sources (Mirza and Szirmai, 2010). As shown in Tables 2 and 3, very few households reported combining biomass and clean fuels like gas and electricity in our study region. This trend has not changed much from previous reports, where the Tanzania Demographic and Health Survey (TDHS) (2010) reported that the total population in Tanzania using firewood and charcoal for cooking was 95%. The domination of biomass for cooking energy implies that the resource will continue to serve the communities for some years to come. This conclusion supports the argument by Puzzolo *et al*. (2011) that improved cookstoves will be a critical means of achieving greater fuel efficiency and improved health.

Fuels	**Frequency**	**Percent**
Firewood only	228	77.5
Firewood and transition fuels	39	13.3
Combination of both	27	9.2
Total	**294**	**100.0**

TABLE 2. Household cooking energy based on energy ladder (n = 294).

The use of biomass as a main source of energy was coupled with the use of inefficient cooking stoves. As shown in Table 3**,** 81.9% of the households owned traditional three stone stoves (open fire), while 20.7% of households owned improved cookstoves with chimneys. This led to our speculation that people were not aware on the availability of ICS. Likewise, ownership of modern cooking stoves using clean energy (fuel), such as gas and electricity, was very low, accounting for around 2.5% of the total households, respectively.

These low levels of clean energy use can be attributed to the cost associated with the clean fuel and the stove itself. In most of these households, ownership of more than one stove was common. This was also found in Ethiopia, where households on average owned between 1 to 6 types of cooking stove (Takama *et al*., 2012). We also found that there were sociocultural factors that could be associated with the ownership of a traditional stove, even for households with other biomass stoves. The traditional stove carried a cultural value for the majority of households. This was clearly supported by information from a key informant from Shimbikati village. When asked what the role of traditional stove was for *wachaga* tribe, and why people choose these stoves even when they have improved stoves available, the informant said:

> Keeping traditional stove is important for many reasons; you cannot find an old woman like me not having a traditional stove in my house. It has several symbolic values like doing some rituals and cooking a certain traditional food for ritual practices. (Female key informant- Shimbikati village)

Stove types	Frequency	Percentages of responses
Traditional three stone cookstove	261	64.4
Improved firewood stove with chimney	61	15.0
Improved firewood stove without chimney	17	4.2
Kerosene stove	14	3.4
Saw dust stove	14	3.4
Unimproved charcoal stove	12	3.0
Electric cooker	10	2.5
Gas cooker	10	2.5
improved charcoal stove	3	0.7
biogas cooker	3	0.7
Solar cooker	1	0.2
Total	**406**	**100**

TABLE 3. Type of stoves owned by household for cooking (n =294)

Although some households own different types of stoves, Figure 3 shows that the improved biomass cookstoves were used fulltime by only 10.2% of the households. 74.5% of households used traditional stoves exclusively. This raises the question of why few households use improved cookstoves. The frequency of use of clean gas and electric stoves was found to be 0.3%; this matches the data reported by TDHS (2010), where the use of gas was 0.3% and electricity, 1.1%. The clean stoves were used partially in combination with biomass stoves. This pattern can be attributed to the high cost of stoves and cost for clean fuels.

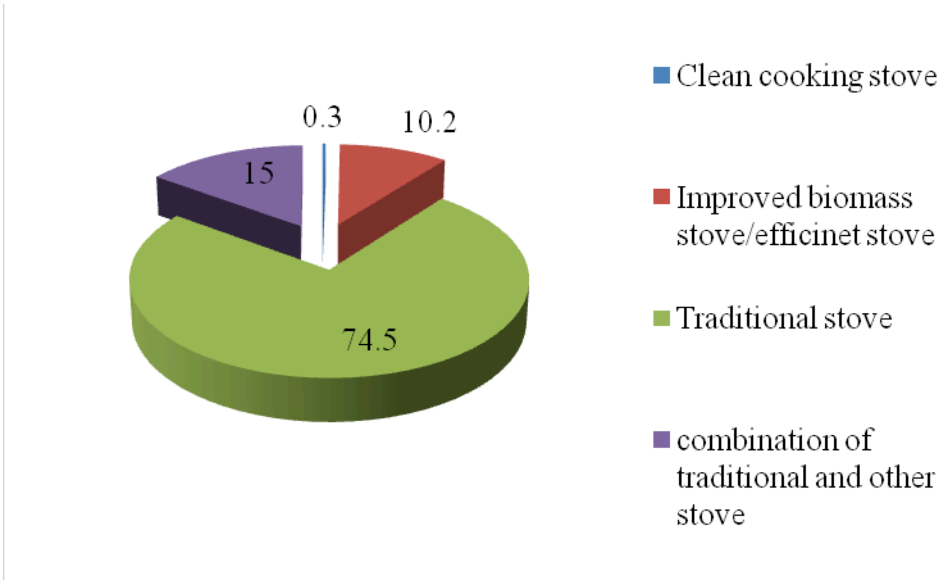

FIGURE 3. Main cooking stoves used by households.

4.3. Type of improved cookstoves (ICS) owned and used by households

As shown in Table 4, the study identified various types of ICS owned and used by households. About 76.8% of users owned an ICS with chimneys, locally known as the *Okoa* stove (Image 1), followed by 17.1% owning ICS without a chimney (movable), locally known as *Dr Mwasha* stoves (Image 2). A portable ICS without a chimney, locally known as *Okoa ndogo* (Image 3) was owned by 3.7% of the households. This model is relatively new to the study area, as it is an imported model. The model was preferred by the people after it became more widely available. ICS without chimneys that are fixed in the kitchen were only found in 2.4% of the households.

Type of ICS owned by household	**Frequencies**	**Percentages**
Okoa with chimney	63	76.8
Okoa (*Dr Mwasha*)	14	17.1
Okoa *ndogo* (portable)	3	3.7
Okoa fixed in the kitchen without chimney	2	2.4
Total	**82**	**100**

TABLE 4. Types of improved stove owned by households (n = 77).

IMAGE 1. An ICS with a chimney (*Okoa*).


IMAGE 2. ICS without chimneys. Locally made (*Dr. Mwasha Stove*).


IMAGE 3. Portable ICS (imported).

The installation or purchase of an ICS is a means to achieve the multiple benefits associted with the use of efficient cooking stoves. The study found that among households that adopted the improved cookstoves, only 39% reported using their stoves full time, while 45% combined them with traditional stoves.

This can be tracked to several perceived technical limitations associated with the ICS. A study by Dey *et al.* (2012) found that among the factors hindering the use of ICS after adoption were technical shortfalls, including the inability of the stoves to accommodate large cooking pans, regular maintenance necessities, fuel options, and sociocultural aspects. It was also found that technical limitations were among the most important factors guiding the decision to not adopt an ICS (Massawe *et al*., 2014).

Rate of ICS use	**Frequency**	**Percentage**
Full time use	30	39.0
Partially used - combined with traditional stove	35	45.5
Stopped/abandoned	12	15.5
Total	77	100.0

TABLE 5. Frequency of ICS use within the household (n = 77).

It was surprising to find that more than 15% of the adopted stoves were no longer in use (abandoned). The households with abandoned stoves raised various reasons for their abandonment, as shown in Fig. 4. More than 28% of the abandoned stoves were reported to be completely broken. Most stoves broke down because of to poor constructions, while a few technical problems—such as smoke becoming trapped within the stove—can be associated with either poor construction or improper use of the stove. It has been reported from other countries that adopters of ICS have a tendency to modify the design of the ICS to fit certain cooking practices. For example, in rural Guatemala, ICS consumers complain that the design of the ICS—with a chimney entryway—is too small to fit enough wood for cooking food on the stove's top (Bielecki and Wingenbach, 2014). ICS consumers modified the stoves to enlarge the entryway and, in doing so, reduced the stove efficiency. The reasons for such a practice can include limited knowledge of the ICS's technical aspects or of ICS usage in general.

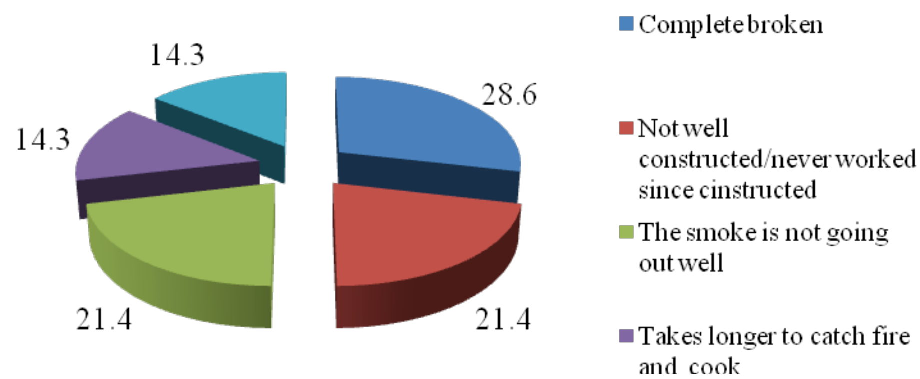

FIGURE 4. Reasons for abandonment of the ICS.

A low frequency of ICS use, and a high rate of ICS breakdown, implies that the ICS is not fully mainstreamed in the household cooking systems of this region. This raises a question on appropriateness of the stove to the household cooking systems. In relevant literature, there is disagreement about what constitutes an appropriate cooking system. According to Troncoso *et al.* (2011) the "appropriate technology is the one which respond to users basic needs, respect[s] local culture, employ[s] local materials and labour, uses the resources in a rational and renewable manner, and recognizes the technological and cultural traditions of rural people." The assumption is that if the technology is appropriate, then the adoption and retention rate will be high, and simultaneously the reported limitations or weakness will be minimal. Looking at the frequency of ICS use and the number of abandoned stoves, it is reasonable to speculate that the stoves are not appropriate to the users.

4.4. Factors associated with the fuel mix at household level

Firewood is a dominant cooking and heating fuel for the majority of the households in the study area. Moreover, we observed that the use of other types of fuel is limited. Despite the dominance of firewood, it was important to fully assess the motivations that existed for the few households that combined biomass and other fuels. This is useful for project implementers, as complete switching appears to not be possible. As Table 6 shows, some factors—like ownership of woodlot, location of kitchen, housing condition, connection to grid electricity, and firewood source—are associated with the way households mix cooking fuels. The variables related to fuelwood availability and household characteristics were significantly associated with fuel mix, with Cramer's values of between 0.16 to 0.66 (moderate to high association).

As shown in Table 6, there were significant associations at $p < 0.05$, χ^2=7.96, Cramer's V= 0.17 among the households not owning woodlots and use of biomass and transition fuels. The few households reported to combine biomass with transition fuels, or with clean fuels, generally lacked woodlots. This suggests that households without woodlots experienced a higher fuel scarcity burden, and hence were compelled to explore and use alternative fuels and stoves. Furthermore, there were significant associations ($P< 0.001$, $\chi^2 = 28.7$, Cramer's value = 0.32) between combination of traditional biomass with transition or other cleaner fuels and household connection to grid electricity. This finding suggests that an electrified household could create the opportunity to move to cleaner and more efficient fuels and stoves. In this study, a connection to electricity was also considered an indicator of higher household socio-economic status (SES), which could also increase the likelihood of a household to adopt ICS.

Factors	**Biomass only**		**Biomass and transition fuels**		**Combination**		**Chi-square**	**p-value**	**Cramer's V-value**
	Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**			
Ownership of woodlot									
Yes	48	16.3	2	0.7	2	0.7	7.96	0.019	0.17
No	180	61.2	37	12.6	25	8.5			
Electricity connection									
Yes	74	25.2	24	8.2	21	7.1	28.1	0.000	0.313
No	154	52.4	15	5.1	6	2.0			
Kitchen Location									
Outside the main living house	212	72.1	10	3.4	9	3.1	125.8	0.000	0.66
Otherwise	16	5.4	29	9.9	18	6.1			
Firewood sources									
Collected	75	25.5	10	3.4	6	2.0	20.19	0.000	0.20
Buying	65	22.1	23	7.8	15	5.1			
Both	88	29.21	6	23.0	6	2.0			
Sex of household head									
Female	39	13.3	8	2.7	6	2.0	0.6	0.735	0.04
Male	189	64.3	31	10.5	21	7.1			
Housing condition									
Poor	85	28.9	14	4.8	3	1.0	7.326	0.026	0.16
Good	143	48.6	25	8.5	24	8.2			
Household size									
1-3	93	31.6	19	6.5	12	4.1	4.67	0.323	0.09
4-7	124	41.5	20	6.8	12	4.1			
>8 people	13	4.4	0	0	10	10			

TABLE 6. Factors associated with the combination of fuelwood (n = 294).

It is common for rural households to locate their kitchen outside their main living area, due to the types of cooking fuel used. It is well known that biomass in its traditional forms produces smoke and soot, which have a tendency to stain kitchen walls and roofs. These results show that there were significant associations ($P < 0.001$, $\chi^2 = 125.8$, Cramer's value = 0.66) between the households that reported their kitchen to be located within their main living houses, or combined with servant quarters, and the tendency to combine biomass with either transition or other cleaner fuels. Households with kitchens within the house (which also tend to indicate a higher standard of living, in terms of quality of houses) opt for cleaner fuels and stoves. It was also found in the study by Ouedraogo (2006) that households with an external cooking facility have an increased probability of adopting firewood as their cooking energy.

Another factor found to be associated with a household's energy mix is the condition of housing. Despite the fact that the majority of households considered their houses to be of good quality, the results in Table 6 illustrate significant associations ($P < 0.05$, $\chi^2 = 7.326$, and Cramer's value = 0.16) among households reported to mix biomass with cleaner or transition fuel and housing condition. This association is relatively weak, possibly because the majority of households categorized themselves as having high-quality houses.

Lastly, the source of firewood for households was also associated with partial fuel switching. The results in Table 6 show a significant association ($P < 0.05$, $\chi^2 = 20.19$, Cramer's value = 0.2) between households that purchased firewood and mixing of firewood with cleaner or transition fuel. The reason for this was captured in a female FGD in Mkuu Sinde village, when they were asked under what circumstances their households use transition or cleaner fuel for cooking. One participant argued:

> Sometimes for households which depend largely on buying firewood normally prefers to buy kerosene to support cooking of simple food like tea, coffee or baby foods. This help us to save firewood to be used for cooking other meals...nowadays firewood and kerosene are competing on the price…the problem is the kerosene stove is not convenient for bigger families. (Female FGD participant- Nkuu Sinde Village)

Her statement implies that the cost of firewood was rising to the point of competing with kerosene. On the other hand, a male FGD in the same village suggested that firewood was becoming scarce and, hence, needed to be saved for special uses once available. When men were asked their views on switching to transition and cleaner fuel for cooking services, one participant responded:

> It just because we don't sit down and calculate the cost, otherwise firewood is one among the expensive item in most of our households. Once I have some money I always buy kerosene as a backup fuel when we don't have enough firewood…My family knows that firewood is scarce and expensive…I tell them to use kerosene and save firewood for other uses like boiling drinking water for cattle or cook foods like ugali,[2] which cannot be cooked with kerosene. (Men FGD- Nkuu Sinde)

[2] *Ugali* is a traditional or staple food for Tanzanians, which is made from maize, flour, and water.

As shown in Table 6, other variables like household size and sex of the household head were not found to have any significant association with household energy mix.

5. Conclusion

The household cooking energy pattern has remained dominated by the use of biomass in its traditional form. Regardless of the existence of various energy sources, the mixing of biomass with other transition and clean fuels was found to be minimal. More diversification or switching was found on cooking stoves (energy conversion devices) than energy carriers (fuels). It was found that even among diversified cooking stoves, the stoves consuming fuel differ, but a single fuel is generally used (biomass). The adoption of clean cooking fuels and improved stoves is very low in this region. Apart from some use of an improved cookstove, it was observed that some of the adopted stoves are no longer working (or had been abandoned). This raises some questions concerning the potential of the stove to become mainstreamed in household cooking systems.

There is very little partial switching of cooking fuels among and within households. Most households included in this study fell into the "non-switching" category. Though few households were found to mix biomass with other fuels, this research found significant associations among households that mix biomass with transitional fuels (or cleaner fuels) with ownership of woodlots, housing conditions, kitchen location, connection to the electrical grid, and household firewood sources. These factors often characterize households that have at switched, at least partially, to a fuel other than biomass.

6. Recommendation

The study found that biomass currently serves as the major source of cooking energy for the majority of households. Very little partial switching to cleaner and alternative cooking energy has occurred. Therefore, there is a need to strengthen efforts to promote use of improved cookstoves, which use the same type of fuel in more efficient ways. The limited use of improved cook stoves suggests a need to explore reasons for the low adoption rate, and a need to solve some technical problems experienced by adopters. Those promoting improved stoves, and technicians, should work with communities to address the technical problems that lead to ICS abandonment, in order to increase the likelihood of adoption. There is also a need for the government of Tanzania to review the cost of alternative energy sources, like LPG, to make them affordable to the majority of people. This will reduce the dependence on fuelwood for household cooking services.

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