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Determinants of Adoption of Improved Stove Technology in Endirta District, Tigiray Regional State, Ethiopia

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The study was developed with the aim of to understand the determinants of adoption of improved stove in rural household energy consumption. Survey was a method of data collection using appropriate instruments such as structured questionnaire based interview technique. The survey was covered a random sample of 120 household heads selected from three rural villages. Probit model and t-test was used to analyze determinants of adoption of improved stove technology using STATA software. Biomass source of energy are found the main source of energy used for cooking food and baking injera (Ethiopian bread) in the study area. The consequence of uses of biomass energy sources lead forest degradation, deforestation, and lands degradation all severe environmental problems. Farm size, awareness about improved stove, proximity household to the health extension center were positive effect on the adoption of improved stove decision of households at statistically significance level of 1%. In addition, livestock ownership, households access to credit services, educational status of household head also positively statistically significant to adopt improved stove. However, age of household head, sex of household head, economic characteristics of households (occupation and per capita expenditure) were not significant relationship with adoption. To enhance adoption of improved stove it was recommended that: all stakeholders (government and development partners) should plan different strategies to its use through demonstrations, posters, and a radio/TV advertisement is vital.

Key Words: Household, energy, improved stove, adoption, biomass

Introduction

Energy is very crucial for daily life to meet human beings basic need such as cooking, boiling water, lighting and heating (WHO, 2006). Thus, energy plays a pivotal role in socio-economic development by raising standard of living (Mirza *et al.*, 2008; Reddy & Balachandra, 2006; Andadari *et al*., 2014). Correspondingly, sustainable development recognizes the significance of key resources such as energy, water, forests and soils in helping to create the bases for human development needs in terms of human welfare and biophysical environmental supports (Osei, 1996; Guta, 2014). It is fact that energy plays an important role for development in terms of poverty reduction (Kanagawa & Nakata, 2007; Zulu and Richardson, 2013).

Household access to clean and affordable energy is critical for the realization of the Millennium Development Goals (MDGs) (Ibitoye, 2013; Ogola *et al.*, 2011). However, in many developing countries, a large proportion of household energy requirements are met by use of non-commercial fuels such as wood, animal dung, crop residues, etc. so this traditional household energy sources associated health and environmental hazards. As a result use of modern fuels (electricity, biogas, solar) for cooking in a reduction of in the overall fuel wood consumption is vital as well as to achieve MDGs (Ibitoye, 2013). Supported by a recent study conducted at Ethiopia has revealed that in order to combat poverty and support the MDGs through providing access to renewable energy sources is a crucial in order to implement them successfully. Hence, household with access to clean energy sources expected benefits in health, work and education; people also notice improvements in the autonomy of children, flexibility, security, family life and the reduction of stress (Müggenburg, *et al*., 2012).

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Moreover, efficient energy consumption is a basic input for socio-economic growth and development at district, regional, national and local as well as global levels. There is a strong linkage between energy and the millennium development goals because the existence of extensive poverty in developing countries particularly sub-Saharan Africa without appropriate energy service provision could not address the challenges in the region. In short the provision of efficient energy services is a compulsory but not sufficient condition for sub Saharan Africa to pull itself out of poverty. Energy services are seen as one of the means rather than the end itself (Hammond, 2007).

Furthermore, according to World Bank (2009), energy service delivery, especially to the poor, contributes to achieving the millennium development goals. Hence, without efficient and accessible modern energy economies cannot grow and develop and also poverty could not be eradicated. Since energy is vital input to all sectors of the economy, mainly such as industry, commerce, agriculture, and social services. However, the majority of the developing countries face a lack of sufficient power supply that is obstacle for their economy growth as well as reducing poverty. Moreover, most of the household in developing countries continue to be dependent on traditional use of solid fuels (biomass) for cooking and heating, due to lack of access to electricity and modern energy sources.

Firewood remains a key source of energy for households in developing countries, so it is a cause of forest degradation and deforestation (Edwards & Langpap, 2005; Bhattarai, 2014). Moreover, wood fuels including charcoal, dung, and agricultural residues are the most heavily used household source of energy in Sub-Saharan Africa including Ethiopia primary energy supply to meet their energy needs and the number of people relying on them (Hanna *et al.*, 2012; Zulu & Richardson, 2013; Bailis *et al*., 2005; Beyene & Koch, 2013; Bhattarai, 2014). As a result heavy reliance on fuel wood can result in a range of negative environmental impacts at both local and global consequences including greenhouse emissions, deforestation, reduction of agricultural production (Gebreegziabher, 2007; Gebreegziabher *et al.*, 2012). In Ethiopia, more than 90% of the total energy supply of the country is derived from biomass fuels including woody biomass (77%), crop residues (8.7%) and dung (7.7%). However, national figures considerable regional and local variations in both supply and consumption patterns, as well as temporal changes in these patterns in face of declining stocks and yields of wood fuels. The energy requirements of a large and fast growing population and the fact that the major proportion is supplied by traditional energy sources have serious implications on the natural resource base. Looking at biomass supply and demand balances, there is a huge and constantly widening gap between demand and sustainable fuel wood supply (GTZ, 2000; Gebreegziabher *et al.*, 2012).

In northern Ethiopia, in Tigary regional state rural household energy consumption characterized by inefficient use of traditional biomass energy sources were used in the region such as firewood, tree residues, animal dung, crop residues and charcoal. In addition, kerosene and diesel are mostly used for lighting (Gebreegziabher *et al.*, 2012).

Statement of the Problem

Biomass is very common in Ethiopia; fuels are mainly burned in inefficient open fires and traditional stoves. In many cases the demand for biomass fuels far exceeds sustainable supply. This leads to massive deforestation, land degradation and desertification (Heimann, 2007; Gebreegziabher *et al.*, 2012). Studies by WHO (2006) have shown that indoor air pollution is a major attributable factor for health problems in developing countries. Especially women, children and older generation are victim indoor pollution since mostly spend their time indoor cooking activities. Moreover, the major reasons for indoor air pollution are inefficient burning of inferior fuels like solid fuels (dung, agricultural residues and fuel wood) as well as poor ventilation system inside the house that exposures to these pollutants, in many ways, have to be linked to several adverse health effects including acute respiratory infection, chronic obstructive lung disease, adverse pregnancy outcomes, and eye diseases (Tekle, 2014).

Girma (2000) and Ibitoye (2013) research has shown that cooking energy has the major share in total household energy consumption in Ethiopia. Accessibility and ease of use of cooking fuels at affordable prices is becoming more difficult day by day especially for poor people, hence many of whom are outside from modern energy system. And also according to Girma (2000), Ethiopia one of the developing nations in the world has proved the close relation that exists between low level of energy consumption and underdevelopment by registering low per capita energy consumption. Moreover, the main household's sources of energy derived from wood and biomass which account about 93% of the total energy consumption of the country. Despite massive efforts and expenditure for electrification in Ethiopia the absolute number of people relying on biomass energy is still increasing; hence research conducted by Embassy of Japan in Ethiopia (2008) have shown that even the access to energy is gradually improving to reach 20% in 2007 by the efforts of the Ethiopian Electric Power Corporation (EEPCo) and the government of Ethiopia through constructing new power plants and expanding the national grid, but lower than the Sub-Sahara African average. This is a major limitation on the country's growth and development.

When a nation intends to measure the level of its development, energy is one that comes to the top priority. Development attained through efficient household energy consumption is last-longing and serves the best of sustained development. However, this ideal issue is not the case for many of the rural population due to a number of factors such as lack of access to modern energy sources, lack of awareness and weaker propensity to adopting improved technologies and so on. Efficient energy supply coverage in the rural areas of Ethiopia is very marginal. The coverage still remains low because of limited progress in energy supply activities in these areas. This major problem is that biomass, which covers 70-80% of Ethiopia's primary energy demand, is used in a very inefficient way (Heimann, 2007). This leads to deforestation and with it to further environmental problems like soil erosion.

This requires a systematic investigation as to how the energy players: users, environment, alternative energy technologies, and the overall provision interact with in the domains of efficient energy supply. For achieving sustainability in rural development with emphasis on livelihood and the means of enhancing the economic well being of the poor households, it is necessary that affordable access to energy is provided to the households. As well as gender issues need to be addressed with adequate focus in the context of energy use. Moreover, little research had been done on the subject and in the study area hence by addressing the issue, the results of the study will serve as baseline information (will fill the knowledge gap) for other researchers who want to conduct further research on sustainable energy options in rural Ethiopia.

The main objective of the study was to assess the determinants of adoption of improved stove to reduce burden on biomass energy source at rural household level and to propose possible solution in the study district. The specific objectives of the study were: 1) to examine the existing opportunities of using the improved stove as an energy saving technology, and 2) to analyze factors affecting adoption of improved stove at household level in the study area. In light of the aforementioned research objectives this study strives to answer the following key research questions: 1) what are the existing opportunities of using improved stove as an energy saving technology? And 2) what are determinants of adoption of improved stove in energy consumption at household level?

Literature Review

The sources of energy consumption patterns at household level in the world could be broadly classified as renewable energy sources such as solar, wind, firewood, charcoal, crop residues, biogas and hydropower and non-renewable energy sources such as fossil fuel, coal, petroleum, natural gas and so on. However, the type of energy consumption might be determined by different factors such as income level, educational status, cultural preference and households' use of energy purposes such as cooking, lighting, boiling water and space conditioning and so on. In short, household's sources of energy consumption patterns in the world are diverse in nature.

Mfune and Boon (2008), illustrates that a great disparity in energy consumption exists between the developed and developing countries. Hence, the latter have 80 percent of the world's population but consume only 30 percent of the world's commercial energy like electricity. However, many of developing countries are richly endowed with energy resources.

Moreover, research by WHO (2006) and Guta (2014) found that cooking is as a task and threat to the lives of the great majority on an open fire in rural area of developing countries such as Africa, south Asia and Latin America especially women, children and older generation who mostly spent their time indoor air pollution. Moreover, worldwide more than three billion people depend on inefficient traditional source of energy such as solid fuels to meet their most fundamental energy needs. Additionally, the inefficient burning of solid fuels on traditional stove indoors creates a dangerous health of hundreds of people due to pollutants.

The open fire stoves have very low energy efficiency, about 10 to 15% for cooking and 7% for baking. This implies that the potential energy (85%) or more is wasted in traditional cooking stoves comparing to improved cooking stoves. As a result, the low utilization efficiency of the open fire stoves (open three stone stove) has resulted in a higher demand for biomass (Gebreegziabher, 2007).

Moreover, research by Kathmandu (2005), illustrate that improved cooking stoves have the potential to save the fuel wood used for household cooking as compare to traditional stoves/open fire energy consumption. Hence, about 11 million tonnes of fuel wood are burnt annually for cooking alone. In theory, it is possible to reduce fuel wood consumption for cooking by half. Because improve cooking stoves have an efficiency factor in the range of 15-30%, while the efficiency of traditional mud stoves varies from 3-15%. However, the amount of fuel wood saved depends among other things such as the type of stoves, the condition of the fuel wood, the type and amount of food prepared, and the type of pots used for cooking. In addition according to Kathmandu even if with a low performance of 11% fuel wood savings, estimates indicate that one ICS can save an average of 1 tonne of fuel wood annually as compare to inefficient traditional stoves.

Furthermore, according to Slaski and Thurber (2009) research indicated that despite the potentially huge health benefits of programs to disseminate improved cook stoves in the developing countries, such programs have struggled to make an impact over several decades of effort.

Determinants of Adoption of Improved Stoves

The adoption of improve stoves in a given society might be affected by variety factors such as income, education, stove price, smoke level, taste preference, cultural preferences and so on.

The determinant of adoption of a new technology is inherent incentive or motivation, hence human beings by nature resistant which is connected with the perceived value of the new product or service. Since cook stove programs are most successful when seen by prospective customers to provide concrete and observable benefits. Currently, in rural areas where fuel is scarce, people similarly see the value of fuel-saving stoves, which help reduce long or dangerous trips to collect wood especially women and children spend majority of their time for collection fire wood rather than participating in productivity activities. Moreover, the other contribution of improved technologies the value that outside observers usually see as paramount the improvement of health through elimination of indoor air pollution. Thus, education about this benefit has for the most part been ineffective; even when informed about health benefits, users do not seem to value them highly enough to overcome preferences for traditional cooking methods. In addition, what have worked better are efforts that actually create and market new perceived value associated with the stove (Slaski and Thurber, 2009).

Moreover, according to Tsephel *et al.* (2009) the socio-economic, level of deforestation, government policy, level of urbanization, availability of stove were determinates of adoption improved cooking stove. For instance, deforestation's effect on fuel choice is influenced by changing price or cost of fuel wood collection, which is a product-specific factor.

Energy and Gender

Gender refers to social creation of men and women to play different roles, have different needs, and face different constraints on a number of different levels. Hence, energy and gender has direct relation in terms of collection of fuel wood, dung, and crop residues for cooking purpose and activities. Moreover, this implies in developing countries including Ethiopia majority of the household energy consumption activities carried out by women as compared to men.

There is a strong gender dimension to the fuel wood issue. By tradition, it is the responsibility of women and children to collect fuel wood, while the marketing of fuel wood, where relevant, is dominated by men. Moreover, women also do the bulk of the household chores such as cleaning, cooking, washing and the like. Hence, women bear the brunt of all the negative aspects associated with the use of fuel wood. These imply that the opportunity cost of the time spent in collecting fuel wood, which can range from several hours up to 30 hours per month. Additionally hazards include an increased risk of injury due to the heavy loads carried (typical head loads have been measured at 20 – 50 kg), and other health hazards related to the regular exposure to wood smoke. In short, rural women spend the majority of their time on survival activities such as cooking, fuel wood collection, water carrying and food preparation, represents a high social and economic cost to the households (Damm and Triebel, 2008).

The link between rural household energy use and women is an area that is often ignored. However, particularly in developing countries like Ethiopia women are as users of energy sources, producers of traditional biomass fuels and educators concerning the collection, management and use of fuels. In addition, women and children are the most vulnerable group in terms of energy scarcity and adverse environmental impacts associated with energy production and use. Furthermore, women are the major users of traditional energy sources for household activities such as preparation of food in most rural areas is the responsibility of women (UN, 2004).

Research Methodology

Study Area

Enderta district is located in South East zone of Tigray, the district one of the few highly populated areas in Ethiopia and its total population estimated 129,876 from which 49.3% male and the remaining 50.7% female (CSA, 2011). Number of family heads are 28,432 which male 18,879 and female 9,553 (CSA, 2011). Enderta district bounded in the north by Kelteie Awelaielo district, in the east by the Afar district Abeala, in the south district Sehartie Samere and Hentalo Wajerat and in the west side by Degua Tenben. The total area of the district is 93,048 km^2 and Altitude in the area ranges from 1400m to 1800m (Almaz, 2008).

Enderta district has been selected in that it is highly populated implying the unbalanced carrying capacity of the natural resource base and hence the main source of energy, is drought prone and low energy per capita consumption. Moreover, majority of their energy consumption depends on traditional energy sources such as wood, charcoal, dung and crop residues leading to the increasing deforestation and reducing agricultural productivity in the study area.

Research Design

In this study exploratory type of study was employed to investigate and examine the current state of problems that affecting energy consumption of households. Survey was a method of data collection using appropriate instruments such as structured questionnaire based on interview technique. Both qualitative and quantitative data were collected to examine the situation of household energy consumption patterns in rural Enderta district. Moreover, both primary and secondary data were collected while the primary data were cross-sectional data. The survey was covered a random sample of 120 household heads selected from three rural villages based on a Probability Proportional to Size (PPS).

Sources of Data and Collection Methods

In assessing the household energy consumption patterns, the secondary data was collected from different sources such as census, regional documents, district manuscripts, records and official documents of energy office. Documents from the ministry of Energy and Water, Annual Statistical Abstract were consulted. Relevant literatures concerning household energy consumption patterns were also reviewed. However, the primary data were gathered from the household heads of the study area.

In the study area the following respondents were selected as primary data source.

a) Household head
b) Rural village leaders and Development agents
c) Key informants: - they were taken to identify household energy consumption patterns

Each sample rural village was randomly selected from 17 rural villages through Simple Random Sampling method. Key informants from each community were selected on the basis of purposive sample technique.

Sampling Design

In this study, multistage sampling procedures were used to select the survey areas and the sampling unit frame of household heads. At the first stage, Enderta disrict was purposively selected since the district is populous and cutting trees for charcoal purposes is a common practice. In the second stage, three rural villages were selected from 17 rural villages through Simple randomly method such as Debri, Mayambesa, Felegeselam in order to accommodate household heads. Finally, the researcher selected 120 household heads through simple random sampling method, 53 households who has access to modern source of energy (electricity) and the remaining 67 household heads from their source of energy were traditional inefficient biomass based on Probability Proportional to Size (PPS). In short, the required information regarding rural villages and the sampling frame were collected from both Enderta district and rural village administration.

Table 1: The distribution of sample sizes of household heads in selected rural villages

Name of rural villages	Total household heads				Proportionality of the sample to actual population
	Actual		Sample proportion		
	Number	Percentage	Number	Percentage	
Myambesa	6665	31.1	31	25.8	10%
Debri	7913	37.0	53	44.2	10%
Felegeselam	6820	31.9	36	30	10%
Total	21398	100	120	100	10%

Source: Enderta district administration, 2011

Model Specification

The probit model was used to identify and quantify factors that affect adoption of improved stove at household level. This model was appropriate because the dependent variable was discrete (that is, binary yes=1, otherwise=0) as it measures whether one had adopted use of improved stove or not. It was preferred to other model because authors anticipate to drawing their sample from normal distributed population (such that the error term is normally distributed) (Maddala, 1983). Following was the probit model to be used:

$$Y_i = \beta_0 + \sum_{j=8}^{k} \beta_j X_{ij} + e_i$$

Where: Y = Adoption of improved stove (1= yes, 0= otherwise); X_1 = Sex of household head (male-headed and female-headed); X2 = Age of household head (age in years continuous); X3 = Marital status of household head (Married/Unmarried /Divorced/ Widowed); X4 = Household size (age in years continuous); X5 = Household head's education level (education years); X6 = Occupation of household head (Farming/non-farming); X7 = Household annual income size (Birr);X_8 = Distance from agricultural extension center (kilometers); X9 = Distance from health extension center (kilometers); X10 = Distance from main road (kilometers); X11 = Distance from market service (kilometers); X12 = Access to credit service (yes or no);X13 = Source of energy cooking (Modern or traditional); X14 = Owner of planted trees (yes or no); X15 = Owner of livestock (yes or no); X16 = Accessibility of fire wood (yes or no); X17 = Distance traveled to collect firewood (km/ week); X18 = Time taken to collect firewood (hour/week); X19 = Accessibility of dung (yes or no);X20 = Distance traveled to collect dung (km/ week); X21 = Time taken to collect dung (hour/week); X22 = Households Awareness on improved stove (continuous codes constructed depending on level of awareness); X23 = Kitchen service (Separate or open space); X24 = Land ownership (yes or no).

Methods of Data Analysis

In this study, both descriptive statistics and econometric model were used for analysis of data collected. Descriptive statistics was used to describe relevant aspects of observable facts about the variables thereby providing detailed information about each relevant variable. Specifically: percentage, mean, standard deviation, maximum and minimum values of the required variables were computed. The statements from scheduled interview were used to substantiate the responses of quantitative findings. For quantitative Probit model and t-test was used to analyze determinants of adoption of improved stove using STATA software.

Results and Discussion

Discussion on Descriptive Statistics of the Survey Result

Occupation and Education of Household Heads

As in Figure 1 illustrates that more than three-fourth of the household heads found illiterate (60.83%) with only 15.83 percent could simply read and write. While about 23.33 percent of the households attained formal education from grade one up to college diploma. In fact, only 39.17% of household heads have got chance to attain formal education. Education is expected to affect the adoption decision of household energy consumption. In this study, educated head of households are assumed to be more aware of the environmental and health effects of using biomass fuels (firewood, dung, crop residues) and, as a result, the researcher expect that education plays a great role of increasing consumption of modern sources of energy as well as adoption of improved stoves in the area of energy consumption. Supported by similar study Gebreegziabher (2007) had shown that the education of household head significantly and negatively influenced the decision to consume wood implies the less likely would the household consume wood the higher level of education. And also supported by other research (Barnes *et al.*, 2010) had shown that education is negatively related to energy use and this would probably mean that they are more aware of the benefits of switching to modern cooking fuels or conserving biomass energy.

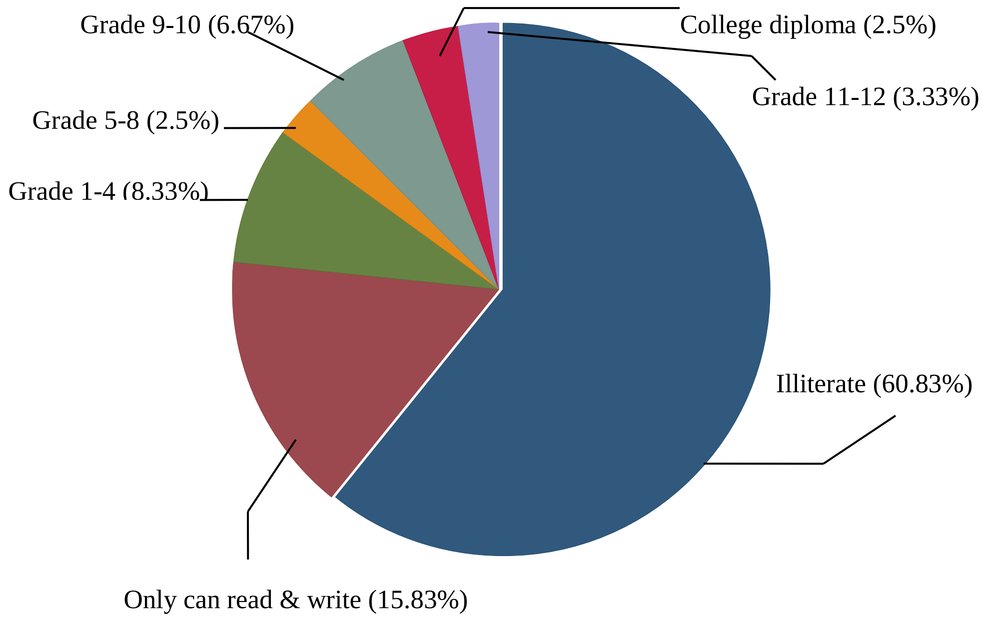

Figure 1 Overall educational statuses of the heads of household

Figure 2 the primary occupation of household heads in the study area is farming in more than four-fifth of the households. The result also shows that of the total household heads; about 5.83 percent are found student, 10% are daily laborer, 10.83% undertaking their business and the remaining only 1.67% are found employed (see Figure 3). As such as have indicated that the educational status has a direct implication to the primary occupation of the sample household heads with greatest number of households are being employed on farming activities. It is expected that the household heads who are employed out of farming activities could use more modern source of energy and adoption improved technologies than who are employed in farming activities. Supported by similar research by (Maser *et al.*, 2000) indicated that households that remained as fuel wood-only users showed no or a small positive change in a stable main occupational structure; all households also remained in the same income group.

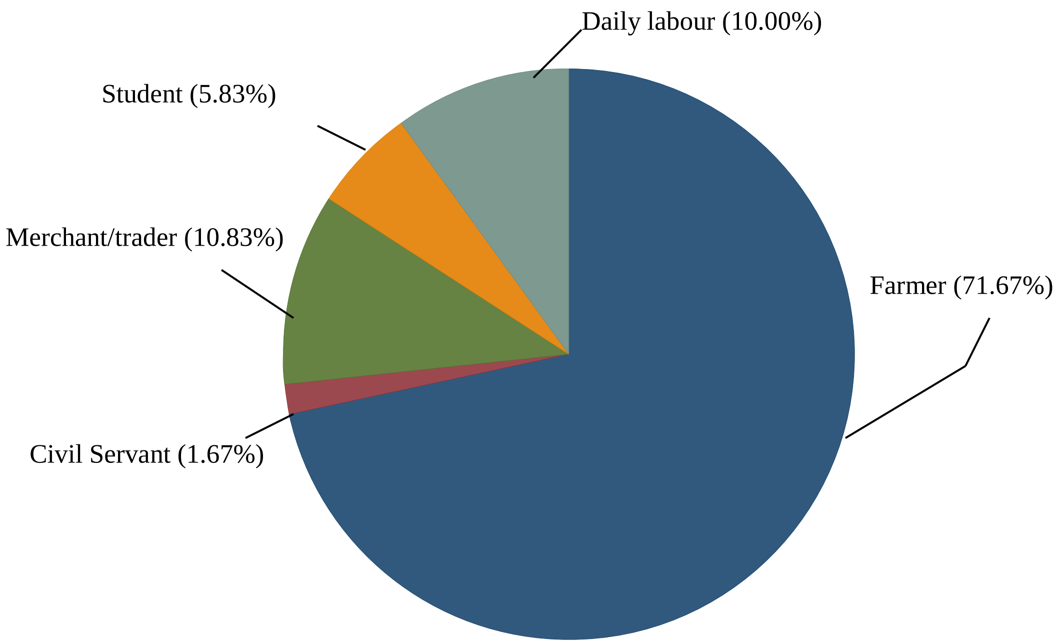

Figure 2 Overall primary occupations of heads of household

Rural Household Energy Consumption

In this section, key variables of interest that characterize households' energy consumption patterns are presented.

Larger proportion of rural households are dependent on traditional fuels (biomass) while some used modern source of energy such as electricity and kerosene for cooking, lighting, baking *injera*[1] and heating. As clearly shown in Figure 3 that larger proportion of households are dependent on firewood and dung source of energy consumption while kerosene and crop residues are found lowest energy consumption in rural Enderta district. The main reasons for preference of household energy consumption in the study area is ease of access (59.70%) and convenience (31.34%) source of energy furthermore the least reasons for choice of rural household's energy consumption is cultural preference and cheap prices, 1.49% and 7.46% respectively. This is supported by similar research Mekonnen and Kohlin (2008) in Ethiopian, rural households have been dependent for centuries on two main solid fuels woody biomass and dung with kerosene used for lighting however electricity, and liquefied petroleum gas are possible alternative energy sources, they are hardly used at all in these rural areas due to high prices and lack of access. The researcher argue in favor of this pervious work hence rural households dependent on biomass source of energy consumption for various reasons but mainly due to lack of availability of modern energy sources. In fact, the results show that the existing in rural household energy consumption patterns in progress hence there is improvement such as access to electricity and distribution of improved stove for rural communities.

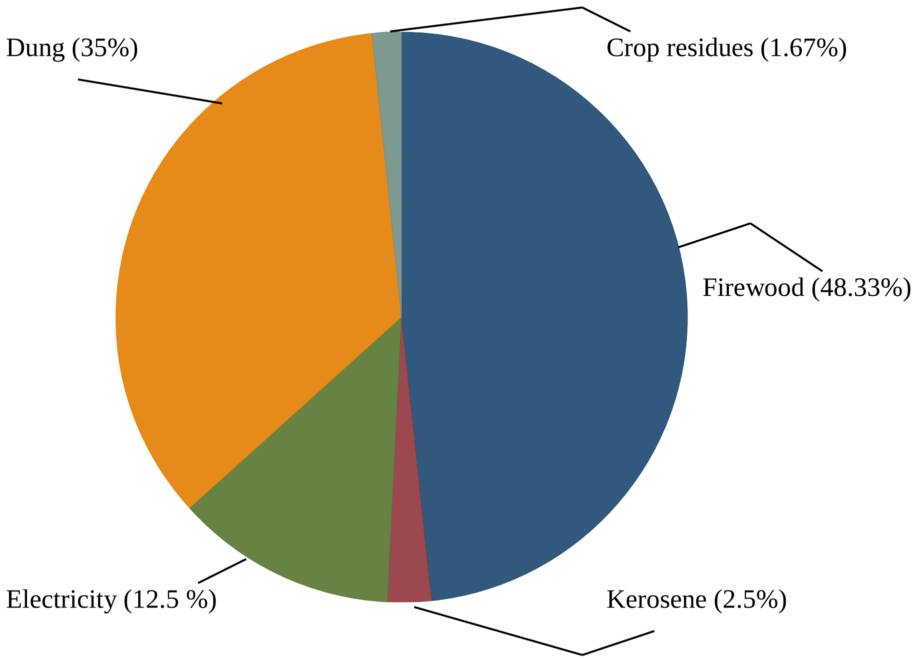

Figure 3 Proportions of household's major energy consumption in the study area.

The characteristic of household fuel utilization is shown (See Table 2) the majority of households use firewood followed by dung for the purpose of baking '*injera'* while crop residues and electricity are found in the third and fourth level respectively. As we can seen from the Table 2, charcoal is the first widely used fuel type, dung is the second, firewood and kerosene is the third and fourth respectively widely used fuel by households for the purposes of cooking (stew (wet), soup, making tea and coffee and likes) with respect to other fuel types. Furthermore, as the third column of Table 2 shows that electricity followed by dry cells, kerosene is found in the third with respect to other fuel types used for household's source of lighting purposes. Study by Gebreegziabher *et al.* (2012) had shown that *injera* baking and general cooking are the two most common end uses of urban domestic energy consumption in Ethiopia. Fuel wood, electricity, and dung are mainly used to bake *injera*, while charcoal and kerosene are used for other cooking. The researcher argue in favor of Gebreegziabher *et al.* (2012) work but this finding conducted in rural area even if some rural households with access to electric service, they did not use for the purposes of baking *injera* as well as cooking mainly only use it for the purposes of lighting.

The finding shown that in the study area larger proportion of households with no access to modern fuel are found using a combination of firewood and dung (83.58%) for domestic source of energy consumption and some of them also use a combination of firewood and crop residue (10.45%) for domestic end sources of energy consumption whereas majority households with access to modern fuel have used a combination of firewood and electricity (90.57%), followed by firewood and dung (5.66%) the next most important source of fuel for a combination of household's source of energy consumption in the study area (see Table 2). The major reasons for a combination of source of energy were availability and convenience of source of energy. For households with no access to modern fuel the most reasons a combination of source of energy are found availability (62.69%) and convenience (37.31%) source of fuel while majority of households with access to modern fuel in the study area the main motive for mixture of source of fuel were convenience (50.94%) and availability (49.06).

Table 2: Proportion of Household Fuel Utilization

Kind of fuel	Proportion of total energy consumption in %		
	Baking *injera*	Cooking	Lighting
Firewood	50.00	16.67	0.00
Charcoal	0.00	38.33	0.00
Crop residue	7.50	0.00	1.67
Dung	40.00	32.50	0.00
Kerosene	0.00	12.50	18.33
Electricity	2.50	0.00	44.17
Candle	0.00	0.00	4.17
Dry cells	0.00	0.00	31.67

Among the various fuels considered wood and dung turned out to be the prominent fuel sources of households in the study area. A descriptive summary of households' energy sources is presented in Table 3 showing that all households in sample use firewood as energy source with small portion of it coming from the market (purchasing).

Dung is the next important for household's sources of energy consumption with largest proportion being collected by the households themselves but almost few of them have not used dung for household source of energy. According to Gebreegziabher (2007), none of the sample households were found using crop residues. However, this finding shows that some households are found using crop residues hence highly depletion of firewood leads to substitution of crop residues for source of energy consumption.

Table 3: Fuel sources, households involved and mode of acquisition of biomass energy sources

Fuel sources	Households involved (%)	No use (%)	Way of acquired (%)	
			Buying (%)	Self collecting (%)
Firewood	100.00	0.00	10.92	89.07
Dung	71.67	28.33	0.83	70.83
Crop residue	20.83	79.17	0.83	20.00
Charcoal	40.83	59.17	10.00	30.81

Damm and Triebe (2008) found out that rural households spend the majority of their time (up to 30 hours per month) on survival activities such as cooking, fuel wood collection and so on include an increased risk of injury due to the heavy loads carried (typical head loads have been measured at 20 – 50 kg). In this study, also finding shown that (See Table 4) on average households traveled 12.94 km, 2.72 km, 32.61 km and 11.45 km for collection of firewood, crop residues, dung and charcoal per week respectively. In the other words, on average 8.48 and 7.98 hours are spent for collecting firewood and dung per week respectively. And also on average 0.70 and 3.95 hours are spent for collecting crop residues and charcoal per week respectively. From this could concluded that households in the study area spent significant amount of time for collecting fuel that could be used for other productive purposes such as carried out agriculture activities and likes.

Table 4: Distance traveled, frequency and time spent for biomass collection

Variable	Mean	Std. Dev.	Min	Max
Distance traveled to collect firewood (km/ week)	12.94	12.67	0	50
Time spent to collect firewood (hour/week)	8.48	7.58	0	36
Frequency of firewood collection per week	1.91	0.93	0	3
Distance traveled to collect crop residues (km/ week)	2.72	10.54	0	60
Time spent to collect crop residues (hour/ week)	0.70	2.21	0	12
Frequency of crop residues collection per week	0.33	0.88	0	3
Distance traveled to collect dung (km/week)	32.61	40.78	0	150
Time spent to collect dung (hour/week)	7.98	9.01	0	36
Frequency of dung collection per week	2.09	1.10	0	3
Distance traveled to collect charcoal per week (km/week)	11.45	19.17	0	80
Time spent to collect charcoal (hour/week)	3.95	6.46	0	27
Frequency of charcoal collection per week	0.82	1.09	0	3

Gender and Energy Interaction

There is a strong linkage between gender and energy dimension to the fuel wood issue. By tradition, it is the responsibility of women and children to collect fuel wood, while the marketing of fuel wood, where relevant, is dominated by men. Rural women spend the majority of their time on survival activities such as cooking, fuel wood collection and food preparation (Damm, and Triebel, 2008). In this study, also as it can be seen (Table 5) the highest contribution of households with no access to modern fuel collection of fuels are done by mothers, followed by daughters and child boys. While in households with access to modern fuel the highest contribution of fuel collection of fuels are done by daughters, followed by child boys and mothers.

In similar way, as clearly seen from (Table 5 column 3), the highest contribution to split of wood fuel for household's energy consumption purposes were done by fathers in both households with no and with access to modern fuel, followed by daughters and child boys third. Relatively the contribution of split wood fuel purposes by mothers less than fathers, daughters and sons in both households with no and with accesses to modern fuel.

The majority of preparation of food was done by mothers in both households with no and with access to modern fuel followed by daughters and servants. Almost fathers and child boys do not have contribution of food participation in both households with no and with modern fuel. This implies women are recognized as the primary source of biomass energy collectors as well as the emission receiver. Hence cooking food is considered as women's task and is generally conducted by women though the male helps her but staying near the fire is always women and the children (see Table 5).

Table 5: Household energy collection patterns and participant in preparation of food

Participant	Fuel collector		Participant in split of wood fuel		Participant in preparation of food	
	Households with no access to modern fuel	Households with access to modern fuel	Households with no access to modern fuel	Households with access to modern fuel	Households with no access to modern fuel	Households with access to modern fuel
	%	%	%	%	%	%
Father	13.43	7.55	53.03	50.94	1.49	0.00
Mother	34.33	24.53	9.09	1.89	92.54	92.45
Child boy	17.91	26.42	18.18	20.75	0.00	0.00
Daughter	29.85	35.85	19.70	24.53	4.48	1.89
Relative	4.48	5.66	0.00	0.00	0.00	1.89
Servant	0.00	0.00	0.00	1.89	1.49	3.77

Household access to information about improved stove

As it can be seen from Table 6, the finding shows that nearly equivalent with households with and with no access to information on improved stove however households with no access to information slightly greater than households with access to information on improved stoves. In the study area Kebele leaders were the main provider of information about improved stove hence 96.88 percent and 100 percent of households with no and with accesses to modern fuel respectively informed by kebele leaders with only least of the remaining households with no access to modern fuel 3.13% of informed by none governmental organization/GTZ.

However, the survey result shows that among aware households on the benefits of improved stove only 43.28 percent and 41.51 percent of households with no and with access to modern fuel respectively are adopted. In other words, majority of informed households about improved stoves did not adopted because of 56.72 percent and 58.49 percent of households with no and with access to modern fuel respectively did not adopted improved stove. The way of acquiring adopting improved stove by households with no access to modern fuel were 34.48%, 6.90%, 27.59% and 31.03% by cash, credit from producer, credit (from governmental or none-governmental organization) and free gift respectively. While adopter households with access to modern fuel were cash (63.64%), credit from producers (4.55%), credit (from NGO, Gov) (27.27 %) and free gift (4.55%). From this we can conclude that even if households are aware the important of improved stoves larger proportion of them did not adopted improved stoves. Furthermore, Kebele leaders were the major provider of information on improved stove for rural households. Among way of acquiring of improved stove cash was the main means for both households with no and with accesses to modern fuel.

Table 6: Sample household's access to information about improved stoves

Variables	Do you have access to information on improved stove?	
	Hhs with no access to modern fuel	Hhs with access to modern fuel
	%	%
Yes	47.76	49.06
No	52.24	50.94

Available Opportunities for Using Improved Stove as an Energy Saving Technology

Table 7, the finding revealed that the household's perception on benefit of improved stove, larger proportion of adopter in both households with no and with access to modern fuel understood that very high improvement in speed of baking, contribution to reducing burden on biomass, fuel economy and reduces smoke/ashes. On the other hand, the data shows that improved stove adopter households are more advantages than non-adopter households hence the respondents are seen very high improvement in speed of baking, contribution to reducing burden on biomass, fuel economy and reduce smoke/ashes. This implies that could contribute reducing deforestation, land degradation and increasing agricultural productivity who are adopting improved stove households. This is supported by recent research Damte and Koch (2011) in Ethiopia, distribution of more efficient stoves will help reduce pressure on biomass resources, increase land productivity by reducing crop residue and dung usage for fuel and improve family health. Moreover, the intervention is expected to benefit women and children, in particular, by reducing fuel collection workloads and limiting exposure to flame hazards and the emission of harmful pollutants.

Table 7: Improved stove adopter household's perception on advantage of improved stove

Advantage of improved stove	Speed of baking		Contribution to reducing burden on biomass		Fuel economy		Reduce smoke/ashes	
	Households with no access to modern fuel	Households with access to modern fuel	Households with no access to modern fuel	Households with access to modern fuel	Households with no access to modern fuel	Households with access to modern fuel	Households with no access to modern fuel	Households with access to modern fuel
	%	%	%	%	%	%	%	%
Very high improvement	86.21	95.45	62.07	77.27	58.62	40.91	68.97	50.00
High improvement	13.79	4.55	34.48	22.73	37.93	59.09	31.03	50.00
Moderate improvement	0.00	0.00	3.45	0.00	3.45	0.00	0.00	0.00
Low improvement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
No improvement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Factors Affecting adoption of improved stove at household level

As it can be seen from Table 8 larger proportions of households with no access to modern fuel have seen durability problem followed by local availability and hotness of external surface. Moreover, households with no access to modern fuel have identified affordability and installation limitation of improved stoves. On the other hand, the preponderance of households with access to modern fuel that have identified hotness of external surface the main limitation of improved stove, followed by durability and installation. Local availability and affordability limitations are also identified by households with access to modern fuel. Despite the limitation of improved stove, majority of both households with no and with accesses to modern fuel strongly agreed that use of improved stove benefits greater than limitation since nearly all improved stove adopter sample households recognized that it helps to very high improvement in speed of baking, contribution to reducing burden on biomass, fuel economy and reduce smoke/ ashes.

Table 8: Improved stove adopter household's perception on limitation of improved stove

Limitation of improved stove	Households with no access modern fuel	Households with access to modern fuel
	%	%
Affordability	6.90	4.55
Local availability	24.14	4.55
Durability	44.83	31.82
Installation	6.90	13.64
Hotness	17.24	45.45

Improved Stove Adopters and Non-adopter Households

As we can be seen in Table 8 concerning the demographic characteristics of households, average age is 36.63 and 36.91 years old for adopter and non-adopter improved households respectively. This difference is statistically not significant. In similar way, the mean family size of improved stove adopter household is 6; the mean family size of non-adopter improved stove household is 6.06. This difference is also statistically not significant. In similar fashion, concerning the sex of household head is 60.78 percent of adopter of improved stove households are male headed of household while non-adopter of improved stove households are account 55.07 percent are male headed of household. This difference is statistically not significant too.

Table 8 indicates that concerning educational status of household, the result of the survey illustrates that 50.98% of the household heads are found illiterate with 23.53 percent can simply read and write while about 25.48 percent the households attain formal education from grade one up to college diploma are improved stove of adopter households whereas non-adopter of improved stove households the result of the survey illustrates that more than half of (68.12%) of the household heads are found illiterate with only 10.14 percent can simply read and write while only 21.75 percent the households attain formal education from grade one up to college diploma. This difference is statistically significant at 10%. We can conclude that education is very important to adopt improved stove for rural household's energy consumption patterns.

A Table 8 also presents the detail economic characteristics of households, 25.49 percent and 30.43 percent are found improved stove adopter and non-adopter households respectively employed out of farming activities with the remaining being employed in farming activities. This difference is statistically not significant. In similar way, the mean per capita expenditure of improved stove adopter household is 402.35; whereas the mean per capita expenditure of non-adopter improved stove household is 349.62. This difference is also statistically not significant.

Table 8 also shows that average farm size is 1.92 and 1.10 *timad* for improved stove adopter and non-adopter households respectively. This difference is statistically highly significant at 1%. Similar fashion, on average total livestock hold is 2.66 and 1.29 TLU for improved stove adopter and non-adopter households respectively. This difference is also statistically significant at 5%. This implies that improved stove adopter households have larger farm size and livestock this help to better opportunity acquire improved stove adopter than non-adopter households because farm and livestock is wealth.

Table 8 detail shows that improved stove adopter households have 86.27% access to credit services while non-adopter improved stove households have 66.67% access to credit services. This difference is statistically significant at 5%. This implies that relatively improved stove adopter households have better access to credit service than non-adopter improved stove households. In similar way, is 100% and 10.14% for improved stove adopter and non-adopter improved stove households respectively have access to information on improved stove. This difference is also highly statistically significant at 1%. This implies access to credit services and access to information on improved stove motivates/helps to adopt improved stove in the study area.

In addition, Table 8 shows that access to kitchen service is 49.02%, 21.57% and 29.41% improved stove adopter households are install on separate kitchen, outdoor and in home respectively while non-adopter improved stove households cooking place is 28%, 14% and 27% on separate kitchen, outdoor and in living room respectively. This difference is statistically not significant too. In similar way, the average distant from the household's home to the agriculture extension center for improved stove adopter and non-adopter households is 1.97 km and 2.15 km respectively; this mean difference is statistically not significant. However, the mean distant from the households' home to the health extension center for improved stove adopter households is about 1.57 km; the mean distance traveled by about non-adopter improved stove households is about 2.33 km. This difference is statistically significant at 1%. This implies that improved stove adopter households are close to health extension center as result, have better opportunity to acquire the services than non-adopter improved stove households.

The average distance from the household's home to the road is 2 km for improved stove adopter households; the mean distance traveled by about non-adopter improved stove households is 2.42 km. This difference is statistically not significant. In similarly way, the average distant from household's home to market services for improved stove adopter household is 11.44 km, while the mean distance traveled by access to non-improved stove adopter households is 11.99 km. In similarly way, this difference is also statistically not significant.

Table 8: Demographic, Economic and Access to Facilities Characteristics of Sample Households Decision on Improved Stove adoption

Variable Name	Adopter		Non-adopter		t-test
	Mean	Std. Dev.	Mean	Std. Dev.	
Age of household head	36.63	9.62	36.91	12.36	-0.14
Family size of household	6.00	1.93	6.06	2.09	-0.16
Sex of household head	0.39	0.49	0.45	0.50	-0.62
Education of household head	0.49	0.50	0.32	0.47	1.91*
Occupation of household head	0.26	0.44	0.30	0.46	-0.59
Per capital expenditure	402.35	224.47	349.62	261.76	1.16
Farm size measured in timad	1.92	1.45	1.10	1.29	3.27***
Total livestock measured in TLU	2.66	4.07	1.29	2.53	2.27**
Access to credit	0.14	0.35	0.33	0.48	-2.49**
Access to improved stove information	0	0	0.90	0.30	-21.08***
Access to kitchen service	0.80	0.87	0.99	0.90	-1.11
Distance from agriculture extension	1.97	1.56	2.15	1.43	-0.66
Distance from health extension	1.57	0.92	2.33	1.74	-2.84***
Distance from road	2.00	1.57	2.42	1.94	-1.26
Distance from market	11.44	5.04	11.99	5.15	-0.58

*, **and *** indicate significant at 10%, 5% and 1% level respectively.

Results of econometric analysis on determinants of improved stove technology

As indicated in Table 9, the educational level of the household head has significant effect on the decision of adoption of improved stove negatively at 10% level of significance. When household head's educational level increased by one; the probability of adoption of improved stove will decrease by 25.4%.

Table 9, that access to credit service has positively significant effect for the household to adopt improved stove at 5% level of significance. This implies that the access to credit service increases by one, the probability of adoption of the improved stove will increase by 26.9%. This implies that credit service helps to adopt improved stove in the study area.

It is also evident; (from Table 9) livestock ownership has significant impact on adoption of improved stove positively at 10% level of significance. This implies that as livestock ownership increased by one total livestock unit (TLU), the probability of adoption of improved stove will increase by 18.4% in household heads.

As it may be clearly presented in Table 9, the distance from the head of the household home to firewood collection have positive effect on the adoption of improved stove decision of households at statistically significance level of 1%. As distance from the head of the household home to firewood collection increased by one kilometer, the probability of adoption of improved stove will increase by 1.4%. Hence improved stove very important for contribute reductions in the demand of biomass resources, hence helps to use in fuel economical moreover, combating land degradation, thus mitigating the effects of drought, as well as having the potential to yield improvements.

The model fitness, the variability of the variances of error term and the multicollinearity is tested and the result shows that the model has 70.00% predicting power and it is free from hetreoscadesticity and multicollinearity. Hence these assure that the model specification is feasible and accurate.

Table 9: Probit regression of the adoption of an improved stove in the study area

Explanatory Variable	*Coefficient*	*Std. Err.*	*Z*	Marginal effect (dy/dx)
Per capital expenditure	-0.0003	0.000	-0.70	-0.0001
Family size	0.058	0.035	0.64	0.022
Educational level of hhh	-0.658	0.135	-1.88*	-0.254
Occupation of hhh	0.495	0.131	1.40	0.184
Sex of respondent	0.282	0.110	0.99	0.108
Access to credit service	0.755	0.107	2.52**	0.269
Age of hhh	-0.002	0.005	-0.11	-0.001
Livestock ownership	0.478	0.112	1.65*	0.184
Wood collection from own farm	0.274	0.351	0.31	0.108
Distance wood collection from home	0.037	0.005	2.99***	0.014
Distance crop residue from home	-0.005	0.006	-0.33	-0.002
Distant dung collection from home	-0.002	0.001	-0.56	-0.001
Distant charcoal collection from home	-0.005	0.003	-0.73	-0.002
Kitchen service	-0.066	0.060	-0.43	-0.026
Smoke/ashes	-0.664	0.250	-1.04	-0.260
Constant	-0.830			

*, **and *** indicate significant at 10%, 5% and 1% level respectively.

Conclusion and Recommendation

The major of households were dependent on firewood and dung for purposes of baking *injera* and general cooking while kerosene, crop residue and electricity are lowest energy consumption in rural Enderta woreda. Therefore, uses of biomass energy sources leads forest degradation, deforestation, and lands degradation all severe environmental problems. To overcome these, rural development planners should be encouraged the rural households to plant trees on their own farm land for fuel wood purpose and also adoption of improved stove could contribute to reducing burden on biomass.

Improvement in resource-use efficiency through adoption of improved stove vital to reduce relies on biomass energy sources. Hence, improved stove adopter households are more advantages in terms of high improvement in speed of baking, contribution to reducing burden on biomass, fuel economy and reduce smoke/ashes as compared to non-adopters. However, the penetration rate of adoption improved stove too low in the study area. To fill these knowledge gap different strategies should be planned to introduce and disseminate the alternative technologies, or at least create awareness to the population about the benefits of energy saving device and technologies via demonstrations, posters, and radio or TV advertisements is vital. Moreover, improved stove adopter household are identified durability, local availability, and affordability limitation of improved stoves. The government and other development partners need to assist producers through different mechanisms such as information, training for local communities and access to credit provision schemes.

Note

1. Injera, made from teff, is the staple bread in Ethiopia

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