ADDIS ABABA UNIVERSITY

FACULTY OF NATURAL SCIENCE

CENTER FOR ENVIRONMENTAL SCIENCE

UTILIZATION OF BIOMASS BASED RENEWABLE ENERGY SOURCE:
IMPLICATIONS FOR CLIMATE COMPATIBLE DEVELOPMENT IN WOLAITA,
ETHIOPIA

BY: ENDRIAS INGALA SAKATO

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Utilization of Biomass Based Renewable Energy Sources: Implications for Climate Compatible Development in Wolaita, Ethiopia

By

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A Thesis Presented to the Graduate Programs of the Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Environmental Science

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July, 2015
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Addis Ababa University
# CONTENT

**ACKNOWLEDGEMENTS** .................................................................................................................................................. ii

I.List of Tables ........................................................................................................................................................... viii

II.List of Figure ............................................................................................................................................................ x

III.ABSTRACT ............................................................................................................................................................... xi

## 1. INTRODUCTION ................................................................................................................................................. 1

  1.1. Background .......................................................................................................................................................... 1

  1.2 Statement of the Problem ............................................................................................................................... 2

  1.3. Objectives of the study area ............................................................................................................................ 3

    1.3.1. General Objective: ...................................................................................................................................... 4

    1.3.2. Specific Objective ...................................................................................................................................... 4

  1.5. Significance of the Study .................................................................................................................................. 4

  1.6. Factors Considered ............................................................................................................................................ 5

  1.7. Organization of the Study ................................................................................................................................ 5

## 2. LITERATURE REVIEW ........................................................................................................................................ 6

  2.1. Biomass Energy Resource Potential In Ethiopia ................................................................................................ 6

  2.2. Utilization of Biomass Based Renewable Energy Sources in Ethiopia ............................................................ 6

    2.2.1. Overview of Global Biomass Energy Source ............................................................................................. 6

    2.2.2. Current Status of Biomass Based Renewable Energy in Ethiopia ............................................................ 8

  2.3. Utilization of Biomass Energy Source and Its Impacts ..................................................................................... 9

    2.3.1. Utilization of Biomass Energy Source and Its Environmental Effects .................................................. 9

    2.3.2. Utilization of Biomass Energy Source and Its Climate Effects ................................................................. 11

    2.3.3. Utilization of Biomass Energy in Household and Its Effect ..................................................................... 12

  2.4. Improved Biomass Energy Technologies (IBETs) ............................................................................................ 14

    2.4.1. Potential Benefits of IBETs ......................................................................................................................... 14

    2.4.2. Improved cook stoves................................................................................................................................. 15

    2.4.2. Biomass Energy Efficiency Development in Ethiopia ............................................................................... 16

## 3. MATERIALS AND METHODOLOGY ................................................................................................................ 17

  3.1. Description of the Study area ............................................................................................................................ 17

    3.1.1. Location ........................................................................................................................................................ 17
List of Tables

Table 1. Age Sex Distribution of Members of Sample Households in Wolaita Zone, Ethiopia..... 22
Table 2. Monthly Income of Households in Birr by Headship in Wolaita Zone, .................... 235
Table 3. Tenure Status of Sample Households by Number of Rooms of the Housing Unit....... 235
Table 4. Responses of study participants on their place of cooking in Wolaita Zone, ............ 24
Table 5. Educational Level of Heads of Sample Households in Wolaita Zone......................... 25
Table 6. Employment Status of Heads of Sample Households in Wolaita Zone.......................... 26
Table 7. Sources of Biomass Energy Supplies in Wolaita Zone, Ethiopia ............................... 28
Table 8. The Prevalence of Biomass Energy Shortage in Wolaita Zone, Ethiopia .................... 30
Table 9. Season of the Year Biomass Energy Shortage Happen in Wolaita Zone, ...................... 30
Table 10. Sample Households Monthly Energy utilization in mega-joules in Wolaita Zone........ 31
Table 11. Benifites about the utilization of Biomass Energy Saving Stoves in Wolaita Zone......... 37
Table 12. Dominance of biomass based renewable energy Technology and Improved Stoves .... 37
Table 13. The accessibility of cooking energy sources in Wolaita Zone, Ethiopia ..................... 39
Table 14. Stoves Availability by House Tenure Status of Sample Households. ......................... 40
Table 15. Stove Availability by Headship Patterns of the Household Head. .............................. 41
Table 16. Stove Availability by Monthly Household Income of Sample Households. ................. 41
Table 17. Monthly Total Household Energy Use in MJ by Sample Household Size.................... 42
Table 18. Monthly Total Household Energy Use in MJ by Sample Household Income ............... 43
Table 19. Monthly Total Energy Use In MJ by Tenure Status of Sample Households ................. 43
Table 20. Monthly Household Energy Use in MJ by Kitchen Availability of Sample HH .............. 44
Table 21. Monthly Total Biomass Energy Use in MJ by Sample Household Size....................... 44
Table 22. Monthly Total Biomass Energy Use in MJ by Sample Household Income .................... 45
Table 23. Monthly Total Biomass Energy Use in MJ by House Tenure Status ............................ 46
Table 24. Monthly Biomass Energy Use in MJ by Kitchen Availability ...................................... 46
Table 25. Monthly Total Household Energy Costs in Birr by Sample Household Size .................. 47
Table 26. Monthly Total Biomass Energy Costs in Birr by Sample Household Size .................... 47
Table 27. Monthly Total Household Energy Costs in Birr by Sample Household Income ............. 48
Table 28. Monthly Total Biomass energy costs in Birr by Sample Household Income ................. 48
Table 29. Monthly Household Energy Costs in Birr by House Tenure Status .......................... 49
Table 30. Monthly Biomass Energy Costs in Birr by House Tenure Status .......................... 49
Table 31. Monthly Household Energy Costs in Birr by Kitchen Availability .......................... 50
Table 32. Monthly Biomass Energy Costs in Birr by Kitchen Availability .......................... 50
List of Figure

Figure 1. The map of wolaita zone 17
Figure 2. Principal Energy Type Used for the Major Types of End Uses in Wolaita Zone, 26
Figure 3. Types of Domestic Appliances Used for InjeraBaking in Wolaita Zone, 28
Figure 4. Types of Domestic Appliances Use For Non-Injera End Uses in Wolaita Zone, 29
Figure 5. Monthly Biomass Energy utilization in Kg and Mega Joules in Wolaita Zone, 32
Figure 6. Sample Households Monthly Energy Costs for Biomass Energy in Birr, 33
Figure 7. Knowledge about the effects of biomass energy utilization in wolaita zone 34
Figure 8. biomass energy technology and biomass energy saving cooking stoves in Wolaita 35
# LIST OF ABBREVIATIONS AND ACRONYMS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLT</td>
<td>Branch, Leafs and Trunk</td>
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<td>BMES</td>
<td>Biomass Energy Source</td>
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<tr>
<td>BoA</td>
<td>Bureau of Agriculture</td>
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<td>BoPED</td>
<td>Bureau of Mines and Energy</td>
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<td>CSA</td>
<td>Central Statistical Authority</td>
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<td>DoPED</td>
<td>Department of Planning and Economic Development</td>
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<td>EEA</td>
<td>Ethiopia Energy Authority</td>
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<td>EEPCO</td>
<td>Ethiopia Electric Power Corporation</td>
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<td>EFAP</td>
<td>Ethiopia Forest Action Program</td>
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<td>ENEC</td>
<td>Ethiopian National Energy Committee</td>
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<td>ENEC-CESEN</td>
<td>Ethiopian National Energy Committee and Centro Studio</td>
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<td>EPAE</td>
<td>Environmental Protection Authority of Ethiopia)</td>
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<td>EREDPC</td>
<td>Ethiopia rural Energy Development Promotion Center</td>
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<td>ESMAP</td>
<td>Energy Sector Management Assistance Program</td>
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<td>ESP</td>
<td>Environment Support Program</td>
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<tr>
<td>ETB</td>
<td>Ethiopian Birr</td>
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<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>GTZ</td>
<td>GTZ is now GIIZ - Deutsche Gesellschaft für Internationale Zusammenarbeit</td>
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<td>HHs</td>
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IBETs:-Improved Biomass Energy Technologies
MME:-Ministry of Mines and Energy
MoEDaC:-Ministry of Economic Development and Co-operation
MoNRDEP:-Ministry of Natural Resource Development and Environmental
MoRD:-Ministry of Rural Development
NBE:-National Bank of Ethiopia
OECD:-Organization for Economic Co-operation and Development
REDD :-Reducing Emissions from Deforestation and Forest Degradation
REDD+ :- plus multiple co-benefits in conservation and livelihoods
REMDPA:- Rural Energy and Mining Resource Development and Promotion Agency
SNNPR:-Southern Nation Nationalities and People’s Region
SSA:-Sub-Saharan Africa
UN:-United Nations
UNDP:-United Nations Development Program
UNECA :-United Nations Economic Commission for Africa
UNICEF:-United Nations Children’s Fund
WB:-World Bank
WBISPP:-Woody Biomass Inventory and Strategic Planning Project
WD:-World Development
WEC:-World Energy Conferenc
ABSTRACT


Endrias Ingala Sakato
Addis Ababa University, 2015

Biomass energy source has been the major source of cooking energy for major segment of Ethiopian population for thousands of years. To investigate household energy consumption pattern of biomass energy sources and the biomass energy quality and safety of technology (wood-stoves) in respect to climatcal, socio-economical and environmental benefits in the wolaita zone. A community based cross-sectional study was conducted employing both quantitative and qualitative approaches on systematically selected 138 households for quantitative and purposively selected 110 people for qualitative parts. Descriptive statistical method and qualitative analysis were used as methodological tools. Moreover, one way analysis of variance (ANOVA) was fitted to assess possible associations and its strength was measured using odds ratio at 95 percent CI. The study indicated that 99.93 percent of households still use biomass energy for cooking. More than 15 percent of households collect tree biomass from their own homestead forests while 79 percent of households acquire their biomass energy through purchase from neighbors’ market and remaining 6 percent of household both collect and purchase. Testing reveals that quantity of firewood consumption by high income households was significantly higher than that of medium income and low income category households. Those who were less knowledgeable about negative health and environmental effects of traditional utilization of biomass energy sources were 5.11 and 3.58 times more likely to utilize them compared with those who were knowledgeable. The most outstanding finding of this study was that households use traditional biomass energy for cooking mainly due to lack of the knowledge and their beliefs about food prepared using biomass energy. Although 13% households were using improved cooking stoves (ICS), mass motivation and subsidized ICS can increase their uses. Therefore, mechanisms should be planned to promote modern energy and to teach the public about health, and environmental as well as climate effects of traditional way of utilization of biomass based renewable energy source. Along with reforestation programs government may take initiative for climate compatible development from ICS programs on household energy markets as part of the Clean Development Mechanism (CDM).

Keywords: Biomass, firewood, cooking stove, reforestation,
1. INTRODUCTION

1.1. Background
Biomass resources are generally includes both plant and animal biomass. Biomass based
renewable energy resources are mainly derived from three sources: agricultural residues, forestry
residues and energy crops (Bereket Kebede, 2000). Biomass energy resources refers to the direct
combustion (often in highly inefficient devices) of wood, charcoal, leaves, agricultural residue,
animal and human waste, for cooking, drying and charcoal production. Traditional forms of
biomass energies sources can be readily converted into all energy carriers, offering employment
options to reduce poverty and if burnt efficiently these could release low carbon (Guta Desai,
2012). The low cost biomass energy does not require processing before use (Sarlos et al, 2003).

Energy for household energy regularly constitutes 90 percent of total energy use in developing
countries (Haiti Hall, 2007). Woody biomass accounts 87 percent of the total annual biomass
energy use globally (Getachew Olana, 2002). It has been estimated that about 2.5 billion people in
these countries rely on biomass energy source to meet their household energy needs. According to
the IEA, 2010, without a substantial change in policy, the total number of people relying on
biomass energies would increase to 2.7 billion by 2030 (IEA, 2010).

According to a World Bank Report, indoor air pollution in developing countries is designated as
one of the four most critical global environmental problems (Amare Gedion, 2012). Burning
biomass energy source indoor is a major source of large amounts of smoke and other pollutants in
the confined space of the home, thereby providing a perfect avenue for human exposure. In rural
areas of Africa, a substantial portion of infants, children, and women is exposed to debilitating
levels of indoor pollution caused by biomass energy source utilize, which has an inefficient
combustion process and a very high particulate matter emission (Clancy Jon, 2004).

A study done in Ethiopia in 2012 showed that about 77 percent of annual biomass consumption in
Ethiopia is met from firewood followed by animal dung (13 percent) and crop residue (9 percent),
respectively. Concerning regional distribution of biomass consumption, annually about 88 percent
of total biomass energy is consumed mainly in three regions: Amhara (34 percent), Oromia (32
percent), and SNNP region (22 percent). For more than 90 percent of the Ethiopian population, the
only energy used for household energy is obtained from biomass energy sources, in which 99 percent is derived from biomass based renewable energy source occupying the leading position.

Despite this fact, no published information is available if any systematic study has been conducted to address the inefficient utilization of biomass energy sources and energy technology quality and safety issue which can have consequently enabled value addition for the consumers and environment such as climate compatible development. Normally, it was the Ethiopian Standard Authority responsible to set standards for the biomass energy sources items in general and biomass energy and utilization of biomass resources in particular efforts being made seem very limited partly due to the gap of knowledge on local and national energy standards was not well studied and merged on top of failure to work on sensitization of stakeholders. Further, the issue of public health was major concern as an effect of using unsafe biomass energy technology.

1.2 Statement of the Problem
The wolaita zone is characterized by low agricultural productivity, shortage of woods for utilization of biomass energy, lack of clean and safe energy technology supply, lack of clean and safe a separate kitchen and windows for ventilation and high rate of deforestation. According to the Forest Service, the total annual removals constitute about 2.2 percent of the forest inventory of wood land and are less than net annual forest growth (Smith et al., 2004). This are the principal causes of inefficient utilization of biomass based renewable energy sources.

According to the IEA, 1998, biomass energy use is expected to increase roughly at the same rate as population growth rates. This in-turn has forced human to expand their farming land to areas previously covered by vegetation including the steep and marginal areas. Cutting of trees without replacement has become a serious problem contributing to biomass cover change in the study area. As a result, areas which are once under wood and flowering shrub cover, are now exposed and affected by climate change, erosion and land degradation.

The uncontrolled depletion of the woody biomass and subsequent shortage of firewood, the increasing utilization of cow dung and crop residues as sources of energy aggravates the environmental problems and indoor air pollutions. According to Getachew (2002), the ever increasing demand of woody energy and the inefficient household utilization which results in a
huge amount of energy loss during cooking and heating are the main causes of subsequent removal of biomass in Ethiopia.

Despite the increasing scarcity of biomass energy particularly firewood, the majority of both urban and rural households of Ethiopia utilize the biomass based renewable energies sources in energy inefficient wood stoves, open three stone stoves. This is because of modern biomass energy devices are either unaccessible or unaffordable. Hence, with increasing of firewood, households are forced to increasingly rely on lower quality of combustible materials such as branch’s, dung and agricultural residues.

Since the 2000s the Ethiopian Government has been taking a number of measures to encourage households to control to kerosene and electricity through subsidies or prices set substantially below their economic cost. However, in some areas where these modern energy sources are wholly or partially available, still a significant number of households continue to depend on the traditional energy sources. There are no recorded evidences, whether the various measures taken by governmental and non-governmental institutions against environmental degradation through afforestation programmes has brought any positive and significant effect on household energy supply and consumption patterns. The issue continues to deserve much attention and worthwhile investigation for a better understanding of the dynamics of household energy and to establish facts on existing biomass energy consumption patterns.

The above stated points are some of the gap and problems that the research tried to address. This research was intended to investigate the factors behind the continued dependence of households on biomass energy sources. The utilization of biomass based renewable energy sources and biomass energy technology was stated and an analysis was made to understand the reasons for biomass energy to continue as the dominant energy sources at the household level in the wolaita zone.

1.3. Objectives of the study area

1.3.1. General Objective:
- This study is done to investigate household energy consumption pattern of biomass energy sources and the biomass energy quality and safety of technology (wood-stoves) in wolaita zone.
1.3.2. Specific Objective

1. To state current status of biomass based renewable energy sources and its utilization in households of wolaita zone;
2. To generate baseline information for resource efficient biomass energy and climate compatible development in wolaita zone;
3. To assess the use of improved traditional energy(heat energy technology) saving appliances for household cooking, and
4. To identify the constraints and opportunity related to biomass energy sources use in the wolaita zone.

1.4. Research Questions

The study specifically seeks to answer the following questions:

1. What is the current status of biomass energy supply and utilization in the wolaita zone?
2. What are the major factors affecting the utilization of biomass energy sources in the wolaita?
3. What is the existing knowledge on improved firewood stoves?
4. How far improved biomass energy saving appliances are adopt in the wolaita zone?
5. What are the major benefits of the utilization of biomass energy source and improved biomass energy technology for household purpose in respect to climatical, socio-economical and environmental?

1.5. Significant of the Study

The study is believed to provide some important bases to improving the household level biomass energy-package. It can also serve as a reference for integrating biomass energy issues with other development endeavors, such as tangible recovery of degraded environments, reafforestation and regeneration efforts, improving land fertility and productivity, improving the human capital and heath, cogent and effective population programs, and development of infrastructures. For climate compatible development to occur in rural Ethiopia, modern and improved biomass energy sources are required to encourage efficient, healthier and environmentally friendly conditions. The basis for the study arose from the need for clean and modern biomass energy sources, which are needed for climate compatible development and improvement in socio-economic conditions in the rural areas.
1.6. Factors Considered

Biomass energy source consumption pattern within a certain community is the process resulting from the simultaneous interaction of factors that force the decision-making behavior of the household. The research considered the amount of biomass energy used, biomass energy costs budget made by households for domestic cooking and access to modern biomass energy sources technology as important variables. The type of variables considered are the aggregate sum of all biomass energy sources, the sum total of all biomass energy sources and modern energy sources as represented by kerosene and electric. The second variable which is costs made by the household defined as monthly costs made by the household for the aggregate sum of all energy sources, the sum total of costs made for all biomass energy sources and costs made for modern biomass energy technology. The third variable, which is access to modern biomass energy sources technology, defined as the acquisition of privately owned improved stoves by households under study.

For the purpose of this study the author considered factors such as household size, income of the household, headship patterns of the household head, house tenure status of the household and accessibility of proper kitchen place as determinants influencing households decisions on the amount of biomass energy used, costs made for biomass energy sources and households direct access to the main modern biomass energy sources technology for climate compatible development. The analysis of the relationships and the level of influence to one another between the different variables are presented in various subsections of the document, as appropriate.

1.7. Organization of the Study

The final study report were be organized in five chapters. Chapter one presents the introduction that includes background, statement of the problem, research objectives and research questions, etc. The second chapter contains review of related literature. Chapter three presents general background of the study wolaita and methods. Chapter four were bee devoted to analysis result and discussion. Chapter five were bee the last chapter which contains summary, conclusion and recommendation.
2. LITERATURE REVIEW


The country’s natural forest which was estimated to have 40 percent before 50 years (45 million hectares) of the total land area now covers less than 3 percent (3 million hectares) (EFAP, 1994). The total available woody biomass resources are estimated to be around 1,389 million tons in terms of standing stock and about 26 million tons in terms of annual sustainable yield. The annual agricultural waste available for energy is about 736,895 TJ per year (ENEC, 1986). The recent studies also indicate that agricultural residues and dung together account for 15-20 million tons per year (MME, 2010).

2.2. Utilization of Biomass Based Renewable Energy Sources in Ethiopia

2.2.1. Overview of Global Biomass Energy Source

Biomass energy source is organic material made from plants and animals. Plants absorb the sun's energy in a process called photosynthesis in which carbon dioxide and water are converted into stored energy. Therefore, biomass contains stored energy from the sun. It is a renewable energy source provided that if we always grow more trees and crops, and wastes from animals and agriculture are channeled into biomass energy sources. When burned, the chemical energy in biomass is released as heat and light.

Biomass energy is a local energy source, which is readily accessible to meet the energy needs of a significant proportion of the population in rural areas of the developing world. It is usually defined as firewood and charcoal, agricultural residues, and animal dung. Biomass energy is low cost and it does not require processing before utilize (Hall Desai, 1994).

The categories in which the biomass energy being harnessed are principally three based on efficiency quality and environmental benefits. They are biomass energy, improved biomass energy and modern biomass energy. The biomass energy use refers to the direct combustion (often in very inefficient devices) of wood, charcoal, leaves, agricultural residue and animal/human wastes for cooking and lighting. Improved biomass energy technologies refers to improved and efficient technologies for direct combustion of biomass e.g. improved cook stoves, improved kilns, etc. Modern biomass energy use refers to the conversion of biomass energy to advanced energies namely liquid fuels, gas and electricity (AFREPREN, 2002).
Biomass energy sources are the major and exclusive energy sources for the great majority of the world people, most evidently in the developing world. Increasing interest in biomass energy sources for energy since the early 1990s is well illustrated by the large number of energy scenarios showing biomass resources as the potentially world’s major and most sustainable energy source of the future at both small and large scale levels (IEA, 2008). It is carbon neutral when produced sustainably. It offers considerable flexibility of energy supply due to the range, diversity and accessibility of energy that can be produced (Habitat, 1993).

Biomass energy resources vary geographically, and are not uniformly distributed across the world (IEA, 2002b). Biomass energy use is dependent on various factors, such as geographical location, land use patterns, preferences, cultural and social issues. For instance, the share of biomass energy in total primary energy supply for Asia, Africa and, Latin America and the Caribbean (LAC) in 2001 was 25 percent, 49 percent and 18 percent respectively (IEA, 2003a). Developed countries record significantly lower levels of biomass energy supply, most of which is modern biomass energy utilize and the average share of biomass energy in total primary energy supply was 3 percent (IEA, 2003b). Income distribution patterns also contribute to variations in biomass energy utilize, with poorer regions relying on traditional forms of biomass energy, and developed zones as well as regions using more modern biomass energy technologies (Leach Greld, 1992). Biomass energy issues also vary in urban and rural areas. For example, while biomass energy sources can be collected for free in any rural areas of developing countries, it is a largely purchased commodity in urban areas.

Despite a growing interest in biomass, as a result of difficulty in accessibility and high prices of fossil fuels, and environmental concerns, and technological advances, its inefficient utilize in developing countries has been linked to a number of economic, social and environmental as well as climatic problems. Biomass energies in the developing countries are typically used in households in ways that yield very low efficiencies. In general, development and utilize of most biomass based renewable energies for use in countries like Ethiopia is associated with a number of problems, such as high development cost, imported technology, low utilization efficiencies, large capital requirement and an undeveloped market (Mulugeta Adamu, 2002).
Since the beginning of civilization, biomass energy source has been a major source of energy throughout the world. Biomass energy source is the primary source of energy for nearly 50% of the world’s population (Karekezi Stephen, 2004) and wood biomass is a major households energy source in the developing world, representing a significant proportion of the rural energy supply (Hashiramoto Olena, 2007). In the past decade, many countries exploiting biomass energy source opportunities for the provision of energy has increased rapidly, and has helped make biomass an attractive and promising option in comparison to other renewable energy sources. According to the Svetlana (2009), the global utilize of biomass energy source for energy increases continuously and has doubled in the last 40 years. Moreover, biomass energy source can be used to produce different forms of renewable energy, thus providing all the energy services required in a modern society (Svetlana, Lawie and Johan Vetie, 2009). Furthermore, compared to other renewable, biomass energy source is one of the most common and widespread resources in the world (WEC, 2004). Compared to other renewable, biomass energy source is currently the largest renewable energy source accounted for 79 percent while hydro power stands second having 17 percent (IEA, 2008).

2.2.2. Current Status of Biomass Based Renewable Energy in Ethiopia

In Ethiopia, the biomass energy resource potential is considerable. According to estimates by Woody Biomass Inventory and Strategic planning project, national woody biomass stock was 1,149 million tons with annual yield of 50 million tons in the year 2000. Owing to rapidly growing population and energy demand, however, the nation’s limited biomass energy resource is believed to have been depleting at an increasingly faster rate. Regarding the country’s distribution of biomass energy resources, the northern highlands and eastern lowlands have lower woody biomass cover. The spatial distribution of the deficit indicated that areas with severe woody biomass deficit are located in many parts of the country Biomass energy demand is increasing at an alarmingly rate in the country.

Biomass energy source constitutes the lion share of the total household energy utilization in the country. More than in any other parts, biomass energy source is important in the household parts. Specifically, firewood with charcoal and agricultural residues with dung account 83 percent and 16 percent respectively, whereas electricity and petroleum together contribute with 1 percent of the total household energy consumption (EFEDPC/MoRD, 2002). The contribution of biomass energy source is still greater in the rural households as compared to the urban counterpart. According to
EFEDPC/MoRD (2002), biomass energies constitute 99 percent of the total energy utilization of the rural households.

In Ethiopia, since the energy systems are almost all traditional, no stoves are energy efficient. Studies on the efficiencies of different cooking devices in Ethiopia confirmed that three stone fires were 5-10 percent (EFEDPC, 2004). Most of the cooking and heating utensils are made of ceramics by the local people traditionally. Charcoal stoves which are made by the local people are not energy efficient too. These are very energy intensive to cook and heat to the required temperature. Stoves are not also well guarded to use the energy efficiently and there are a lot of energy losses.

The pattern of biomass energy utilization among the households is quite complicated. It is affected by a number of factors. Some of the major factors include; income level, cultural background, household size, types of stove used, the type of food usually cooked, the food taste of the family, the accessibility of energy wood etc. (EFAP, 1993). The type of stoves used is one of the many factors affecting the amount of energy consumption. Hence, in traditional three stone stoves, 90-95 percent of the biomass energy content is wasted (Konemumud Tury, 2002). Regardless of the variations in the estimates from one study to the other and the limitation of the theoretical basis underling the estimates, different studies confirm the existence of a wider gap between supply and demand. There is a consensus that the volume of wood harvested in the past few decades far exceeds the incremental yield the forest resources, could generate leading to an ever diminishing stock (Araya Asefa and Edward Sinc, 2006).

Biomass Energy source shortage may be easily described using the trend observed between firewood supply and demand. It documented by MoNRDEP, (1994), indicate that the demand for firewood was 58 million m$^3$ whereas the supply was 11 million m$^3$ indicating the deficit was more than four times the supply. The projection made for the year 2020 indicated that the demand will be 100 million m$^3$ against a supply projection of 7.7 million m$^3$ envisaging a deficit of 92.3 million m$^3$ (MoNFDEP, 1994). A multitude of reasons are believed to have been responsible for the consistent imbalance between demand and supply of firewood. A continued degradation of forest has led the natural forest resources to decline at an alarming rate both in size area and in quantity.
2.3. Utilization of Biomass Energy Source and Its Impacts

2.3.1. Utilization of Biomass Energy Source and Its Environmental Effects
The high prevalence of mass poverty can be indicator of modern and efficient energy source and associated appliances even if available in the market, are not affordable for most poor people in the developing world (Kassa Mekonnen, 2002), and this makes an unique case in the energy sphere, e.g., over utilization of low-graded biomass energy source, and under utilization of high quality modern biomass energy on the other hand. Although biomass energy source has important benefit in the overall energy balance, its inefficient use in developing countries has been linked to a number of adverse environmental effects like excessive deforestation at local, regional and national scales, indoor air pollution and decline in crop yields (Getachew Olana, 2002). Thus, the high and direct dependence on biomass energy source coupled with low efficiency in its end use at household level, mainly for cooking on open fire, are contributing to unnecessary high level of biomass energy resource extraction (Kassa Mekonnen, 2002).

This great dependence on biomass energy source is believed to have led chronic depletion of forest resource, there by resulting in declining in safety of households, a reduction in agricultural productivity, and environmental degradation. For example, this situation is severe in highlands and midland areas of Ethiopia, where centuries of cultivation by settled agriculturalists, with poor management practices, have left the landscape poorly covered by natural vegetation. This destruction of the vegetable cover has aggravated soil erosion, with disturbed drainage system and water balance, and ultimately land degradation. In 1990 accelerated soil erosion caused by a progressive annual loss in grain production was estimated at about 40,000 tons, which unless arrested will reach about 170,000 tons by 2010 (Mekonnen Kassa, 2002).

The natural forest cover of Ethiopia is declining very fast and the annual loss of these forests has been estimated to be 150,000 to 200,000 ha (WB, 1990). There is also a fear that if continued at this rate, the last highland forests would disappear by the year 2020 (WB, 1990). It was forecasted that 16 million ha of rural energy wood plantation, with another 1.2 million ha of forest that provide timber are required to meet the growing rural firewood needs and replace the use of dung as energy by the year 2010 (WB,1990). The current national forest cover is claimed to be below 3% (Eshete et at, 2006).
In Ethiopia, forest resources are highly valued due to several economic and environmental reasons. Apart from environmental advantages and firewood supplies, trees serve as savings or reserves for farmers, which they first revert to at times of food shortages. However, with depletion of forest resources, farmers who are desperate switching to dung and agricultural residues to meet their immediate needs for energy and as source of income substitutes dung for firewood. Thus along with the depletion of forest resources, the demand for dung as biomass energy is not only becoming rural events but it is also happening in the urban poor. In some urban centers, the market value of dung for energy is more than its value as farm manure and also as compared to the costs of producing firewood from reforestation (Miller Alan, 1986).

In many localities and places in Ethiopia, people are now left with no choice but utilize animal dung and agricultural residue as their main sources of energy, which constitutes a significant of the total energy supply of the country (MoRD, 2002). In this regard, if cow dung and agricultural residues are used as main sources of domestic energy, they could leave the cropping fields hardly supplied with adequate organic matter. It is estimated that in Ethiopia some 600,000 tons of crop production is lost annually as a result of burning of dung rather than using it for maintaining soil fertility or twice the average yearly request for food aid in Ethiopia (Araya Asefa and Edward Sinc, 2006). In this respect, improvement in resource utilizes efficiency through technological alternatives like modern biomass energy is vital. Still application of modern biomass energy production and utilize in Ethiopia is in an infant stage. Empirical evidence of the role of innovative modern biomass energy application is lacking. The fact that modern biomass energy was largely seen as replacement to firewood and its role in redressing land degradation was not realized might have resulted in much limited attention.

2.3.2. Utilization of Biomass Energy Source and Its Climate Effects

Given the continuing importance of biomass based renewable energy to satisfy energy needs, a sustainable wood energy part could reduce GHG emissions throughout its entire value chain and thus taking a key role for implementing low-carbon growth strategies in Ethiopia. However, if charcoal were to be sustainably produced, it would be carbon neutral since the emitted carbon could be sequestered by trees that are planted: In this scenario, one ton of sustainable charcoal would offset one ton of non-sustainable charcoal or nine tons of carbon dioxide (GEF, 2010).
Sustainably produced biomass has minimal emission effects although, if taken into account, traditional utilize of biomass energy may include transportation over long distances, which uses fossil fuels. Nevertheless, it must be recognized that Africa accounts for only (2 –3) percent of the world’s CO₂ emissions from energy and industrial sources, and 7 percent if emissions from land use (forests) are considered (UNECA, 2002). It is essential to target the utilization of biomass based renewable energy sources if recent financial mechanisms that support sustainable forest management programs to reduce GHG emissions are to succeed, such as REDD, REDD+, and FIP. At present, the often free and unregulated use of forests for biomass energy exploitation causes significant forest degradation and coupled with other land-use changes deforestation. Most if not all REDD strategies developed by country contain actions to make the extraction of firewood sustainable, helping country achieve low-carbon growth while simultaneously satisfying the basic energy needs of rapidly growing populations. If they were expanded beyond the pilot phase, they should deliver benefits for both climate change mitigation and provide new sources of financing. Further, enabling local populations earn a steady income through biomass based renewable energy extraction has a direct economic value as it reduces the incentive to convert forests into other land-use systems that deliver higher direct benefits.

Biomass burning in cook-stoves emits black carbon (BC) as part of visible smoke. Black carbon is particulate matter that results from incomplete combustion. Black carbon absorbs heat from the Sun, and keeps it in the atmosphere. According to Climate science, now views BC as the second or third largest warming agent after carbon dioxide, alongside methane. In biomass burning, BC is emitted together with large amounts of organic carbon particles, which exert a cooling influence on climate. In the case of biomass energy sources utilization for cooking, the warming effects of BC and the cooling effects of organic carbon appear to be closely balanced. There is thus some uncertainty at present about the net impact on global warming of smoke from cook-stoves. Intensive research on this aspect of climate change is currently underway. However BC from biomass burning can have a large impact at the regional level: it accelerates melting of ice and snow, and contributes to regional pollution which can alter climate and precipitation over a wide area.
2.3.3. Utilization of Biomass Energy in Household and Its Effect

Many epidemiological studies across the world have linked indoor air pollution to illnesses like acute lower respiratory infection (currently the leading cause of death among children less than five years), chronic obstructive disease, lower birth weights, and higher risk of tuberculosis (Domanski et al, 2005). Although many sources of indoor air pollution exist, studies conducted by the World Health Organization have identified coal and biomass energy source burning for heating, lighting and cooking are the leading contributor to indoor air pollution in the rural households of developing countries (Domanski et al, 2005). The WHO estimates that 1.6 million deaths a year world wide and 1.4 million illnesses can be attributed to the household burning of such biomass resources (Manish Desai and Smith Kirk, 2004).

As women are primarily responsible for cooking, and as children often spend time with their mothers while they are engaged in cooking activities, women and young children are disproportionately affected. For example, the WHO(2002) estimates that acute respiratory infection is one of the leading causes of child mortality in the world, accounting for up to 20 percent of fatalities among children under five years, almost all of them are in developing countries. In addition to impacts on mortality, indoor air pollution may have long lasting effects on general health and well-being: early exposure to indoor air pollution during childhood may stifle lung development, suggesting that the cost of this pollution may continue later in life. In fact, literatures indicate that environmental insults at early ages can have long lasting influences on human health and productivity (Almond Devedo, 2006).

Children living in households exposed to biomass energy have a two to three times greater risk of developing acute lower respiratory tract infection compared with those living in households using cleaner energies of suffering less exposure to smoke (Smith et at,2000). In Ethiopia, acute lower respiratory tract infection deaths under 5 years attributable to biomass energy use reaches 50,320(WHO, 2007). For example, a study from Zimbabwe identified an association between birth weight and type of energy used. The babies of mothers using open wood fires were lighter compared with babies born to mothers using cleaner energies (Mishra et at, 2004). A recent report has also suggested that exposure to biomass energy smoke in young children contributes to chronic nutritional deficiencies including anemia and stagnant growth (WHO, 2007).
In Ethiopia, chronic obstructive pulmonary disease deaths greater than 30 years attributable to biomass energy use reaches 6,410. The percentage of national burden of disease attributable to biomass energy is 4.9 (WHO, 2007). Evidence is emerging that the incidence of Tuberculosis is increased amongst biomass energy exposed women. Studies from Mexico and India have implied a causal role of current biomass energy smoke exposure and the development of Tuberculosis (Perez-Padilla et al, 2001). These findings have been seen as the evidence supports for the hypothesis that exposure to respirable (small enough to be inhaled) pollutants from combustion of biomass energy increase the risk of Tuberculosis infection and disease (Lin et at, 2007). The International Agency for Research on Cancer recently termed biomass energy smoke as a carcinogenic to humans (Straif et at, 2006).

Even though there has not been documented detail data concerning indoor air pollution and emissions in relation to traditional utilization of biomass based renewable energy source, few surveying studies performed to observe some of the emissions measured and their impacts in Ethiopia. According to Faris (2002), most of the main problems of indoor air pollution emanate from the type of energy source, the technology used to burn the biomass energy, and lack of a separate kitchen with proper ventilation or smokestack. The quality of wood, leaves, dung and other biomass energy sources is such that it produces a lot of smoke.

Three very important parameters has be seen whether indoor air pollution is problem in some area of the country where sample surveying was conducted to determine the status of indoor air pollution in the rural houses. For instance, Oromy (Jimma zone) region of Ethiopia, carbon monoxide, particulate matters, and polyaromatic hydrocarbon were selected as the indicators. All of these pollutants in the living environment were in excess of human tolerance indicate that those exposed, especially small children and women, were or would eventually suffer from problems associated with the pollutants including lung cancer (Kebede Faris,2002). According to Kumie et at.(2007), the sample taken in Gurage zone of Ethiopia, the mean level of NO₂ was measureable (WHO, 2005). Clearly, the health costs of bad indoor air quality can be detrimental to a rural family, making the transition to clean energy sources such as modern biomass energy (biogas) even more pertinent. Modern biomass energy are extremely effective at lowering indoor air
pollution by converting traditional biomass based renewable energy resources into a gaseous energy that utilized (burns) cleanly.

2.4. Improved Biomass Energy Technologies (IBETs)

2.4.1. Potential Benefits of IBETs

Improved biomass energy technologies have the potential to reduce the negative impacts of current utilization of biomass energy. Many policy makers and researchers in the developing world as well as interested decision makers in the more developed parts of the world are keen to see a progressive shift from utilization of biomass energy to improved utilize, and eventually to modern biomass energy utilize (Karekezi Stephen, 2004). Of priority interest in developing countries is the need to first improve the current utilization of traditional biomass energy, and secondly to transform biomass energy source into high-quality low-emission electricity, energies and gases (Goldemberg Jon and Coelho Sevntlana, 2003).

Improved biomass energy technology, for example, are designed to save heat energy, decrease pollutants, increase combustion efficiency and attain a higher heat energy transfer (Masera et al, 2000). This results in savings in the amount of biomass energy source, which translates to direct income savings. Reduced firewood collection times can also translate to increased time for education of rural children (Karekezi Stephen, 2004).

Under the current limitations in the traditional and modern biomass energy parts, the improvements of biomass energy efficiency, in particular increasing end-use efficiency at the household level received major attention by the energy planners and government institutions (Konemund Tury, 2002). Konemund further notes that biomass energy saving stoves could be produced at low cost and provide a cost-effective solution, environmental protection and improved livelihoods. In addition, they can also have significant economic effects on both at the household level and at the macroeconomic level at large.
2.4.2. Improved cook stoves

2.4.2.1. Improved Stove development in Ethiopia
Given the low level of efficiency attained by traditional biomass technology used in the Ethiopian households, improving domestic cooking efficiency has been given emphasis. Cooking efficiency improvement has been carried out in Ethiopia by government and NGO’s. Since the 1970s the EREDPC, has been engaged in the business of improving household cooking efficiency, resulting in three improved cook stoves, namely: “Laketch” charcoal stove, “Mirt” firewood stove for making Injera (a large, flat bread (pancake) made of sour dough staple diet in Ethiopia), and the “Gonzie” multi-purpose wood stove used for baking, cooking and boiling.

The “Laketch” charcoal stove has an efficiency of 19 – 21 percent and an energy saving of 25 percent compared with traditional stoves. The stove is popular among urban dwellers and is used mostly for coffee making and cooking stew. To date over 2.5 million stoves have been disseminated (Gashie Worku, 2005).

The “Gonzie” multi-purpose stove attains an efficiency of 23 percent. It has energy saving potential of 54 percent for baking and 42 percent for boiling and cooking compared with traditional practices. There are two major groups of stoves i.e. charcoal stoves and Biomass Injera baking stoves (Gashie Worku, 2005).

2.4.2.2 Biomass Energy Efficiency Development in Ethiopia
Improved rural and urban Biomass energy source stoves, which are designed to save heat, increases combustion efficiency and attain a higher heat transfer, would be an appropriate response option. These stoves could insure efficient utilization of firewood and could significantly reduced indoor air pollution thus mitigating respiratory health problems associated with smoke emissions from stoves (Karekezi et al, 2002).

Recently the governmental and nongovernmental organizations are trying to minimize this energy loss by introducing improved stoves. The first improved stove designed and distributed was ‘Lackech’ (better) charcoal stove. These stoves have saved one fourth of the energy than the traditional metal charcoal stoves (GTZ, 2007).
3. MATERIAL AND METHODOLOGY

3.1. Description of the Study area

3.1.1. Location

The study zone, Wolaita Zone is located in southern Ethiopia and is bound by geographical coordinates 6.4° and 7.1° N latitudes and 37.4° and 38.2° E longitudes. It has a total area of 4400 km². Its altitude ranges from 1,200 to 2,950 m above sea level. It is located at a distance of 380 km along the main road that stretches north to south from Addis Ababa to Arbaminich, and is also connected with the South Nation National Regional State capital, Awassa, 160 kms, Via Shashemane - Wolaita road to the south. See figure 5. Wolaita zone.

![Figure 1. The map of Wolaita zone](image)

From the selected districts of Wolaita zone. Hence, first, Boddit, Damot Woide and Dung Fango districts were bee selected among 12 rural woredas in Wolaita Zone. This aims at having representation of households with different characteristics in the study.

3.1.2. Demographics

Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia, this Zone has a total population of 1,527908, of whom 752668 are men and 775240 women. This zone represents one of densely populated area within the country. According to zonal social- economic profile
which indicated in Wolaita zone finance and economic department (2007), average population density for zones was about 342 persons per square Kilo meter. While 172,514 or 11.49 percent are urban inhabitants, a further 1,196 or 0.08 percent are pastoralists. A total of 310,454 households were counted in this Zone, which results in an average of 4.84 persons to a household, and 297,981 housing units (CSA, 2007).

3.1.3. Climate

3.1.3.1. Rainfall

The rainfall in Wolaita Zone is typically characterized by seasonality, poor distribution and fluctuation (variability) in amounts from time to time and place-to-place. The mean annual rainfall varies from less than 800 mm to 1400mm with the central part escarpment receiving the highest rain and the lower parts in the eastern and western of the zone receiving the least. The average rainfall for the entire region was 1350 millimeters per year. The short rains or belg is usually occurs in the period of February to May, the main rainy season kiremt from June to September (CSA 2007).

3.1.3.2. Temperature

Temperature in Wolaita varies widely through the diurnal and seasonal variations and with altitudinal zonations. The temperature variation between 24 and 30°C during the day and 16 to 20°C at night, all year round. Average temperature varies between 16 and 20 °C in the Zone (CSA 2007).

3.1.4. Land Use and Cover

Agriculture in this zone is dominated, almost exclusively, as in most parts of the highlands, by small scale and largely subsistence-oriented rain fed crop production. The remainder of the land is under different types of forest and vegetation (grass, shrubs, and trees) used for extensive grazing. The major soil types found in the Zone are Nitosols, haplic Yermosols, eutric Cambisols, orthic Andisols and calcaric Fluvisols. Mixed farming involving the production of cereals, root crops, enset (enset ventricosum Welw), coffee, etc. are practiced. In the 1997/8 production year households which had a holding of one hectare and below in the Zone, of which Wolaita was a part then, accounted for 90.4 percent of the
different types of livestock are also kept. Pressure on the land due to increasing density of both human and livestock population is high.

3.2. Methodology

3.2.1. Study Design

A Completely Randomized Design were been used for analysis of consumption pattern of biomass energy sources and the biomass energy quality and safety of technology benefits samples and field survey analysis were done in all selected woredas of wolaita zone and all experts who are working in mine’s and energy source related sectors and all government employed women and men who have better experience, knowledge, and belief about biomass energy source and utilization. The analysis of biomass energy source potential of biomass, baseline information for resource efficient biomass energy and climate compatible development. The analysis of improved energy saving appliances were done and the constraints and opportunity related to biomass energy sources and use in the wolaita zone.

3.2.2 Sampling procedures and Sample Size Determination

In any sample survey, sample size determination was an important step. To determine sample size of households those to participate in the study, a sampling technique (formula), which was used (McClave Joky and Sincich Thomas, 2003). In this case population variable (P) was house units variable, and was given as: n = N Z^2 P Q / d^2 (N-1) + Z^2 P Q or n = Z^2 P Q / d^2

Where n= Sample size of housing units
P= Housing unit variable (residential houses)
Q= Non-residential houses (office, etc.) = 1-P
N= Total number of housing units
d = Allowable error (0.05)

Z= Standardized normal variable and its value that corresponds to 95 confidence interval = 1.96

According to data obtained from Housing Development Section of the wolaita zone (2006), there are about 297,981 housing units (N): out of these more than 90 percent (P) are of residential and the rest 10 percent (Q) is for commercial activities and offices. Therefore, n is the minimum sample size of housing units for reliable results. To be safe in cases of non-cooperativeness of households, unforeseen problems during collection and other cases the sample size was increased to 138 households. However, due to incomplete participation, incomplete socio-economic data and different reasons some 28 households were excluded from final analysis. Therefore, results of 110
households’ utilization of biomass based renewable energy source were analyzed; which is sufficiently enough according to the sample size calculated above. For qualitative part, two experts Agricultural sector, two experts from Water, Mineral and Energy offices of Wolaita Zone, and government employed women and men from the community, a total of less than 28 households were purposively selected for key informant interview and for an interview, respectively. The total number of household was identified through reviewing records in each woreda office. Then, the total number of households was divided into the required sample size in each kebele proportional to the size of household. Based on this, a sampling interval of every 50th household was visited to get the required number of study subjects in each kebele.

3.2.3 Variables and Measurement

The dependent variable of the study were been utilization of biomass energy and the independent variables are socio demographic variables (Age, Occupation, Religion, Educational status, Family size, Household income), Stove related factors (accessibility of biomass energy saving stoves), kitchen related factors, knowledge related factors(Knowledge about health hazards, Knowledge about environmental consequences, Knowledge about cost of household energy sources), and household energy related factors(Cost of household energies, accessibility of household energies). Biomass energy utilization: a respondent were been considered as utilizing biomass energy sources when he/she utilized firewood, charcoal, BLT and animal dung for different household purposes.

3.2.4 Data Collection

Both quantitative and qualitative data from primary and secondary sources have been gathered and analyzed. A combination of the following data collection methods were employed for the study.

3.2.4.1. Household Sample Survey

Conventional household survey was adopted for the study as the main method designed to gather quantitative information from sample households. Three enumerators were assigned to conduct the household survey using the structured questioner.

3.2.4.2. Focus Group Discussion

Focus group discussions with senior, knowledgeable and well-experienced residents of Wolaita were one of the qualitative data collection methods employed for the study. The discussion was
undertaken with two groups that comprised both adult and elderly men and women, with in the range of 6 to 9 individuals for each focus group.

3.2.4.3. Key Informant Interview
Individuals who were considered knowledgeable and rich in experiences about household energy and socioeconomic condition of the residents in Wolaita were identified and interviewed. The key informants interviewed included professionals from different governmental and non-governmental organization, improved traditional Mitad producers, and biomass energy source and technology distributes. In addition to the formal interviews, personal experiences and observations of the researcher facilitated the understanding of the overall conditions related to domestic energy use and related significant factors and constraints in the wolaita.

3.2.4.4. Secondary Data Collection
By reviewing relevant books and journals, published and unpublished documents the researcher collected secondary data and used the information primarily to set the research context and also to relate the research findings with other empirical studies on the subject of the study.

3.2.5. Data Quality Assurance
Training was given to data collectors and supervisors by the principal researcher. The questionnaire was translated into Amharic and translated back into English language to ensure the comparability of results. There were a meeting with data collectors to discussed the daily data collection procedures. For the qualitative data, notes was taken during each interview and in addition, afield observe has used to safeguard against the loss of information. The overall activity was controlled by the principal researcher.

3.2.6. Data Processing and Analysis Methods
The data collected through various methods are presented and analyzed using appropriate descriptive and quantitative methods, such as mean, range, percentage, proportion and graphs. In addition to the quantitative data, the household survey data was inputted, processed and analyzed by using the appropriate SPSS software. Relevant statistical methods mainly bivariate correlation and ANOVA test of significance were employed to validate the relationship or association between the dependent and explanatory or the independent variables.
4. RESULTS AND DISCUSSION

4.1. Results

4.1.1. Household Characteristics

4.1.1.1. Age-Sex Distribution of Sample Household Population
Accordingly, out of the surveyed 110 sample households 57.27 percent of the household in the area were male-headed and 42.72 percent female-headed (Table 1). The surveyed households of the Wolaita zone, where the average household size consisted of 6.5 persons. The age distribution of the members of the sample households shows that 21.81 percent of the people were of between age 12 to 25, 53.64 percent ranged between the age group of 26 to 40, and 20.90 percent ranged between the age group of 41 to 60 while the remaining 3.64 percent were above 61 years old (Table 1).

Table 1. Age Sex Distribution of Members of Sample Households in Wolaita Zone, Ethiopia, 2015.

<table>
<thead>
<tr>
<th>Age Category</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
</tr>
<tr>
<td>12-25</td>
<td>13</td>
<td>11</td>
<td>24</td>
</tr>
<tr>
<td>26-40</td>
<td>37</td>
<td>22</td>
<td>59</td>
</tr>
<tr>
<td>41-60</td>
<td>9</td>
<td>14</td>
<td>23</td>
</tr>
<tr>
<td>&gt;61</td>
<td>4</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>47</td>
<td>110</td>
</tr>
</tbody>
</table>

N=110, X²=5.30, DF=3, F=76.830 and P≤0.01

This reflects the situation in most Wolaita Zone, where a combination of high fertility and declining mortality results in high population growth rates and a high percentage of young people.

4.1.1.3. Monthly Household Income
The monthly income of the households ranges from the lowest figure of Birr 251.00 to the highest level of Birr 4000.00. Thus, on average the sample households earn Birr 2125.50 per month each. Field survey clearly indicated that female-headed households are more concentrated in lower and medium income group, while the male headed were comparatively better off in their income status (Table 2).

<table>
<thead>
<tr>
<th>Income Categories</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. %</td>
<td>No. %</td>
<td>No. %</td>
</tr>
<tr>
<td>Low</td>
<td>13 20.64</td>
<td>17 36.17</td>
<td>30 27.3</td>
</tr>
<tr>
<td>Medium</td>
<td>13 20.64</td>
<td>29 61.70</td>
<td>42 38.2</td>
</tr>
<tr>
<td>High</td>
<td>37 58.73</td>
<td>1 2.13</td>
<td>38 34.5</td>
</tr>
<tr>
<td>Total</td>
<td>63 100</td>
<td>47 100</td>
<td>110 100</td>
</tr>
</tbody>
</table>

N=110, $X^2 = 15.213$, DF=3, $F=74.092$ and $P \leq 0.01$

Economic features of the sampled households are summarized in Table 2. The majority of the respondents (34.5 percent and 38.2 percent) in high and medium income categories were engaged in agriculture where as 27.3 percent of respondents in low income categories were daily laborers. Considering all sources, the mean monthly income across three categories of households was found as ETB 251-500, 501-1000 and 1001-4000 respectively, which was significantly different (ANOVA: df=3, $F=74.092$, $P<0.01$). The reason for this difference was that the lion’s share of income (34 percent) of high income households comes from service and business. All households in three income categories had no access to electricity but there was no natural gas supply in the wolaita.

4.1.1.4. Housing Characteristics

According to the residential patterns, the data on house tenure status revealed that 73.6 percent of sampled households live in their own housing unit, while 26.4 percent live in rented houses. Kebele is the chief renting institution households (Table 3).

Table 3. Tenure Status by Number of Rooms of the Housing Unit in Wolaita Zone, 2015

<table>
<thead>
<tr>
<th>Tenure Status</th>
<th>BedRoom Only</th>
<th>One Room With Kitchen</th>
<th>More Than One Room With Kitchen</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owner Occupied</td>
<td>-</td>
<td>2</td>
<td>3</td>
<td>81</td>
</tr>
<tr>
<td>Rented</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>29</td>
</tr>
<tr>
<td>Total</td>
<td>No 9</td>
<td>12</td>
<td>13</td>
<td>110</td>
</tr>
</tbody>
</table>

N=110, $X^2 = 17.823$, DF=1, $F=300.997$ and $P \leq 0.01$

Indicators on the quality of houses obtained from the survey gave a picture of highly poor dwelling conditions in Wolaita zone. About 19.09 percent of households reside in single room dwellings.
(10.91 percent with kitchen and 8.18 percent without kitchen), while 80.90 percent households live in two rooms units or more dwellings (69.09 percent with kitchen and 11.81 percent without kitchen) (Table 3).

4.1.1.5. Kitchen Characteristics
The kitchen characteristics in the majority of the households were remarkably similar. As shown in Table 4, about 69 (62.73 percent) of the households of the samples had separate kitchen.

Table 4. Responses of study participants on their place of cooking in Wolaita Zone, Ethiopia, 2015.

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of Households</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>In the living room</td>
<td>27</td>
<td>24.54</td>
</tr>
<tr>
<td>In the separate private kitchen</td>
<td>69</td>
<td>62.73</td>
</tr>
<tr>
<td>In the open field</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>In the shared kitchen</td>
<td>14</td>
<td>12.73</td>
</tr>
<tr>
<td>Total</td>
<td>110</td>
<td>100</td>
</tr>
</tbody>
</table>

N=110  \( X^2 = 2.408 \)  DF=2  F=300.573  P=0.000

More than half of the households had separate indoor kitchens outside the house with one window and without ventilation conditions; otherwise, in 14 (12.73 percent) of the households, the kitchens were found attached to the living houses. About 27 (24.54 percent) of the respondents were cooking in their living room (Table 4). During the interview as well, a 38-year-old woman was asked where she usually cooked, she replied, “place of cooking depends on the weather condition. In the winter season, we usually cook in the open field; whereas, in the summer seasons we will be restricted to cook inside just in the kitchens if we have or in the parts of our residences. While we are cooking with charcoal we usually use our residence as proper place of cooking.” Hence, … the problem observed some of the household is knowledge gap about place of cooking and the other is low income to proper the kitchen.

4.1.1.6. Educational Status of the Household Head
Educational levels of heads of the households was found out to be that 4.55 percent were illiterate and 10.91 percent knew only how to read and write, the remaining 27.27 and 26.36 percent of the groups had passed the primary and secondary examinations respectively. 30.91 percent had above grade 12 education (Table 5).
According to the survey result, there was a significant difference in the level of education between the male heads and female-heads, showing females being far less educated than males. More than 8.51 percent of such females were either illiterate or could only read and write (14.89 percent), and only 48.93 and 17.02 percent had primary and secondary school level education respectively, in fact, 10.64 percent of them possessed above secondary level education. In case of male-heads, only less than 2 percent were either illiterate or could only read and write (7.94 percent); more than 11 percent, however, had primary education. Among male heads, while 33.33 percent had secondary school education, and only 46.03 percent male heads had a higher educational level above secondary school.

4.1.1.7. Employment Status
Survey shows different situations in terms of employment of household heads, the majority being self-employed (48.18 percent). Of the remaining group, 25.45 percent were employee and only 7.27 percent enjoyed employer status. The rest were either pensioned and dependent (10.00 percent) or unemployed (9.09 percent) (Table 6).

<table>
<thead>
<tr>
<th>Types of Employment</th>
<th>Sex of the Household Head</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Self Employed/Own Account Worker</td>
<td>32</td>
<td>29.09</td>
</tr>
<tr>
<td>Employer</td>
<td>6</td>
<td>5.45</td>
</tr>
<tr>
<td>Employee</td>
<td>27</td>
<td>24.55</td>
</tr>
<tr>
<td>Pensioned / Dependent</td>
<td>2</td>
<td>1.81</td>
</tr>
</tbody>
</table>

Table 5. Educational Level of Heads of Sample Households in Wolaita Zone, 2015. N=110

<table>
<thead>
<tr>
<th>Educational Level</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Illiterate</td>
<td>1</td>
<td>1.59</td>
<td>4</td>
</tr>
<tr>
<td>Literate</td>
<td>Read and Write</td>
<td>5</td>
<td>7.94</td>
</tr>
<tr>
<td></td>
<td>Primary</td>
<td>7</td>
<td>11.11</td>
</tr>
<tr>
<td></td>
<td>Secondary</td>
<td>21</td>
<td>33.33</td>
</tr>
<tr>
<td>College</td>
<td>29</td>
<td>46.03</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>100</td>
<td>47</td>
</tr>
</tbody>
</table>

$X^2 = 1.743$ $\text{DF}=4$ $F=5.362$ $P=0.001$
Disaggregated figures on gender status showed that, 19.09 percent of women heads were engaged in their own business, and 0.91 and 1.81 percent were employer and employee, respectively. Either as much as 8.18 and 6.36 percent of the female heads were pensioned or dependent and unemployed, respectively (Table 6). On the other hand, male-heads comparatively were better off in their employment status. Only 1.81 and 2.73 percent of them were pensioned and unemployed respectively, while, 29.09, 24.55 and 5.45 percent enjoyed self-employment, were employee and have the status of employer respectively (Table 6).

4.1.2. Characteristics of Household Energy Consumption

4.1.2.1. Principal Energy Used In Households

Out of the surveyed 110 sample households 106 (96.36 percent), 105 (95.45 percent), 100 (90.91 percent) and 102 (92.73 percent) of the households under study baked Injera and prepared wot, tea and coffee in their home respectively (Fig.2).

Figure 2. Principal Energy Type Used for End Uses in Wolaita Zone, 2015. N=110

<table>
<thead>
<tr>
<th>Types of HHs Energy</th>
<th>Amount of HH Energy Yield(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firewood</td>
<td>0</td>
</tr>
<tr>
<td>BLT</td>
<td>0</td>
</tr>
<tr>
<td>Agriculture residue</td>
<td>0</td>
</tr>
<tr>
<td>Caw-Dug</td>
<td>0</td>
</tr>
<tr>
<td>Charcoal</td>
<td>100</td>
</tr>
<tr>
<td>other</td>
<td>0</td>
</tr>
</tbody>
</table>

Such a high proportion of use is an indication of the importance of the above-mentioned meal items in the study zone. This survey showed that biomass energy was the principal energy source with highest percentage share employed by 96 percent of sampled households for Injera baking, 96
percent for Wot, 91 percent for tea and 93 percent for coffee. In fact, contribution of modern energy source is minimal except being slightly higher for that of tea, in which kerosene makes sizeable use (Fig.2).

Further analysis indicated that wood is used as the principal biomass energy source for Injera baking by as high as 93 percent of households, followed by zero percent dry cow dung. A zero percent of the sample households generally use electrical energy for Injera baking (Fig.2). It is further indicated that charcoal forms the principal energy source for wot; tea and coffee as high as by 72, 60 and 57 percent of households respectively. While the pattern for tea reveals that slight difference exist between the traditional biomass and modern energy sources especially with that of kerosene. Though, charcoal and wood both constitute 88 percent of sample households’ energy demand for tea, the role of kerosene is also highly pronounced in this use. Kerosene in particular plays not significant role as the principal source for tea making. It constitutes about not half the number of households (1.82 percent) in this sector, sharing almost equal part as charcoal.

A comparative analysis of different energy types within traditional biomass energy group also indicated that, biomass energy sources other than wood and charcoal also played some role in the household energy use. BLT as the principal energy for Injera baking is used by 3 percent of sampled households while crop residues constitutes 1 percent (Fig.2). The use of crop residues is less than that of BLT. This may be due to the prevalence of drought in the study area that prevented crop production and lead to the unavailability of farm wastes in general.

4.1.3. Households Energy Acquisition

Households are asked about the sources of biomass energy from where they get for domestic consumption. The survey result showed that the majority of households acquire their biomass energy through purchase (79.09 percent), and 6.36 and 14.55 percent fulfill their biomass energy demand through freely collection in the environs as well as purchase in the local (Table 7).

Table 7. Sources of Biomass Energy Supplies in Wolaita Zone, Ethiopia, 2015. N=110

<table>
<thead>
<tr>
<th>Biomass Energy Source</th>
<th>No of Hhs</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchased</td>
<td>83</td>
<td>75.50</td>
</tr>
<tr>
<td>Collected</td>
<td>20</td>
<td>18.18</td>
</tr>
<tr>
<td>Purchased and Collected</td>
<td>7</td>
<td>6.36</td>
</tr>
<tr>
<td>Total</td>
<td>110</td>
<td>100</td>
</tr>
</tbody>
</table>

\[ X^2 = 4.664 \quad DF = 2 \quad F = 79.36 \quad P = 0.000 \]
The table reveals that biomass for domestic energy is now commercialized as a high proportion of households acquire their biomass energy through market. This is in agreement with the result of household energy needs assessment in Amhara (Woldia, Wollo) and Tigray, where all forms of domestic energy sources in urban areas are almost entirely commercialized (Oxfam GB, 1999).

4.1.4. General Technology on Utilization of Biomass Energy Source

4.1.4.1. Types of Stoves for Injera Baking

In Wolaita, almost and as high as 49.09 percent of households use open fire three stone Injera Mitad (Fig.3). Other 37.27 percent of the surveyed households employ Enclosed Traditional Injera Mitad, which have better efficiency in energy use than open fire Mitads. People adopt this oven as a result of better awareness about shortage of firewood production and supply, and also as a strategy to save money as firewood cost is be increasing. Traditionally people in this area adopted enclosed fireplaces as a strategy to cope with the prevailing energy wood crises in the area (Oxfam GB, 1999).

Figure 3. Types of Domestic Appliances Used for Injera Baking in Wolaita Zone, 2015. N=110

Despite two decades of effort to encourage and persuade people to use the modern and improved traditional stoves for Injera baking, the penetration of the modern and improved stoves in the study zone is still in its infancy. Mirt Mitad and electric stove users are only 12.72 percent and 0.91 percent respectively (Fig.3). Though, the residents of Wolaita are well aware about the benefit of enclosed stove over open fire Mitad, they are constrained by several factors from switching over to new model ovens.

Due to its fixed nature and spatial inflexibility to use, Mitad requires fixed and proper kitchen place. The survey results show that even enclosed traditional Injera Mitads are mostly used by
those households, which have their own proper kitchen (Fig.3). In general, therefore, households still stick to use open fire Injera Mitad. The other problem is the financial limitation of households to purchase Mirt Injera Mitad. The cost of one Mirt Injera Mitad is about Birr 50.00, the payment for which is to be in cash. This is obviously above the financial capacity of most households in Wolaita. According to the discussion with two of the three Mirt Injera Mitad producers in Wolaita, most of the residents can ill afford to pay the required lump sum of Birr at once.

Obviously, in general, households in Wolaita still depend more on inefficient open fire and Enclosed traditional Injera Mitad. This kind of stove cannot trap most of the heat energy, and thereby wastes lot of energy during combustion process.

### 4.1.4.2. Types of Stoves Used for Cooking

The pattern for cooking other items of food is quite different. Here varieties of end uses and their peculiar demand for specific energies seem to have imposed on households’ burden of acquiring and choosing different types of stoves. Metal charcoal stove, a traditional and inefficient stove, is alone employed by 50.00 percent of households along with 24.55 percent of other types of stoves, the penetration of the modern and improved stove, is highly pronounced. Butagas and Lakech stoves used as cooking appliances are owned and used by 7.27 and 17.27 percent of households use either as the only cooking stove or use it in combination with other types of stoves respectively (Fig.4).

**Figure 4.** Types of Domestic Appliances Use For Non-Injera End Uses in Wolaita, 2015. N=110

One can infer from the above discussion that, major use of stoves is accounted for by its flexibility in use at any place in or around the dwelling, and also by its relatively easier availability of varieties of stoves in line with the diversified demands of households in the area. Stoves other than baking are available in the market with costs ranging from the minimum Birr 100.00 for Lakech charcoal stove each up to the maximum of Birr 145.00 for Gas stove.
4.1.5. Prevalence of Biomass Energy Source Shortage

The surveyed households seriously feel troubled financially and irregular availability of biomass energy in the study zone. A vast majority of households (97.27 percent) reported the seriousness of the prevailing biomass energy shortage in the market (Table 8). The overall situation of sustainable biomass energy supply in terms of the existing and projected demand in the study area is far on lower side, indicating an overall prevalence of biomass energy shortage in the wolaita zone. This is largely due to the fact that most of the surveyed households still continue to depend upon biomass energy especially on wood and charcoal for their daily routine domestic cooking.


<table>
<thead>
<tr>
<th>Response</th>
<th>No. of Households</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>107</td>
<td>97.27</td>
</tr>
<tr>
<td>No</td>
<td>3</td>
<td>2.73</td>
</tr>
<tr>
<td>Not Stated</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>110</td>
<td>100</td>
</tr>
</tbody>
</table>

Almost the same residents (89.09 percent) reported about a serious shortage of supply from June to September, while the remaining household heads felt it during February to May. A small number (4.55 percent) noted shortage from October to January (Table 9). It can not be fully possible to explain clearly, why do they feel and experience shortage at different times of the year, but some senior residents and biomass energy sellers responded that different sets of people required different types of biomass energy sources, which are all not available in all seasons.

Table 9. Season of the Year Biomass Energy Shortage Happen in Wolaita Zone, Ethiopia, 2015

<table>
<thead>
<tr>
<th>Season of the Year</th>
<th>No. of Households</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>June – September</td>
<td>98</td>
<td>89.09</td>
</tr>
<tr>
<td>October-January</td>
<td>5</td>
<td>4.55</td>
</tr>
<tr>
<td>February- May</td>
<td>7</td>
<td>6.36</td>
</tr>
<tr>
<td>Total</td>
<td>110</td>
<td>100</td>
</tr>
</tbody>
</table>

N=110,  \(X^2=.514, \ DF=2, \ F=8.900\) and \(P\leq0.01\)

However, there seems to have been some explainable facts through fieldwork and observation. This is concerning the fluctuating supplies made in the market, accessibility of biomass energy at the sources, and amount of labor available for the purpose in relation to the seasons of the year. When the surrounding biomass energy supplier peasant community members are busy in their agricultural work in the fields, they restrained their labor from the energy business. Some of them indicate that dry seasons are better for them to supply energies to the user than that of the wet
season, as they can engage in this business as off-season activity or non-agricultural work. Collection of firewood in dry season is also felt to be easier in the woods in the environs. Moreover, journey to cover the distance up to five to ten kilometers back and forth, and collecting from various scattered points in the area becomes quite an arduous, tiresome and time-taking task in wet season, which is not a feasible exercise.

4.1.6. Household Energy Balance

4.1.6.1. Total Household Energy Used by the Household

The survey households used 339934.5 mega-joules of energy per month on average for domestic cooking. Biomass energies constitutes 339685.5 mega-joules (99.93 percent) of this total average per month and the remainder 250 mega-joules (0.07 percent) is constituted by modern energy sources (Table 10).


<table>
<thead>
<tr>
<th>Energy Types</th>
<th>Household Energy Consumption</th>
<th>Energy Use in MJ: - Low = &lt; 300000, Medium=300001-379870 and High = &gt;379871</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 All Biomass Energy</td>
<td>17644 339684.5 100 99.93</td>
<td>99.93</td>
</tr>
<tr>
<td>2 Modern Energy</td>
<td>250 100 0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>Total</td>
<td>339934.5 100 100</td>
<td>100</td>
</tr>
</tbody>
</table>

4.1.6.2 Biomass Energy in the Household Energy Balance

Fire wood forms naturally the dominant energy both in its gross weight and energy terms. Fire wood constitutes 11989kg (67.95 percent) of the total 17644 kg of biomass energy used by sample households each month on average. In terms of energy content, also firewood is still by far the dominant energy, contributing 209807.5 mega-joules (61.72 percent) of energy out of the total 339934.5 mega-joules of biomass energy and 60.68 percent of the total household energy consumed on average per month (Fig.5).

Figure 5. Monthly Biomass Energy utilization in Kg and Mega Joules in Wolaita Zone, 2015
The comparison between the position of firewood in terms of its weight and energy content reveals that firewood contribute more in its weight than its energy content. This is mainly due to the fact that the calorific value of wood is less than that of charcoal, which is a more concentrated energy source.

Charcoal is used as energy source by the majority of the surveyed households for domestic cooking, especially for that of coffee and for roasting grains which occasionally accompanies coffee drinking at ceremonial occasions. Charcoal forms the next most common household energy after firewood. According to the survey, it constitutes 3218 kg (18.24 Percent) of the total 17644 kg of biomass energy utilized by sample households per month (Fig.5). Charcoal constitutes 93322 mega-joules (27.47 percent) of energy out of the total 339934.5 mega-joules of biomass energy and 26.99 percent of the total household energy consumed by the surveyed households (Fig.5). In energy terms, charcoal provides much higher heat than that produced by wood.

Animal dung as domestic energy source contributes about zero kg (0 percent) of the total 17644 kg biomass energy consumed by the surveyed households per month in average. Animal dung contribute zero in energy terms than its gross weight, which factor signifies the inferior quality of dung in the energy content as compared to that of fire wood and charcoal. Dung constitutes zero mega-joules (0 percent) out of the total biomass energy and 0 percent of the total household energy consumed per month (Fig.5).

Crop residue is also a much less preferred substitute for wood. It is used generally by the lower income families that can ill afford to pay the increasing price of firewood. In the general household energy balance, however, crop residue constitutes a minimal 219kg (1.24 percent) of the total 17,644 kg of biomass energy. In energy terms also, it constitutes only 3285 mega-joules (0.97 percent) of the total biomass energy and 0.97 percent of the total household energy consumed each month on average (Fig.5).
BLT also plays significant role in the surveyed household energy demand. It constitutes 2218kg (12.57 percent) and 33270 mega-joules (9.79 percent) of the total 17644 Kg and 339934.5 mega-joules of biomass energy consumed by the surveyed households each average month respectively. Out of the total household energy it constitutes 9.79 percent (Fig.5). Annex V

4.1.7. Effects of Cost of Biomass Energy Sources on Energy Utilization

Findings show that, monthly costs for firewood constitutes the highest share of energy expenditure made for both total and biomass energy. Out of Birr 424 spent for biomass energy per month by the sample households, Birr 275 (64.86 percent) was spent on firewood, which also constitutes the highest share (52.08 percent) of the total costs for household energy per monthly and per year (Fig.6).

**Figure 6.** Sample Households Monthly Energy Costs for Biomass Energy in Birr, 2015. N=110

Owing to the still dominating prevalence of the use of inefficient traditional open fire Injera Mitad in most households, one could deduce this being the driving force for the dominance of wood in the surveyed household energy balance in terms of both its gross weight and costs.

Charcoal is one of the main biomass energies that comes entirely from energy market supply. It also constitutes significant part, covering 21.23 and 17.05 percent of the total biomass energy and costs made by the sample households per monthly and per year (Fig.6). Thus, it stands only next to firewood in the energy costs balances of the surveyed households.

Surveyed households spent Birr 0 per month for dry cow dung for their domestic energy demand entirely for Injera baking. It took 0 and 0 percent of biomass energy sources and total energy costs on energy per monthly and per year respectively (Fig.6).
Crop residue is also a lower scale substitute for wood for households energy that could not afford the increasing price of firewood. The monthly costs spent on it is an average of Birr 32 and constitutes 7.54 and 6.10 percent respectively of biomass energy and total costs made for energy per monthly and per year (Fig.6).

BLT is one of biomass energy sources in the household energy part of the households under study. The monthly costs spent on it is an average of Birr 27, and constitutes 6.37 and 5.1 percent of biomass energy and the total household energy costs of the sample households per monthly and per year respectively (Fig.6).

### 4.1.8. Knowledge on Health, Environment and Cost Effects of Biomass Energy

As shown in Fig.7, out of the total households(people) who responded to have knowledge of health effects of biomass energy sources, only 51 (46.36 percent) are able to name most of the accepted biomass energy utilization related health problems such as cough, irritation of eyes, and breathing related problems. Regarding the respondents’ multiple responses about their knowledge of the type of cooking energy sources that cause health problems, 76.36 percent of the respondents mentioned smoke from charcoal, 93.4 percent of the respondents said smoke from firewood, 80.91 percent of the respondents said smoke from crop residue, 88.18 percent of the respondents said smoke from animal dung and 73.64 percent of the respondents reported that smoke from BLTs disrupt one’s health (Fig.7).

**Figure 7.** Knowledge about the effects of biomass energy utilization in Wolaita zone

Respondents are asked whether they knew that smoke from firewood, animal dung, leaves, and charcoal affects the environment. As shown in Figure 7 Above, 92 (83.64 percent) of respondents said that they knew about it, while mentioning most accepted environmental consequences.
resulting from excessive firewood consumption, above 103(93.46 percent) of them mentioned deforestation, erosion, land degradation, pollution, climate change, and wild life destruction.

4.1.9. Experience on Current Biomass Energy Technology

As shown in Fig.8, out of the total sample households who responded to have experience of problems of current biomass energy technology, only 38(34.55 percent) are able to name most of the accepted current biomass energy technology and remaining 72(65.45 percent) are unable to name most of the accepted current biomass energy technology related problems such as energy, hot, exposure to accidental burns and smoky related problems (Fig.8).

**Figure 8.** Biomass energy technology and biomass energy saving cooking stoves in Wolaita

![Bar chart showing the distribution of households who have experience about the problem of biomass energy technology, those who have heard the quality of biomass energy saving cooking stoves, and those interested in using biomass energy saving cooking stoves.]

Respondents are asked whether they know that saving or wasting heat energy from firewood, leaves, and charcoal by using current biomass energy technology affects the biomass energy sources and climate. As shown in Figure8 Above, 38(34.55 percent) of respondents said that they know about it, while mentioning most accepted biomass energy source consequences resulting from moderate firewood consumption, about 72(65.45 percent) of them mentioned as reduced rate deforestation, controlled erosion, land degradation, pollution, and mitigated climate change.

4.1.10. Still heard quality of biomass energy saving cooking stoves

As shown in Fig.8, out of the total sample households the majority 93(84.55 percent) of respondents’ reported they heard the quality of biomass energy saving cooking stoves, only 17(15.45 percent) of respondents’ are reported not heard the quality of biomass energy saving cooking stoves in their households (Fig.8). The most of surveyed households significantly be aware of efficiency and accessibility of biomass energy saving stove in the wolaita zone. A vast majority of households reported the seriousness of the existing biomass energy saving stoves in the local market.
An expert from the mining and energy bureau is asked about the awareness of efficiency and biomass energy saving stoves accessible for environment. According to the expert, both awareness of efficiency and biomass energy saving stoves were gave value for the health, indoor air as well as community.

**4.1.11. Interested in using biomass energy saving cooking stoves**

As shown in Fig.8, out of the total sample households the majority 88(80 percent) of respondent’s reported interested the utilization of biomass energy saving cooking stoves, only 22(20 percent) of respondents’ are reported uninterested the utilization of biomass energy saving cooking stoves in their households (Fig.8).

The some of surveyed households slightly feel concerned awareness of efficiency and irregular accessibility of biomass energy saving stove in the wolaita zone. A majority of households reported the seriousness of the existing biomass energy saving stoves in the local market.

An expert from the mining and energy bureau is asked about the efficiency of energy saving and biomass energy saving stoves accessible for cooking. According to the expert, both efficiency of energy saving and biomass energy saving stoves are available for the cooking and community.

“...though biomass energy saving stoves are becoming available and efficient for the households; firewood and charcoal are the primary means for cooking even in the rural and urban areas of zone.”

The expert gave the following reasons for this trend.

“... households of wolaita zone has been using charcoal, firewood, BLT and crop residue for hundreds and hundreds of years. It was not what they know-how and what they were comfortable with to open fire to biomass energy saving stove.”

**4.1.12. Benefits on utilization of biomass based renewable energy resources**

As shown in Table 11 below, most of the average respondents, 80 (72.73 percent), reported that they are mentioned benefits of biomass based renewable energy. Accordingly, 98(89 percent) of respondent are mentioned social and economical, whereas 88 (80 percent) of the respondents are reported household. Only 54 respondent (49 percent) reported environmental. According to an expert from EEPCO, people in zone have a cultural attachment to cooking with wood, animal dung, leaves, and charcoal.
“...the government is working hard to promote electricity use for household cooking. In the last few years for example, there has been a large increase in grid connections, however, people still choose not to use electricity for cooking purposes.


<table>
<thead>
<tr>
<th>Benefits</th>
<th>Frequency of mention households</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household</td>
<td>88</td>
<td>80</td>
</tr>
<tr>
<td>Social and Economical</td>
<td>98</td>
<td>89</td>
</tr>
<tr>
<td>Environmental</td>
<td>54</td>
<td>49</td>
</tr>
</tbody>
</table>

The same of surveyed households a little sense concerned awareness of benefits utilization of biomass based renewable energy in the wolaita zone. A majority of households reported the benefits of the existing biomass based renewable energy in the local area.

An expert from the mining and energy bureau is asked about the benefits of biomass based renewable energy. According to the expert, benefits of biomass based renewable energy are accessible for the households and community as well as zone and region.

“...though biomass energy are becoming accessible for the households; modern energies are the primary means for cooking even in the rural and urban areas of zone.”

The experts gave the following reasons for this drift.

“… Social, economic development, energy access, energy security, and climate change mitigation and the reduction of environmental and health impacts.”

4.1.13. Exercise of Biomass Based Renewable Energy Technology and Improved Stoves

The surveyed households exercise disturbed economically and irregular availability of biomass based renewable energy Technology in the study zone. Greater than one-fourth of the sampled households 34(30.91percent) reported the utilization of the existing biomass based renewable energy technology and improved stoves in their village (Table 12).

Table 12. Dominance of biomass based renewable energy Technology and Improved Stoves in Wolaita Zone, Ethiopia, 2015. N=110

<table>
<thead>
<tr>
<th>Response</th>
<th>No. of Households</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>34</td>
<td>30.91</td>
</tr>
<tr>
<td>No</td>
<td>76</td>
<td>69.09</td>
</tr>
<tr>
<td>Total</td>
<td>110</td>
<td>100</td>
</tr>
</tbody>
</table>

The overall dominance of improved biomass based renewable energy technology distribution in terms of the existing and probable demand in the wolaita zone is far on lower side, indicating an overall dominance of biomass based renewable energy technology scarcity in the wolaita. This is
largely due to the fact that most 76.09% of the surveyed households still continue to depend upon unimproved biomass energy technology especially on open firewood stove and charcoal stove for their daily routine domestic cooking. It can not be fully possible to explain clearly, why do they feel and experience lack of distribution at different village of the wolaita zone, but some senior residents and biomass based renewable energy technology distributors responded that different sets of people required different types of biomass based renewable energy technology, which are all not accessible in all village.

This is concerning the fluctuating supplies made in the market, accessibility of biomass based renewable energy technology at the industry, and amount of production accessible for the purpose in relation to the economic development. An expert from the mining and energy bureau is asked about the Improvement of improved biomass energy technologies efficiency and design of biomass energy saving stoves for environment .According to the expert, both Improvement of improved biomass energy technologies efficiency and design of biomass energy saving stoves for environment and community.

“… the potential to reduce the negative impacts of current utilization of biomass energy”
“…designed to save heat energy, decrease pollutants, increase combustion efficiency and attain a higher heat energy transfer”
“… in savings in the amount of biomass energy source, which translates to direct income savings”
“…that accrue from increased utilize of improved biomass energy source technologies include the alleviation of the burden placed on women and children in biomass based renewable energy sources collection, freeing up more time for women to engage in other activities, especially income generating activities”
“The provision of more efficient stoves can reduce respiratory health problems associated with smoke emission from biomass energy stoves.”
“the capacity to improve the efficiency of biomass energy utilize in traditional energy-intensive rural productive activities such as charcoal production, crop drying, wood briquettes and the other related activities”

The expert gave the following reasons for this development.

“ Be produced at low cost and provide a cost-effective solution, environmental protection and improved livelihoods.”
“…Under the current control in the traditional and modern biomass energy source parts, the improvements of energy efficiency, in particular increasing end-use efficiency at the household level received major attention by the energy planners and government institutions.”

An expert from the mining and energy bureau of Zone is asked about the distribution of improved stoves technologies for cooking. According to the expert, about 2862 Lakech and 1328 Mirt stoves have distributed throughout the zone.

“…the whole rural and urban households to be about 4190/14.06 percent) in Wolaita shift to the improved Lakech and Mirt stoves, a saving of about 1,000,000 ton of firewood which requires clear cutting of forest would been achieved in an annual basis.”

An expert from the mining and energy bureau is asked about the distribution of improved stoves and modern energy technologies for cooking. According to the expert, both improved stoves and modern technologies have been introduced in some areas of the zone, among which the Mirt firewood stove, the Lakech charcoal stove, the improved ‘Gonziye’ wood stove, the ‘Fetenech’ cooking stove and biogas technologies are worth mentioning. Annually on average, about 1,000 improved Lakech and Mirt stoves are distributed in woreda of the wolaita zones.

With regard to the accessibility of biomass energy sources, almost all, 86 (78 percent), of respondents agreed that wood, charcoal, crop residues, animal dung, and leaves are easily accessible, whereas only 24 (22 percent) of study participants reported that modern energy is easily accessible for cooking (Table 13).

<table>
<thead>
<tr>
<th>Category of household energy source</th>
<th>accessibility of Cooking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.Hhs</td>
</tr>
<tr>
<td>Biomass Energy</td>
<td>86</td>
</tr>
<tr>
<td>Modern Energy</td>
<td>24</td>
</tr>
<tr>
<td>Total</td>
<td>110</td>
</tr>
</tbody>
</table>

An expert from the mining and energy bureau is asked about the energy alternatives accessible for cooking. According to the expert, all biomass energy sources are accessible for the community.

“…though clean energy sources are becoming accessible for the households; firewood and charcoal are the primary means for cooking even in the rural and urban areas of zone.”

The expert gave the following reasons for this trend.
“. . . people of zone has been using charcoal, firewood, BLT and crop residue for hundreds and hundreds of years. It was not what they know and what they were comfortable with to change to modern sources.”

“. . .still food cooked with charcoal for example is believed to taste delicious than when cooked with other means.”

4.1.15. Factors of Biomass Energy Use Pattern

4.1.15.1. Stoves Acquisition and Determinant Variables

For the purpose of this study the researcher considered the residential pattern or house tenure status, headship pattern and household income as explanatory factors in one way or another determines households' decision to acquire privately owned stoves.

Field observation shows that, the residential pattern of households in Wolaita is one of the constraining factors for most of the residents to have no direct access to the main interconnected biomass energy technology. According to the survey result households that reside in there owned housing unit have better access to the main power grid than households in rented housing units (Table 14).

Table 14. Stoves Availability by House Tenure Status of Sample Households, 2015

<table>
<thead>
<tr>
<th>Stove Availability</th>
<th>House Tenure</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Owner occupied</td>
<td>Rented</td>
</tr>
<tr>
<td></td>
<td>No. HH  %</td>
<td>No. HH %</td>
</tr>
<tr>
<td>Yes</td>
<td>44 84%</td>
<td>5 10%</td>
</tr>
<tr>
<td>No</td>
<td>37 34%</td>
<td>24 22%</td>
</tr>
<tr>
<td>Total</td>
<td>81 74%</td>
<td>29 26%</td>
</tr>
</tbody>
</table>

N=110  X²= 29.228, DF =1 and P≤ 0.01

The data implies that the association between house tenure and having privately owned stove is significant at 1% probability level. One can infer from the result that residential permanency is one of the prerequisite to have own stove. Households living in rented housing units, even if they possess better income, they might be discouraged from having privately owned stove. Thus, most households are unable to use the readily available utilities. This aspect in turn diminishes the hopes to shift from biomass to stove use for cooking mainly for Injera baking.
Stoves acquisition also seems to have some patterns of association with headship patterns of the household head. Field survey indicated that nearly half of male-headed households acquire their own electric stove. While for female-headed households the share is about 40.43 percent (Table 15).

**Table 15. Stove Availability by Headship Patterns of the Household Head, 2015**

<table>
<thead>
<tr>
<th>Stove Availability</th>
<th>Sex of the Household Head</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td></td>
<td>No. HH</td>
<td>%</td>
</tr>
<tr>
<td>Yes</td>
<td>29</td>
<td>46.03</td>
</tr>
<tr>
<td>No</td>
<td>34</td>
<td>53.97</td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>100</td>
</tr>
</tbody>
</table>

N=110, $X^2 = 0.010$, DF = 1, F=.038 and $P \geq 0.01$

However, the data implies that the association between electric stove availability and headship patterns of the household head is not significant ($P > 45$ percent probability level). The survey result also indicate that household income level have impact on the acquisition of stove by the households. The share of households that acquire their own stove decrease from the lowest 73.33 percent for households in the lowest income group to 26.19 percent for medium income households and further down to 5.26 percent for the highest income families. And the pattern for households without stove is the reverse (Table 16).

**Table 16. Stove Availability by Monthly Household Income of Sample Households, 2015**

<table>
<thead>
<tr>
<th>Stove Availability</th>
<th>Household Income</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>No. HH</td>
<td>%</td>
</tr>
<tr>
<td>Low</td>
<td>22</td>
<td>73.33</td>
</tr>
<tr>
<td>Medium</td>
<td>5</td>
<td>16.67</td>
</tr>
<tr>
<td>High</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>100</td>
</tr>
</tbody>
</table>

N=110, $X^2 = 41.459$, DF = 1, F=172.480 and $P \leq 0.01$

Income Range: Low = Birr 250-500, Medium = Birr 501-1000 and High = Birr 1001.00-4000

The data reveal that the pattern of association of electric stove acquisition with monthly income of the household is statistically significant at 1 percent probability level. Owing to the overall low-income level of the country in general and zones like Wolaita in particular, this constraints calls for EEPCO to strength the residents capacity by availing credit schemes for the services it provides.
4.1.15.2. Domestic Energy Utilization and Determinant Variable

4.1.16.2.1. Gross Household Energy Utilization and Determinant Variables

Energy consumption for household cooking varied from household to household depending on family size, and other factors such as standard of living as measured by income, house tenure whether households reside in owner occupied or rented housing units and availability of proper kitchen place. According to field survey households with large family members consume more energy for the daily cooking chore than households with few household members (Table 17).

The data reveal that the relationship between total energy consumption in mega-joules and household size is statically significant at 1 percent probability level. One can infer from the result that head count is one of the determinate factors that determine the amount of energy consumed by the household.

Table 17. Monthly Total Household Energy Use in MJ by Sample Household Size, 2015

<table>
<thead>
<tr>
<th>Household Energy use in MJ</th>
<th>Household Size</th>
<th>No. HH</th>
<th>%</th>
<th>No. HH</th>
<th>%</th>
<th>No. HH</th>
<th>%</th>
<th>No. HH</th>
<th>%</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>16</td>
<td>48.49</td>
<td>10</td>
<td>33.33</td>
<td>9</td>
<td>19.15</td>
<td>35</td>
<td>31.82</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>12</td>
<td>36.36</td>
<td>11</td>
<td>36.67</td>
<td>15</td>
<td>31.92</td>
<td>38</td>
<td>34.55</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>5</td>
<td>15.15</td>
<td>9</td>
<td>30</td>
<td>23</td>
<td>48.92</td>
<td>37</td>
<td>33.64</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>33</td>
<td>100</td>
<td>30</td>
<td>100</td>
<td>47</td>
<td>100</td>
<td>110</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

N=110, \( X^2 = 15.004 \), DF = 4 and \( P \leq 0.01 \)

Household Size: - Low = 1-5, Medium = 6-8 and High = 9 - 12

Household Energy Use in MJ: - Low = < 300000, Medium=300001-379870 and High = >379871.

Total energy consumption also manifests anticipated kind of relationship with income level of the household. According to the survey result the proportion of high energy consuming households increases as income level rises. It ranges from the lowest 19.15 percent of low level consumption to as high as 48.92 percent of high energy consumption level for households in the highest income range and from the highest 48.49 percent of low energy consumption level down to 15.15 percent of high energy consumption level for households in the lowest income category (Table 18).

Table 18. Monthly Total Household Energy Use in MJ by Sample Household Income, 2015

<table>
<thead>
<tr>
<th>Household Energy use in MJ</th>
<th>Household Income</th>
<th>No. HH</th>
<th>%</th>
<th>No. HH</th>
<th>%</th>
<th>No. HH</th>
<th>%</th>
<th>No. HH</th>
<th>%</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>16</td>
<td>48.49</td>
<td>10</td>
<td>33.33</td>
<td>9</td>
<td>19.15</td>
<td>35</td>
<td>31.82</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>12</td>
<td>36.36</td>
<td>11</td>
<td>36.67</td>
<td>15</td>
<td>31.92</td>
<td>38</td>
<td>34.55</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>5</td>
<td>15.15</td>
<td>9</td>
<td>30</td>
<td>23</td>
<td>48.92</td>
<td>37</td>
<td>33.64</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>33</td>
<td>100</td>
<td>30</td>
<td>100</td>
<td>47</td>
<td>100</td>
<td>110</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

N=110, \( X^2 = 15.004 \), DF = 4 and \( P \leq 0.01 \)
The data reveal that the relationship or association between total energy consumption and monthly income of the household is significant at 1 percent probability level. The degree of association indicates that in urban areas where all energy sources are commercialized access to energy is determined by the purchasing power of the families. Thus, households with better income level could have better access to all sorts of energy available in the market.

Total energy consumption also has association with tenure status of the household. According to the survey, households reside in owner occupied housing units consume more energy than those households reside in rented housing units (Table 19).

Table 19. Monthly Total Energy Use in MJ by Tenure Status of Sample Households, 2015

<table>
<thead>
<tr>
<th>Energy Use In MJ</th>
<th>House Tenure</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Owner occupied</td>
<td>Rented</td>
</tr>
<tr>
<td>Low</td>
<td>10</td>
<td>12.35</td>
</tr>
<tr>
<td>Medium</td>
<td>30</td>
<td>37.04</td>
</tr>
<tr>
<td>High</td>
<td>41</td>
<td>50.62</td>
</tr>
<tr>
<td>Total</td>
<td>81</td>
<td>100</td>
</tr>
</tbody>
</table>

The data reveal that the relationship or association between house tenure and total energy consumption of the household is statistically supported at 1 percent probability level. This association might be due to the fact that the majority of households resides in their own housing units are the ones who have better income. These households might also be advantageous in the generation of additional income from house rent. On the other hand households in rented housing units mostly suffer from additional extra ordinary costs like house rent, since housing costs is the largest expenditure for most of the lowest and medium income families in the wolaita zone.

Kitchen as part of the main housing units and the place for almost all cooking activities, its availability expected to exert an impact on the consumption of energy for household cooking. Field
A survey indicates that, households with proper kitchen place, 21.62 percent of them constituted low energy consumption and 47.30 percent high energy consumption. And the pattern for households without proper kitchen place is 52.78 percent and 11.11 percent respectively (Table 20).

Table 20 Monthly Total Household Energy Use in MJ by Kitchen Availability in Wolaita Zone

<table>
<thead>
<tr>
<th>Household Energy Use in MJ</th>
<th>Kitchen Availability</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>No. HH</td>
<td>%</td>
</tr>
<tr>
<td>Low</td>
<td>16</td>
<td>21.62</td>
</tr>
<tr>
<td>Medium</td>
<td>25</td>
<td>33.78</td>
</tr>
<tr>
<td>High</td>
<td>35</td>
<td>47.30</td>
</tr>
<tr>
<td>Total</td>
<td>74</td>
<td>100</td>
</tr>
</tbody>
</table>

\[X^2 = .286, \text{ DF} = 1, F=2.076 \text{ and } P \leq 0.01\]

The data reveal that the association between total energy consumption and availability of proper kitchen place is statistically supported at 1 percent probability level. The association is might be due to the fact that as most of the households prepared Injera in the home and as it is the major energy consuming activity and demanding proper fixed place to install the appliances, households who didn't have proper kitchen place may constrained from baking as they demanded. Thus, they might reduce the energy consumption per the reasons mentioned above.

4.1.15.2.2. Biomass Energy and Determinant Variables

The aggregate sum of biomass energy consumed for domestic cooking purpose also bears anticipated relationship with household size. According to field survey, households with large family member more represented in the highest biomass energy consumption range and households with few family members are the reverse (Table 21).

Table 21 Monthly Total Biomass Energy Use in MJ by Sample Household Size, 2015

<table>
<thead>
<tr>
<th>Biomass Energy in MJ</th>
<th>Household Size</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>No. HH</td>
<td>%</td>
</tr>
<tr>
<td>Low</td>
<td>15</td>
<td>45.45</td>
<td>4</td>
</tr>
<tr>
<td>Medium</td>
<td>10</td>
<td>30.30</td>
<td>16</td>
</tr>
<tr>
<td>High</td>
<td>8</td>
<td>24.24</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>33</td>
<td>100</td>
<td>30</td>
</tr>
</tbody>
</table>
The data implies that, the relationship between biomass energy consumption and household size is significant at 1 percent probability level. One could infer from the finding that as energy for cooking is one of the most important inputs of food items that demanded by the household members on daily basis; thus, households with large member size could exert an influence on the consumption of biomass energy for cooking.

Total biomass energy consumed by households is also substantially influenced by monthly income of the household. Households within the low-income range constituted more within low-level consumption than the high-income families. On the other hand only 7.89 percent households with large family member consume less biomass and about three quarter of the same group consume high amount of biomass energy as compared to 13.33 percent of the lowest income group for the same consumption level (Table22).

Table 22. Monthly Total Biomass Energy Use in MJ by Sample Household Income, 2015

<table>
<thead>
<tr>
<th>Biomass Energy in MJ</th>
<th>Household Income</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Low</td>
<td>20</td>
<td>12</td>
</tr>
<tr>
<td>Medium</td>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td>High</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>42</td>
</tr>
</tbody>
</table>

N=110, X² = .533, DF = 1 F= 14.757 and P≤ 0.01

Biomass Energy Use in MJ: - Low = < 300000, Medium=300001-379370 and High = >379371.

The data reveal that the association between biomass energy consumption and income level of the household is statistically supported at 1 percent probability level. This might be due to the fact that all energy sources including biomass energy in wolaita became commercialized, and access to the source nearly all determined by market forces. Thus, households with better income status could have better access to all energy sources including biomass energy.

Per reasons discussed in part 4.1.16.2.1, the residential pattern, whether households reside in owner occupied or rented housing units could exert an influence on the consumption of biomass energy for domestic cooking. According to survey, households residing in owner occupied
housing units more belong to the highest biomass energy consuming group and only 21.16 percent of households in the same group fall under low level consuming group. The pattern for households from rented housing units is 17.24 and 44.83 per cent respectively (Table 23).

Table 23.Monthly Total Biomass Energy Use in MJ by House Tenure Status in wolaita zone

<table>
<thead>
<tr>
<th>Biomass Energy Use In MJ</th>
<th>House Tenure</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Owner occupied</td>
<td>Rented</td>
<td></td>
<td>No. HH</td>
<td>%</td>
<td>No. HH</td>
</tr>
<tr>
<td>Low</td>
<td>22</td>
<td>13</td>
<td>35</td>
<td>21.16</td>
<td>44.83</td>
<td>31.82</td>
</tr>
<tr>
<td>Medium</td>
<td>27</td>
<td>11</td>
<td>38</td>
<td>33.33</td>
<td>37.93</td>
<td>34.55</td>
</tr>
<tr>
<td>High</td>
<td>32</td>
<td>5</td>
<td>37</td>
<td>39.51</td>
<td>17.24</td>
<td>33.64</td>
</tr>
<tr>
<td>Total</td>
<td>81</td>
<td>29</td>
<td>110</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

N=110, X² = 5.097, DF = 1, F=56 ,687 and P≤ 0.01

The data reveal that, the association between biomass energy use and house tenure status of the household is statistically supported at 1 percent probability level.

Field survey also indicates that biomass energy consumption has some sort of association with kitchen availability. The majority of households with proper kitchen place consume high biomass energy (47.30 percent) as compared to 5.56 percent of households’ without kitchen facility (Table 24).

Table 24.Monthly Total Biomass Energy Use in MJ by Kitchen Availability in wolaita zone, 2015

<table>
<thead>
<tr>
<th>Biomass Energy in MJ</th>
<th>Kitchen Availability</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No. HH</td>
<td>%</td>
<td>No. HH</td>
<td>%</td>
<td>No. HH</td>
</tr>
<tr>
<td>Low</td>
<td>15</td>
<td>20</td>
<td>35</td>
<td>22.27</td>
<td>55.55</td>
<td>31.82</td>
</tr>
<tr>
<td>Medium</td>
<td>24</td>
<td>14</td>
<td>38</td>
<td>32.43</td>
<td>38.89</td>
<td>34.55</td>
</tr>
<tr>
<td>High</td>
<td>35</td>
<td>2</td>
<td>37</td>
<td>47.30</td>
<td>5.56</td>
<td>33.64</td>
</tr>
<tr>
<td>Total</td>
<td>74</td>
<td>36</td>
<td>110</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

N=110, X² = .389, DF =1, F=10.761 and P≤ 0.01

The data reveal that the association between biomass energy consumption and availability of proper kitchen place is statistically significant at 1 percent probability level. Per the reason discussed above, as far as Injera baking is concerned, the major energy consuming and fixed kitchen-demanding chore that prepared in the majority of households, households without proper kitchen place were constrained from baking, as they demanded. Due to the challenges faced by these households could have employed their own coping mechanisms such as reducing the
frequency of baking or changing their feeding habit that demanded lesser energy as compared to Injera baking.

4.1.15.3. Household Energy Costs and Determinant Variables
Depending on different decision-making contexts households expend part of their income for different energy sources. Low-level household energy costs more constituted by households with few family members than households with highest family size. And the pattern for the highest costs category is the reverse (Table 25). The same pattern is also observed for the total household and specific energy sources as represented by biomass (Table 26).

Table 25.Monthly Total Household Energy Costs in Birr by Sample Household Size, 2015

<table>
<thead>
<tr>
<th>Household Energy Costs in Birr</th>
<th>Household Size</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>No. HH %</td>
<td>No. HH %</td>
</tr>
<tr>
<td>Low</td>
<td>15 45.46</td>
<td>9 30</td>
</tr>
<tr>
<td>Medium</td>
<td>13 39.39</td>
<td>13 43.33</td>
</tr>
<tr>
<td>High</td>
<td>5 15.15</td>
<td>8 26.67</td>
</tr>
<tr>
<td>Total</td>
<td>33 100</td>
<td>30 100</td>
</tr>
</tbody>
</table>

N=110, $X^2 = .006$, DF = 2, F=.666 and $P \geq 0.01$

Household Energy Costs: - Low = < Birr 100, Medium = Birr 101.00-950 and High = >Birr 951


<table>
<thead>
<tr>
<th>Biomass Energy costs in Birr</th>
<th>Household Size</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>No. HH %</td>
<td>No. HH %</td>
</tr>
<tr>
<td>Low</td>
<td>17 51.52</td>
<td>8 26.67</td>
</tr>
<tr>
<td>Medium</td>
<td>12 36.36</td>
<td>14 46.67</td>
</tr>
<tr>
<td>High</td>
<td>4 12.12</td>
<td>8 26.67</td>
</tr>
<tr>
<td>Total</td>
<td>33 100</td>
<td>30 100</td>
</tr>
</tbody>
</table>

N=110, $X^2 = 31.112$, DF = 2, F=341.823 and $P \leq 0.01$

Biomass Energy Costs: - Low = < 100, Medium = Birr 101-Birr 748 and High = >Birr 749

The data reveal that, the association of costs made for the above mentioned biomass energy sources and household size is statistically supported at 51 percent probability level for the total household energy and at 1 percent probability level for biomass energy source.
Household income is one of the most determinant factors that enable households to choose and expend part of their income for domestic energy. The general patterns of costs made for household energy indicate that as one starts scaling up from the lowest to the highest income group costs made for domestic fuel increases. The proportion of households with minimum household energy costs for total energy ranges from the highest 70 percent for households in the lowest income category to 33.33 percent for the median income group and further down to 0 percent for the highest income families (Table 27). And though it differs, the same pattern is also observed for biomass (Table 28) energy costs. The data reveal that household energy costs made for both sources have significant association with household income at 1 percent of significant level.

Table 27 Monthly Total Household Energy Costs in Birr by Sample Household Income, 2015.

<table>
<thead>
<tr>
<th>Household Energy costs in Birr</th>
<th>Household Income</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No. HH</td>
<td>%</td>
<td>No. HH</td>
<td>%</td>
<td>No. HH</td>
<td>%</td>
<td>No. HH</td>
</tr>
<tr>
<td>Low</td>
<td>21</td>
<td>70</td>
<td>14</td>
<td>33.33</td>
<td>0</td>
<td>0</td>
<td>35</td>
</tr>
<tr>
<td>Medium</td>
<td>7</td>
<td>23.33</td>
<td>19</td>
<td>45.23</td>
<td>12</td>
<td>31.58</td>
<td>38</td>
</tr>
<tr>
<td>High</td>
<td>2</td>
<td>6.67</td>
<td>9</td>
<td>21.42</td>
<td>26</td>
<td>68.82</td>
<td>37</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>100</td>
<td>42</td>
<td>100</td>
<td>38</td>
<td>100</td>
<td>110</td>
</tr>
</tbody>
</table>

N=110, $\chi^2=0.0009$, DF = 2, $F=.946$ and $P\geq0.01$

Table 28 Monthly Total Biomass energy costs in Birr by Sample Household Income, 2015.

<table>
<thead>
<tr>
<th>Biomass Energy costs in Birr</th>
<th>Household Income</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No. HH</td>
<td>%</td>
<td>No. HH</td>
<td>%</td>
<td>No. HH</td>
<td>%</td>
<td>No. HH</td>
</tr>
<tr>
<td>Low</td>
<td>23</td>
<td>76.67</td>
<td>11</td>
<td>26.19</td>
<td>1</td>
<td>2.63</td>
<td>35</td>
</tr>
<tr>
<td>Medium</td>
<td>6</td>
<td>20</td>
<td>20</td>
<td>47.62</td>
<td>12</td>
<td>31.58</td>
<td>38</td>
</tr>
<tr>
<td>High</td>
<td>1</td>
<td>3.33</td>
<td>11</td>
<td>26.19</td>
<td>25</td>
<td>65.79</td>
<td>37</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>100</td>
<td>42</td>
<td>100</td>
<td>38</td>
<td>100</td>
<td>110</td>
</tr>
</tbody>
</table>

N=110, $\chi^2=33.293$, DF = 2, $F=662.330$ and $P\leq0.01$

Residential pattern is one of the socioeconomic factors that make differences among households. Households having privately owned housing units have better opportunity to reside permanently in the same housing units. Such patterns of residential advantage might have encouraged households to possess permanent equipments used for cooking. In addition households having their own housing units also free from high price housing rent which may helps us to explain the significant costs share of households reside in rented private households. The advantage of having own housing units seems to reflect in the costs patterns of households made for household energy. The
general trends in household energy costs made for domestic energy indicate that, the highest costs made for energy is largely constituted by households from owner occupied housing units (Table 29 and 30). The data revealed that the association between energy costs and residential patterns of the household is statistically supported at 5 percent probability level for total household energy at 1 percent level for biomass energy source.


<table>
<thead>
<tr>
<th>Household Energy Costs in Birr</th>
<th>House Tenure</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Owner occupied</td>
<td>Rented</td>
</tr>
<tr>
<td></td>
<td>No. HH</td>
<td>%</td>
</tr>
<tr>
<td>Low</td>
<td>27</td>
<td>33.33</td>
</tr>
<tr>
<td>Medium</td>
<td>18</td>
<td>22.22</td>
</tr>
<tr>
<td>High</td>
<td>36</td>
<td>44.44</td>
</tr>
<tr>
<td>Total</td>
<td>81</td>
<td>100</td>
</tr>
</tbody>
</table>

N=110, \( X^2 = .25 \), DF = 1, F=2.840 and \( P \geq 0.01 \)


<table>
<thead>
<tr>
<th>Biomass Energy Costs in Birr</th>
<th>House Tenure</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Owner occupied</td>
<td>Rented</td>
</tr>
<tr>
<td></td>
<td>No. HH</td>
<td>%</td>
</tr>
<tr>
<td>Low</td>
<td>20</td>
<td>24.69</td>
</tr>
<tr>
<td>Medium</td>
<td>26</td>
<td>32.10</td>
</tr>
<tr>
<td>High</td>
<td>35</td>
<td>43.21</td>
</tr>
<tr>
<td>Total</td>
<td>81</td>
<td>100</td>
</tr>
</tbody>
</table>

N=110, \( X^2 = 37.964 \), DF = 1, F=120.590 and \( P \leq 0.01 \)

Availability of proper kitchen place also has its own impacts on energy costs patterns of households. According to field survey the significant majority of households with a proper kitchen place made the highest costs for energy than households without a proper kitchen place. The data revealed that costs made for both the total and biomass fuel sources is significantly associated with availability of kitchen at 1 percent probability level for both the sum total household energy and biomass energy (Table 31 and 32). This pattern might be due to the fact that energy costs made for total household energy and biomass energy as dominated by firewood and as it is also influenced by Injera baking, one could explain how the availability of kitchen place exert an impact on the costs patterns of households made for total household energy and biomass energy sources.

Table 31 Monthly Total Household Energy Costs in Birr by Kitchen Availability in wolaita, 2015.
### Household Energy Costs in Birr

<table>
<thead>
<tr>
<th>Kitchen Availability</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Owner Occupied</td>
</tr>
<tr>
<td></td>
<td>No. HH</td>
</tr>
<tr>
<td>Low</td>
<td>18</td>
</tr>
<tr>
<td>Medium</td>
<td>24</td>
</tr>
<tr>
<td>High</td>
<td>32</td>
</tr>
<tr>
<td>Total</td>
<td>74</td>
</tr>
</tbody>
</table>

N=110, $X^2 = .019$, DF = 2, F=2.076 and $P \geq 0.01$


<table>
<thead>
<tr>
<th>Total Biomass Energy Costs in Birr</th>
<th>Kitchen Availability</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Owner Occupied</td>
<td>Rented</td>
</tr>
<tr>
<td></td>
<td>No. HH</td>
<td>%</td>
</tr>
<tr>
<td>Low</td>
<td>17</td>
<td>22.97</td>
</tr>
<tr>
<td>Medium</td>
<td>23</td>
<td>31.08</td>
</tr>
<tr>
<td>High</td>
<td>34</td>
<td>45.95</td>
</tr>
<tr>
<td>Total</td>
<td>74</td>
<td>100</td>
</tr>
</tbody>
</table>

N=110, $X^2 = 51.585$, DF = 1, F=273.388 and $P \leq 0.01$

### 4.1.16. Implications for Climate Compatible Development

To find out Climate Compatible Development of utilization of biomass energy and variable analysis were conducted considering socio-demographic variables, knowledge related variables, energy related variables, and socio-cultural variables as independent variables and biomass energy utilization as dependent variable. In analysis, income group, knowledge about effects of biomass energy smoke on health, knowledge about effects of biomass energy smoke on the environment, knowledge about effects of unimproved and improve biomass energy technology on forest covers, knowledge about effects of forest(wood) on global warm, effect of cost on household energy choice, knowledge about effects of potential, supply and productions on resources and accessibility of household energy sources were found to be associated with utilization of biomass energy.

Variable analysis based on backward stepwise logistic regression also showed that knowledge about the effects of biomass energy smoke on health, knowledge about the effects of biomass energy smoke on the environment, income, availability of household energy sources, and effect of cost on household energy choice (expense perception) had an association with utilization of biomass energy. Statistical significant association is also found between respondents’ knowledge about effects of biomass energy smoke on the environment and biomass energy utilization.
Knowledge about effects of biomass energy smoke on health had shown statistically significant association with utilization of biomass energy. Households who had less knowledge about the effects of biomass energy smoke on health were 3.2 times more likely to utilize biomass energy sources as compared with those who had sufficient knowledge. Household who had less knowledge about the effects of biomass energy smoke on the environment were 5.11 times more likely to utilize biomass energy sources than those who had sufficient knowledge about them.

When asked how people could be educated to shift to modern energies sources, the expert from the mining and energy office said

“. . .it will be possible to motivate people of this zone to shift to modern energies; however, it will require much effort from both government and other non government organizations in the promotion of such energies.”

The following points were proposed by this expert.

“. . .people need to be educated about the dangers associated with traditional biomass energy utilize; they need to understand the benefits of modern stoves as well.”

“. . .people need to understand that when using traditional biomass energies, trees have been cut; this tree that serves many functions as ecological imbalance, fruit bearing, shade creating, and many more.”

According to the expert from the mining and energy bureau of administrative zone, it is important to mobilize different government and nongovernment factors for the promotion of modern energies.

A 26-year-old woman when asked about the effects of biomass energy sources for cooking on health, environment, and the economy, she reported “I know that smoke from firewood, charcoal, BLT and crop residues affects our health irrespective of what specific problems can results.”

“mini - media is reporting that smoke from any biomass energy sources is affecting our planet, but I do not know how it is happening.” I do not think that biomass energy sources are cheaper than the modern energy sources.”

4.2. Discussion

In this study, it is found that utilization of biomass energy was 99.93percent which is almost the same as the 99.8 percent of Ethiopian households’ utilization of biomass energy (Legros et at,2009). On the other hand, utilization of biomass energy sources contribution(99.93percent) of
total households energy, 61.8 percent is from firewood, 27.5 percent from charcoal, 9.8 percent from BLT, 0 percent from animal dung, and 0.97 percent from crop residues the study area is found to be slight similar as compared with the national figure in 2012 (99 percent), where 77 percent is from firewood, 13 percent from animal dung, and 9 percent from crop residues (Araya Asfaw, 2011). This can be attributable to the fact that participants of the present study are only from local levels resident.

Participants’ knowledge about the harmful effects of smoke from biomass energies in this study is found to be much lower as compared with a study conducted in Costa Rica (81 percent). However, the respondents’ knowledge about effects of smoke from utilization of biomass energy in households whether it causes cough or not according to this study (46.4 percent) is generally not better than Costa Rica’s counterparts (65 percent) (Edward Park and Lee Khan, 2003). This slight mismatch can be explained by the awareness differences between the two study areas.

Literature indicated that education of the respondents can play a pivotal role in the choice of household energy source for cooking (Edward Park and Lee Khan, 2003). However, despite the fact that the (30.9 percent) of the study participants are educated, they used biomass based renewable energy sources. This finding is reliable with findings in studies conducted in southwestern Nigeria (Ololade et al, 2012). However, the present study showed that significant proportion of respondents (67.95 percent) relied on firewood as their primary biomass energy source not much against study results in Nigeria, where the respondents’ primary biomass energy source is charcoal (27 percent) (Ololade et al, 2012). This difference in choice between Ethiopians and Nigerians can be a function of geographical variation in the level of urbanization, living standard, and climate and socioeconomic and cultural factors (Ololade et al, 2012). In addition to this, participants in the reference study being from rural and urban dwellers can be one reason for the observed discrepancy.

In this study, income is found to have statistically significant association with utilization of biomass based renewable energy source, which is relatively the same as the study conducted in the United Kingdom concerning the spending pattern of the urban poor on cooking energy (Clancy Jon, 2004). Knowledge of respondents had strong positive effects on utilization of biomass based
renewable energy; about 46.4 and 83.6 percent of the respondents reported that biomass energy sources smoke affects health and environment. This finding is much lower and higher as compared to the result of studies conducted in southern Philippines (USAID, 2005). But, almost a similar finding to this study is reported by a study conducted in Catembe, Mozambique, that compared respondents’ knowledge about the effects of smoke from charcoal and firewood on the environment (54 percent and 53 percent), respectively (Becker Atanassov, 2010). This similarity may be partly explained by the fact that people became aware of the existence of global climate change and its consequences. About (62.73 percent) of the respondents of this study had separate kitchens which appeared to be higher and lower than findings from other studies conducted in Ethiopia such as Jimma and Markos, where only 27.5 percent and 84.2 percent of respondents had separate kitchens (Kebede Faris, 2012). This mismatch can be due to study period differences and study subject differences in the three researches. On the other hand, accessibility of household energy sources showed statistically significant association with utilization of biomass based renewable energy source as it had no significant association in other previous studies (Edward Park, 2003 and Kebede Faris, 2012). However, this finding is contrary to the fact that wood becomes less accessible through time which leads to climate change, soil erosion, and severe social implications (Edward Park and Lee Khan, 2003).

The degree of expensiveness (expense perception) showed statistically significant association with utilization of biomass energy. This might be explained by the fact that lower income people are retailers such that they rely on easily accessible biomass energies despite their consequences. This finding clearly showed that most study participants are blindly reserving themselves from not utilizing modern energies for cooking. The quantitative findings of this study are supported by qualitative findings which increase the strength of the study findings. Being of a cross-sectional study design, it may not clearly indicate causal effect relationship due temporal relationship.

5. SUMMARY, CONCLUSION AND RECOMMENDATION
5.1 Summary

Energy as a whole and household energy in particular is a basic requirement for human life. Households require energy for their subsistence; they need energy for cooking, lighting, heating and cooling different items. The study Wolaita zone and its surroundings from where biomass energy source is extracted and supplied are among the most drought-prone and environmentally degraded areas of the country. The natural vegetation resources especially that of biomass is severely degraded. In light of population growth, expansion of farmland, pastures and excessive, unplanned and unsystematic woodcutting, forest areas are further decreasing. As in many parts of the country, in Wolaita Zone, firewood require is by far in excess of the sustainable supply. Many people especially the poor suffer the most, and are forced to further exploit the environment or obtain at high prices from the market to obtain biomass energy source for their household energy need.

Lack of human capital such as technology, motivation, general and technical education and social conflicts have constantly put barriers in resource development. In addition low income levels also prevent many households from using improved modern appliances and switching to the use of higher-grade energies. The existing constraints that hold back the fulfillment of the household energy need explain the evidence stress for firewood and other forms of biomass energy.

Household energy for cooking for all households in the wolaita is primarily biomass energy. According to the 2007 CSA Census report, out of the total 297981 housing units in zones of Wolaita zone, about 99 percent of the housing units exclusively depended on biomass energy sources for their domestic cooking. Identical pattern was also observed in Wolaita zone.

The study shows that major energy types used by households for domestic cooking are firewood, charcoal, kerosene, BLT, crop residue and electricity in their order of importance. The overall balance indicates that biomass energy sources constitute the larger proportion (99.93 percent) of energy for household cooking as compared to the conventional modern energy sources (0.07 percent). In study areas, energies are traded and marketed commodities, whether they are wood, charcoal, kerosene or electricity. Households in Wolaita obtain biomass energies through purchase and with fewer cases through collection on their own children in the surrounding
The diversified demand for energy in the study areas coupled with the monetization of energy services means that households, especially the poor, compete for energy with the affluent and productive sectors of the economy. These situations exert a pressure on many households in small villegges to spend a relatively high proportion of their income to meet basic energy needs.

With regard to energy utilization efficiency, the study revealed that households in Wolaita depend on inefficient traditional open fire stoves or ovens for cooking and baking. A significant portion of households (49.09 percent), use inefficient open fire three stone traditional Mitad for Injera baking. Households who use the traditional enclosed Injera Mitad and the Mirt Injera Mitad are 37.27 and 12.72 percent respectively. Only 0.91 percent of households were found to be users of electric Mitad.

Staying types such as having a fixed kitchen or absence of kitchen exert an influence on the achievement and use of appliances used for baking. Improved Injera Mitad is inflexible to use; it needs fixture and resultant site. This means the improved Injera Mitad demands fixed and proper kitchen place. Thus, enclosed Mirt Mitad, including the traditional one is mainly used by households that have proper kitchen place. The other problem is the financial limitation of households to purchase Mirt Injera Mitad. Hence, households tend to use open fire Injera Mitad, which wastes high amount of biomass energy source of energy. The high and direct dependence on biomass energies coupled with low efficiencies in its end use at household level, mainly for cooking on open fire, are contributing to unnecessary high level of biomass energy resource extraction and utilization. This pressure has led to the enormous depletion of forest and/or woodland resources resulting in serious shortage of firewood and severe energy crisis. It also leads to higher wood and charcoal prices, hitting adversely all consumers but most critically the low-income groups.

A large portion of households (97.27 percent) reported that biomass energy shortage is a growing and serious problem in Wolaita. The problem has become worse and severe since the last decade. This is partly explained by the ever-increasing firewood and charcoal prices, which exert adverse effects on the proportion of the household budget for energy, consequently cutting the family budget for other basic needs. The study result indicate that households in the lower income and
costs group spend higher proportion of their budget on energy than the highest income and costs group.

The study also revealed that socioeconomic status like income of the household plays a critical role in the favorite and consumption of biomass energy for household energy. It was observed that other things being the same, households with high monthly income consume more biomass energy and have better access to the efficient and modern energy sources than the lower income families. For countries like Ethiopia where generally multiple dishes are prepared using several major biomass energy types used for domestic cooking, biomass energy consumption differ according to different food items prepared within the households. Owing to the overall low-level of socioeconomic status of the people and the lack of alternatives for balanced household energy mix, and the peculiar demand of households for traditional biomass energy for certain food items, a typical urban household in Ethiopia in general and in zones like Wolaita in particular depends on biomass energy as a major source of energy. This is partly because some traditional energies are needed for specific type of cooking. The study also shows that families may use different types of energies and stove types but seldom leave the traditional energy or stove types completely.

Generally, the study has revealed that households in Wolaita dominantly rely on biomass energies for domestic cooking purpose. This trend seems to continue dominating the household’s energy consumption for quite a long time to come. Since the 2000s, the supply side intervention to mitigate the energy crisis at the macro and household level was considered as an important solution to the problem. However, observations by this researcher, the discussions made with various informants and facts from the documents reviewed have confirmed that the level of achievement in this regard has been generally poor and unacceptable. As a response, demand side interventions from the consumers’ decision context were given particular attention to positively influence the current biomass energy require and consumption pattern. However, this strategy also seems to be very slowly coming forth as the two important factors of stagnant income level and the growing number of people militates against its likelihood.

Under the current limitations in both the biomass and modern energy sources as per reasons explained above and the inefficient mode of energy utilization, the improvements of energy
efficiency in different sources, in particular increasing end use efficiency at the household level should be taken as a prerequisite to tackle biomass sources and biomass energy-related problems at the household level. According to other study, Notes that energy saving stoves were have a cost effective solution, environmental protection, mitigates climate change and improved income and they can also have significant economic effects on both at the household level and at the macro economy level at large.

5.2. Conclusion
Utilization of biomass based renewable energy for traditional cooking among households of wolaita zone inhabitants was found to be high. The major driving forces for this high utilization were wrong perception about cost of biomass energy sources, insufficient knowledge about the consequences of biomass energy utilization, limited household income, and wrong perception about the accessibility of cooking energy sources. The implications of biomass energy utilization on the community of zone were poor health, ecological imbalance, and cost ineffectiveness. Therefore, understanding the utilization of biomass based renewable energy sources and its implication among households of wolaita zone is the fundamental element of interventions for climate compatible development, improving the health of the community, maintaining ecological balance, and minimizing cost of living.
This possibility may also lead to regeneration of woodlots and biomass energy use and supply. Therefore, based on the findings of the study, the following issues are identified for further consideration to tackle household energy-related problems in areas.
In general, households in Wolaita are aware of the benefits of biomass energy saving as reflected in their slowly emerging trend in the use of enclosed traditional and improved stove in some households. Therefore, further promotion activities to use improved stove such as comparative cooking demonstration, like three stone fire versus improved stove as well as joint discussion with the community at places of social, cultural and religious events have to be conducted.
Empowering the local improved stove producers by providing loans in the form of revolving fund so as to improve production and marketing.
Household energy problems should also be considered in line with other development activities. Like improving the quality of housing and solving housing problem should be taken as one part of solving households’ energy problem.
The demand side management of household energy should be given due emphasis and considered as important as the supply side. Different institutions working in the area of afforestation and natural resource protection and conservation should be encouraged to mainstream household energy issues in their development agendas.

5.3. Recommendation

Based on the findings of this study, the following recommendations were forwarded:
in order to get our country, Ethiopia, developed clean cooking energies, more efficient biomass energy technologies should be promoted and scaled up by the government as alternatives to biomass energies,
government and nongovernment organizations should raise the awareness of the community about the climate, health, cost, and environmental benefits of modern biomass energies,
the community should be encouraged to use improved biomass energy technology mix for making energy change,
more research is needed to measure the health, economical, and climatic impacts of energy interventions in regions where there is high dependence on biomass energy sources like wolaita zone.

6. REFERENCES


CSA, (2007). SNNPR, Tables 2.1, 2.4, 2.5, 3.1, 3.2 and 3.4.


Faris, K., (2012). “Survey of indoor air pollution problems in the rural communities of Jimma,” Ethiopian Journal of Health Sciences,


Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.


7. Annex

7.1. Annex I: General/main Household Questionnaire

Introduction
The Ethiopian energy sector has showed unprecedented developments in recent years. These thesis include the manufacture of different stoves and improves traditional technology and installation of biomass energy technology. While the study of these thesis have multidimensional social, environmental and economic benefits to the country, the utilization of biomass based renewable energy sources has raised different argument as it has social and environmental impacts.

The aim of this questionnaire is to research whether Ethiopians are for or against the current state of utilization of biomass based renewable energy sources, distribution of biomass energy based
technology and/or safety and quality of the improved stoves in the study area. For the purpose of this study, there are four suggested action alternatives that could be applied to the utilization of biomass based renewable energy sources. This questionnaire focuses on people’s opinion on the usage of the biomass considering environmental, economic and social aspects. There are no right or wrong answers and genuine replies are highly appreciated. The following are the given action alternatives:

1. Household Details
1.1. Indicate the household details of all members of the household according to the options listed below. Name Of Woreda (1)

Sex (2) 1. Male  2. Female

Age (3) 1. From(12-25)year  2. From(26-40)year  3. from(41-60)year  4. Above 61 year


6. Others/specify ____________________________________________


Length Of Staying In Wolaita (6)

Educational level (7) 1. Illiterate  2. Read and Write  3. Primary  4. Secondary  5. Above secondary

6. Others/specify _____________________________


6. Others/specify________

Monthly income (10) 1. Main _____________ birr  2. Others _________

1.2. Tenure status of the housing unit

1. Owner Occupied  2. Rented from private households

1.3. Number of rooms the housing unit has

1. Bed room only  3. More than one room with out kitchen

2. One room with kitchen  4. More than one room with kitchen

1.4. Number of households living in the housing unit _____________________________

1.5. The situation of the housing unit in the town/village 1. Periphery  2. Center

2. GENERAL ENERGY USE RELATED QUESTIONS
2.1. Do you use any energy for domestic cooking purpose?  1. Yes  2. No
2.2. If you use any type of energy for domestic cooking indicate [by putting X marks] the type of principal energy you use for cooking and baking mostly employed for household purpose.

<table>
<thead>
<tr>
<th>Energy Types</th>
<th>Wood</th>
<th>BLT</th>
<th>Agriculture Residue</th>
<th>Dung</th>
<th>Charcoal</th>
<th>Other/specify</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injera baking</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Wot</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tea</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coffee</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other/ specify</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

2.4. Why you prefer the above mentioned energy as the principal source of energy [Indicate your answer by putting X mark]

<table>
<thead>
<tr>
<th>Injera baking</th>
<th>Wot</th>
<th>Tea</th>
<th>Coffee</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
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<td>5</td>
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</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

2.5. Indicate the type of domestic appliances used in the household for Injera baking.

1. Didn’t bake Injera
2. Open fire Injera Mitad
3. Enclosed traditional Injera Mitad
4. Mirte Injera Mitad
5. Others/Specify ____________________________

2.6. Indicate the type of domestic appliances used in the household for cooking and boiling.

1. Open fire with metal tripod, stone/clay seat
2. Metal charcoal stove
3. Lakech charcoal stove
4. Kerosene stove
5. Others/Specify ____________________________

2.7. If you have more than one baking and cooking appliances, what is the reason?

1. To cope with any energy failure
2. To cope with any technical failure
3. To cope with any fuel price increment
4. Others/specify ____________________________

2.8. If you use open fire for baking and other cooking, what are the main problems?

1. Consumes too much energy
2. It is hot while baking
3. Exposure to accidental burns
4. Too smoky
5. Others/specify ____________________________

2.9. Did you know where is baking Injera and other cooking in your home?  1. Yes  2. No

2.10. If your answer for question 2.9 is yes, Where do you bake Injera?
1. Separate kitchen
2. Shared kitchen
3. In the living room
4. Open air
5. Others/Specif

2.11. The frequency of baking and other cooking in the household?

<table>
<thead>
<tr>
<th>Frequency period</th>
<th>Injera</th>
<th>Wot</th>
<th>Tea</th>
<th>Coffee</th>
<th>Other/ specify</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per Week</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per Month</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. SPECIFIC BIOMASS ENERGY SOURCE RELATED QUESTIONS
3.1. How do you usually obtain your biomass energy sources?
1. Purchased
2. Collected
3. Purchased and collected
4. Others/ Specify

3.2. Indicate the average amount of biomass energy source the household purchased and the fee pay for the energy per month in Birr

3.3. Indicate the amount of biomass energy source collected by the household per month

3.4. Is there specific season that you experience biomass energy source shortage? 1. Yes 2. No
3.5. If the answer for question 3.4 is yes, during which part of the year biomass energy source scarce mostly happen? 1. June to September 2. October to January 3. February to May
3.6. How to mitigate the seasonal biomass energy source scarcity?
1. Do nothing
2. Substitute with other energy
3. Conserve energy use
4. Stock on energy
5. Stop energy using
6. Decrease frequency of baking and cooking
7. Others/specify
8. __________________________

3.7. Do you feel firewood utilization is a problem in Wolaita/village? 1. Yes 2. No 3. No idea
3.8. If your answer for question 3.7 is yes, how do you explain the seriousness of the problem?
1. Utilization efficient decreases
2. The price increases
3. Utilization of crop-residue and dung increase
4. Others/Specify
5. __________________________

3.9. Do you believe there is health problem in the area within your utilization of biomass energy source? 1. Yes 2. No 3. I don’t know
3.10. If yes, what is the extent of the problem compared to the time before the utilization of biomass energy source in the area?
1. I don’t know
2. Under control
3. Minor
4. others(specify)

3.11. According to you, what are the causes of utilization of biomass energy source in your surrounding?(max of four in order of seriousness)
1. Erosion
2. Deforestation
3. Land degradation
4. Climate change
5. Human population pressure
6. others(specify) _____

3.12. According to you, what are the effects of utilization of biomass energy source in your surrounding?(max of four in order of seriousness)
1. Drought
2. Famine
3. Poverty
4. Reduced size of livestock
5. Reduced Yield
6. Migration
7. Others(specify) _____

4. SPECIFIC BIOMASS ENERGY TECHNOLOGY RELATED QUESTIONS
4.1 Do you experience any problems with your current biomass energy technology? 1. Yes 2. No
4.2 If your answer for question 4.1 is yes or No; why
1……………………………………….. 2………………………………………..

4.3 Are you interested in using biomass energy source technology? 1. Yes 2. No
4.4 If your answer for question 4.3 is yes or No; why
1……………………………………….. 2………………………………………..

4.5 Have you ever heard of biomass energy saving cooking stoves? 1. Yes 2. No
4.6 If your answer for question 4.5 is yes, where did you hear that from?
1………………………………………… 2…………………………………………

4.7 When did you start using biomass energy saving cooking stove(s)? ……………………
4.8 Are you interested in using biomass energy saving cooking stoves? 1. Yes 2. No
4.9 If your answer for question 4.8 is yes, why have you not gone for such energy options?
1………………………………………… 2…………………………………………

4.10 What benefits have you gained so far from the use of biomass based renewable energy resources?
Household
1……………………………………….. 2………………………………………..
Economically
1……………………………………….. 2………………………………………..
Socially
1……………………………………….. 2………………………………………..
4.11 What improvements would you wish to see if you were to obtain optimum benefits from your biomass based renewable energy technology use?
   1. ...................................................... 2. ......................................................

4.12 Do other people in your village use biomass based renewable energy source and improved wood stoves? 1. Yes 2. No

4.13 If your answer for question 4.12 is yes, what forms of biomass energy source and improved wood stoves do they use?
   1. ...................................................... 2. .................................

7.2 Annex II: - Biomass Energy Weight Survey Format

The following format was employed to determine the average weight of biomass energy supplied to Wolaita zone.

<table>
<thead>
<tr>
<th>No.</th>
<th>Energy Type by Carriers</th>
<th>Weight in Kg</th>
<th>Energy Sources</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Region</td>
<td>Zone</td>
</tr>
</tbody>
</table>

7.3 Annex III: - Checklists for Key Informants and Focus Group Discussion

Name of the Interviewer------------------------Date--------Month---------Year---------

The following checklist were used with questions to guide in the informal interviews and group discussions that held with adult and elderly men and women, professionals from different governmental and non governmental organizations, improved stove producers, zonal and municipal officials.

1. Is household energy a problem in Wolaita zone, in what way?
2. What are the major problems?
3. What are the major sources of energy used in the area to meet daily basic energy requirements?
4. Generally how do people cope with household energy problems both cooking and baking?
5. Do you think people could shift more and more to commercial fuels such as kerosene and electricity for cooking and baking?
6. What are the major constraints or possible new avenues for such shift?
7. What intervention measures were tried to alleviate household energy problems?
8. Patterns and adoption of traditional enclosed and improved stoves and major problems related to their use
9. Are credit facilities willing to extend credit for people willing to purchase improved stoves?
10. What are the major constraints to have access and use electric utilities for household cooking and baking?
7.4. Annex V: Conversion Factor Calorific(power) values (Energy Contents) of Domestic Biomass Energies Sources

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Weight</th>
<th>Calorific Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass Energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Firewood</td>
<td>1Kg</td>
<td>17.5 MJ/Kg</td>
</tr>
<tr>
<td>Charcoal</td>
<td>1Kg</td>
<td>29 MJ/Kg</td>
</tr>
<tr>
<td>Agricultural Residue</td>
<td>1Kg</td>
<td>15 MJ/Kg</td>
</tr>
<tr>
<td>BLT</td>
<td>1Kg</td>
<td>15 MJ/Kg</td>
</tr>
<tr>
<td>Dung</td>
<td>1Kg</td>
<td>12 MJ/Kg</td>
</tr>
<tr>
<td>Modern energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kerosene</td>
<td>1L</td>
<td>44 MJ/Kg</td>
</tr>
<tr>
<td>Electric</td>
<td>1kwh</td>
<td>3.6 MJ</td>
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</tbody>
</table>


<table>
<thead>
<tr>
<th>Biomass Energy Type</th>
<th>Biomass Energy Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In Kilogram</td>
</tr>
<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>Firewood</td>
<td>11989</td>
</tr>
<tr>
<td>Charcoal</td>
<td>3218</td>
</tr>
<tr>
<td>Agricultural Residue</td>
<td>219</td>
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<tr>
<td>Dung</td>
<td>0</td>
</tr>
<tr>
<td>BLT</td>
<td>2218</td>
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<tr>
<td>All Biomass Energy</td>
<td>17644</td>
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</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>N</th>
<th>Range</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Sum</th>
<th>Mean</th>
<th>Std. Deviation</th>
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</thead>
<tbody>
<tr>
<td>Biomass energy use in households per month</td>
<td>110</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>222</td>
<td>2.02</td>
<td>.813</td>
</tr>
<tr>
<td>Average cost of biomass energy in household per month</td>
<td>110</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>222</td>
<td>2.02</td>
<td>.813</td>
</tr>
<tr>
<td>Average amount of modern energy use in quantity/MJ/ per month</td>
<td>110</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>152</td>
<td>1.38</td>
<td>.488</td>
</tr>
<tr>
<td>Average cost of modern energy in birr per month</td>
<td>110</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>152</td>
<td>1.38</td>
<td>.488</td>
</tr>
<tr>
<td>Utilization of biomass energy in household purpose</td>
<td>110</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>146</td>
<td>1.33</td>
<td>.471</td>
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<tr>
<td>Utilization of biomass energy affect by stoves availability</td>
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<td>1</td>
<td>1</td>
<td>2</td>
<td>172</td>
<td>1.56</td>
<td>.498</td>
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<td>Kitchen availability related utilization of biomass energy</td>
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<td>1</td>
<td>2</td>
<td>146</td>
<td>1.33</td>
<td>.471</td>
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<tr>
<td>Valid N (list wise)</td>
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