TRADITIONAL BIOFUELS AND THE NEED FOR DEVELOPING RENEWABLE BIOENERGY SOURCES, THE CASE OF KONCHER-TIK-SUBSHENGO AREA, DEJEN WOREDA, AMHARA REGION

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DEVELOPMENT STUDIES

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Acronyms and Abbreviations

AMRERDPD:	Amhara Mining and Rural Energy Resources Development and Promotion Department
Br:	Birr (Ethiopian Currency)
BIREC:	Beijing International Renewable Energy Conference
CSA:	Central Statistics Authority
DWARDO:	Dejen Woreda Agriculture and Rural Development Office
EEA:	Ethiopian Energy Authority
EFAP:	Ethiopian Forestry Action Programme
EMPDA:	Educational Materials Production and Distribution Agency
ENEC:	Ethiopian National Energy Committee
EREDPC:	Ethiopian Rural Energy Development and Promotion Center
FAO	Food and Agricultural Organization
FDRE:	Federal Democratic Republic of Ethiopia
FBRTPC:	Former Bahirdar Rural Technology Promotion Center
ha:	hectare
ILCA:	International Livestock Centre for Africa
kg:	Kilogram
L:	Litre
MJ:	Mega Joule
mm:	Millimeter
MoRD:	Ministry of Rural Development
MW:	Mega Watt
OPHCC:	Office of Population and Housing Census Commission
Qt:	Quintal
SEPK:	Special Energy Program/Kenya
SHHs:	Sample households
TGE:	Transitional Government of Ethiopia
UNESC:	United Nations Economic and Social Council
UNICEF:	United Nations Children's Fund
WBISPP:	Woody Biomass Inventory and Strategic Planning Project

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Abstract

Depletion of woody biomass is one of the pertinent environmental problems facing Ethiopia. Specifically, central and northern highland parts of the country, where cultivation and settlement have occurred over centuries, have confronted severe woodfuel scarcity and its multiple environmental consequences. The study examined the sources and consumption patterns of traditional biomass fuels as well as the potentials for developing renewable biomass energy sources. It was conducted in Koncher-Tik-Subshengo area, Dejen woreda, Amhara region.

The study relied both on secondary and primary data sources. Secondary data were gathered from both published and unpublished materials. Primary data were generated using structured interview questionnaire, key informant interview, focus group discussion and observation. For the study, 90 sample households were selected using proportionate random sampling technique from three purposefully selected sample villages. The data were analyzed using both quantitative and qualitative data analysis techniques.

The study disclosed that the principal types of biomass fuels utilized in the area are fuelwood, dung and crop residue. The other biomass fuels, which are utilized occasionally by a few households but probably are unique to the study site and its environs, are caster bean and cotton seed. The study as well uncovered the existence of serious fuelwood scarcity and the related environmental problems. This is evidenced by the comparatively high proportion of the consumption of inferior biomass fuels-dung and crop residues and low level of daily per capita biomass fuel consumption. While fuelwood accounted 44.14%, dung and crop residues constituted 43.62% and 12.24% of the total biomass fuel consumption respectively. The average daily per capita biomass fuel consumption was 21.93MJ (1.51kg of fuelwood equivalent). Free sources of fuelwood are exhausted. Tree planting has not yet been developed to the level that counteracts the energy problems of the area. Only some enlightened households have sufficient number of planted trees and shrubs. Besides, despite the prevalence of shortage of biomass fuels in the site, the majority (~77.78%) of the households use energy inefficient traditional stoves.

To alleviate the energy problems and related adverse environmental impacts, promotion of improved stoves, consolidation of tree planting practices both at community and private levels and development of biogas technology in the area are promising options. In the case of biogas, the study disclosed that about 34.44% and 10% of the total households of the area have enough number of cattle to feed a family size biogas plant in zero and non-zero grazing systems respectively. For these ends, however, educational status of the people should be raised. Comparative demonstrations between energy efficiencies of open three stone stoves and improved stoves should be made. Households should be encouraged to practice zero grazing system and use all type of dung including human wastes for biogas production. Long term loan should be facilitated for those who have enough sources of dung to feed biogas plant but can't afford its construction cost. Periodical maintenance and follow up ought to be carried out following biogas plant installations. Appropriate institutional arrangements should be made to avail biogas plant accessories. Proper training should be given to potential biogas users. Support for funds from non-governmental organizations or other sources should be sought

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Energy is one of the basic inputs that determine the status and pace of development. This is clearly manifested in the amount of per capita energy consumption and type of dominant energy being utilized among countries in the world. Per capita energy consumption sharply rises with the level of development. Besides, while the least developed countries dominantly consume traditional fuels, the most developed countries dominantly utilize modern fuels.

Being one of the least developed countries, Ethiopia has, therefore, one of the lowest per capita energy consumption and is dominated by traditional sources of energy. A more pressing problem, however, is not even the low level of per capita energy consumption and the dominancy of traditional sources of energy. Rather it is the inability to maintain the already low level of per capita energy consumption. For instance, according to Hailu (2002:18), the average per capita energy consumption fell from 333kg oil equivalent in 1984 to 280kg oil equivalent in 1999.

A high rate of population growth has brought about increased demand for resources and rapid rate at which the resources are exploited. But the pace of technological development in the country has not kept with the need for greater productivity. As a result, environmentally harmful and economically counter productive methods of exploiting the natural resources are resorted to meet immediate needs. Thus, rainfall conditions are becoming erratic, soil fertility is deteriorating rapidly and forest resources are declining at alarming rate (TGE, 1993:7).

Owing to the rampant depletion of the woody biomass and subsequent shortage of woodfuel, the increasing utilization of cow dung and crop residues as sources of energy aggravates the environmental problems. According to Getachew (2002:105), the ever increasing demand of woodfuel and the subsequent degradation of woody biomass is one of the top causes of environmental degradation in Ethiopia. Similarly, Miller, Mintzer and Hoagland (1986:14) and Asress (2002:89) argued that declining of biomass has serious negative economic, social and environmental consequences. Some of the major consequences include: declining of soil fertility and, hence, agricultural productivity, declining of biodiversity, climate change and desertification as well as more costs in time, labour, health and nutrition.

Ethiopia is endowed with abundant renewable energy resources such as hydropower and geothermal. But it has not been able to develop and utilize many of these resources for optimal economic growth (ENEC, 1987:9; EREDPC/MoRD, 2002:4; TGE, 1994:1). For instance, the country has a huge hydropower potential of about 30,000MW (EREDPC/MoRD, 2002:4) but it has developed only 2 to 4% of the total potential (Michael, 2004). Various assumptions and arguments are forwarded with regard to the underdevelopment of the energy sector in the country. Some of the major assumptions and arguments include: less attention given to improve the traditional energy production, supply and utilization; little or no attention provided to develop renewable energy; the non existence of strong energy organization; the low level of household income; and lack of capital, technical know-how and trained man power (Asress, 2002:91).

In spite of more than two decades attention given to energy sector in Ethiopia following the 1970s international oil crisis, specifically the rural people have continued to be deprived of modern sources of energy. Modern sources of energy are almost unavailable in the rural areas while traditional sources are being exhausted rapidly. As a result, energy problems are exacerbating in the rural areas (EREDPC/MoRD, 2002: 1). Obviously, the absence of modern energy in the rural areas deprive the people from the opportunities of getting various social services such as clean water supply, health services, educational facilities and the like for which modern energy sources are essential inputs (EREDPC/MoRD, 2002:7; FDRE, 2002:63).

Given modern development remains the goal of every society, the puzzling questions concerning the heavy reliance on traditional biomass fuels are how long such dependence can continue in the presence of rapid population growth and deforestation. And how the energy needs of the rural people might be met in a sustainable manner. Having these problems in mind, close assessments of biomass fuel sources, consumption patterns and potentials for developing renewable biomass energy of a given locality are compulsory to search on.

1.2 Statement of the Problem

Environmental problems of Ethiopia are among the most serious even by the African standards. The scale and intensity of environmental disasters have increased particularly over the last three decades due to the rapid depletion of life supporting resources. Increasing human and livestock populations, inappropriate land use practices and a stagnant productive technology coupled with the rugged nature of the country's topography and erratic and torrential rainfall have resulted in the present conditions of near ecological disasters through deforestation, over grazing and soil erosion (Nigussie, 1996:xii).

Depletion and degradation of woody biomass is one of the major environmental problems in Ethiopia (EFAP, 1994:6). Consequently, the major parts of the country have been suffering from woodfuel scarcity. According to EFAP (1992:1), about 75% of the country's regions are experiencing woodfuel scarcity and the figure is likely to rise up to 89% unless some intervention measures are taken. In the Amhara region, for instance, the demand of wood is higher than the sustainable supply in all of its ten administrative zones. More importantly, even in eight of its zones, demand is twice greater than that of the sustainable supply (AMRERDPD, 2005: 3).

Modern fuels are either unavailable or unaffordable sources of energy specifically for the people of rural Ethiopia. Hence, with increasing scarcity of fuelwood, households are forced to increasingly rely on lower quality combustible materials such as dung and crop residues. Even worse, in areas experiencing shortage of grazing lands, most of the crop residues must be devoted for animal feed (EEA, 1990:A-2). Thus, in many rural areas of north central and northern Ethiopia, cow dung accounts more than 35% of the total household energy consumption. Even in towns such as Bichena and Debre Markos its share is as high as 35.6% and 10.6 % of the total energy consumption respectively (ENEC/CESEN, 1986:108-109). These are all higher than the national average which is 9.2% (Sherief, 1987:7).

Crop residues and dung fuels produce inferior fire, less heat and more smoke. As a result, they pose health risk and make cooking task time consuming and less pleasant (Wright, 1993:20-21). Thus, scarcity of fuelwood has further been deteriorating the lives of the people. It causes worsening of the household welfare through increased use of the inferior fuels. higher fuelwood price and reduction in agricultural productivity.

Despite the increasing scarcity of traditional biomass fuels particularly fuelwood, the majority of both urban and rural households of Ethiopia utilize the fuels in energy inefficient stoves-open three stone stoves. Open three stone stoves have biomass energy end use efficiency of about 5-10% (Hailu, 2002:21).

Hence, the problem can be reversed if planners and government institutions give due attention to increased use of decentralized renewable energy sources and technologies and the improvement of energy end-use efficiency particularly at household level. The major policies and strategies of the country such as Energy Policy, Environmental Policy, Poverty Reduction Strategic Paper and Rural Energy Strategies have underscored the necessity of developing renewable energies in their objectives (EEA, 1994:2-3; EREDPC/MoRD, 2002:16; FDRE, 1997:11-12; FDRE, 2002:112). However, significant practical changes haven't been achieved yet. Therefore, Ethiopia has continued to suffer severe energy problems owing to a number of factors such as the rampant depletion of its wood resources, its inability to establish and manage woodfuel plantations as well as its incapability to avail alternative energy sources as quickly as required (EFAP, 1992:1).

In light of the evidences cited above, the study area too is experiencing acute fuelwood scarcity and related environmental problems. This can further be substantiated by the statement of Jackson (1972:15-16) which stated that the "Debre Markos-Dejen-Bichena-Mota region and the Dangla area" have got almost total deforestation. Based on personal observation and experience as well, people in the area are commonly observed competing for dung in the communal grazing lands. Though they failed, more likely understanding the energy problem of the area, model biogas plants had been installed. Moreover, in the site, no research work has been done related to the topic under discussion.

Therefore, a thorough understanding of a problem is the beginning towards intervention. Hence, this research was an attempt to investigate sources and consumption patterns of biomass fuels, reasons behind the failure of model biogas plants and the potentials for developing renewable biomass energy sources in the area.

1.3 Objectives of the Study

The main objective of the study is to assess sources and consumption patterns of biomass fuels as well as potentials for developing renewable biomass energy sources in the study area. More specifically, the study is intended to:

- assess the various sources of biomass energy in the study area;
- examine consumption patterns of biomass energy with reference to particularly household size and income levels in the study area;
- investigate the reasons behind the failure of model biogas plants installed in the area and the possibilities of making them functional again ; and
- assess the potentials for developing renewable biomass energy sources in the study area.

1.4 Research Questions

The study attempts to answer the research questions stated below:

- What are the sources of biomass energy in the study area?
- Do the patterns of biomass fuel consumption vary with income levels and size of households?
- Why do model biogas plants installed in the area fail to operate? Are there possibilities to make them functional again?
- What potentials are there for developing renewable biomass energy sources in the study area?

1.5 Scope and Significance of the Study

The study was limited to Koncher-Tik-Subshengo area, which covered three rural kebeles in Dejen woreda, Amhara region. However, the findings of the study may be useful and applicable for other similar areas particularly to the rest woina dega part of the woreda to which it belongs.

The study focused on rural households' biomass fuel sources, consumption patterns and potentials for developing renewable biomass energy sources. Assessment of the potentials for developing renewable biomass energy sources gave special attention to opportunities and constraints for promoting household level tree planting practices and biogas technology. To promote biogas technology in a given area, there are a lot of factors that can be considered.

However, in this paper, factors which though to be basic requirements, namely, availability of sufficient sources of dung and water, presence of positive attitude towards the technology and availability of sufficient sources of income to be able to finance its construction cost were merely considered.

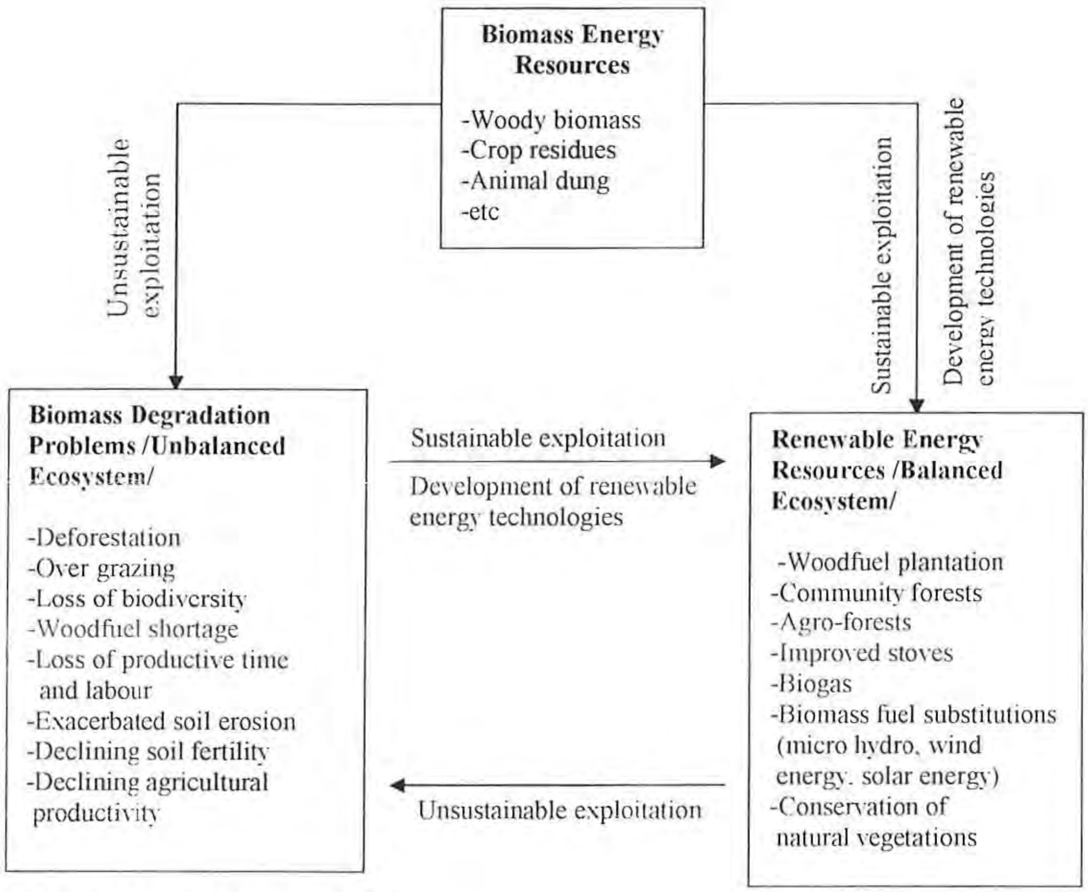
The study attempted to disclose the source and type of biomass fuels used, patterns of biomass fuel consumption, constraints and opportunities for developing renewable biomass energy sources, reasons behind the failure of model biogas plants installed in the area and possibilities of making them functional again. This information could serve as a feedback for policy makers. Because information of a more local situations of different parts of a country is of crucial importance in order to design appropriate policies and strategies that compromise spatial disparities.

Besides, successful interventions, not only in the energy sector but also in others, require a thorough understanding of the actual situations in the specific localities. Thus, this paper may help local planners, administrative bodies or funding agencies for their decision in taking appropriate remedial actions against energy and related environmental problems in the area. The study may also serve as a steeping stone for other research works in the area. Further more, it may fill the existing literature gap on the issue about the study area.

1.6 Research Methodology

1.6.1 Conceptual Framework

The visual representation of the conceptual framework that guided this study is depicted below in figure 1.1. It displays the relationships among biomass energy resources, systems of their exploitations and the resulting outputs.



Source: Adapted from Kimani, 1991:18

Figure 1.1 Diagrammatic Representation of the Conceptual Framework

For better comprehension of the relationships among components in the scheme, an 'input-process-output' type of analogy can easily be made. The **biomass energy resources** can be taken as 'inputs'. The **systems of resource exploitation**, whether it is sustainable or unsustainable one, can be considered as 'processes'. **Biomass degradation problems** and establishment of **renewable energy resources** resulting respectively from unsustainable and sustainable resource exploitations can be considered as 'outputs'. These two **outputs** have reciprocal relationships provided that the **processes,** systems of exploitations, are reversed.

Therefore, if biomass resources are being exploited unsustainably, various interrelated problems such as loss of biodiversity, woodfuel scarcity, loss of productive time and labour, exacerbated soil erosion, declining soil fertility, declining agricultural productivity, etc may arise. To the contrary, if biomass resources are exploited sustainably, in other words, if the rate of exploitation doesn't exceed the regeneration and carrying capacities of the resources, renewable energy resources can be maintained. For this success, meaning for the establishment of renewable energy resources, renewable energy technologies should be integrated with the systems of resource exploitation.

As can be seen in the figure, what is interesting with regard to degraded biomass energy resources is that these degraded resources can be rehabilitated, recovered and be transformed into renewable energy resources through improving the systems of resource exploitation and development of renewable energy technologies. In deed, in contrast to this, a reverse process may also happen. Meaning, there may be a transformation from a situation of more balanced ecosystem into unbalanced ecosystem.

In the study area, being part of the Ethiopian highlands where human settlement have been occurring over centuries, deforestation and its subsequent negative impacts have undoubtedly undergone over many years. But what one can argue, as understood from the scheme, is that the problem can be reversed through a variety of techniques like conservation of the remnant resources, intensification of reforestation and afforestation programs and development of renewable energy sources.

1.6.2 Types and Sources of Data

The data inputs for the study were gathered from both secondary and primary sources. Secondary data were explored from different published and unpublished materials like books, reports and research works. They were particularly helpful for description of the study area, comparisons and as conversion factors.

Primary data were generated through a variety of techniques including structured interview, key informant interview, personal observation, photographing and focus group discussion.

1.6.2.1 Structured Interview

Structured interview was used to generate both qualitative and quantitative data pertaining to the demographic characteristics, income[1] of the households, type and number of livestock, landholding size, sources of biomass energy, amount of biomass fuel consumption, perception of people about fuelwood scarcity, suggestions given in solving fuelwood problems, time spent to gather fuelwood, distances of water sources and their reliability, attitude of respondents towards improved stoves and biogas technology.

Thinking that it may be difficult and even strange for the respondents to estimate the amount of biomass energy consumption in terms of weight, they were requested to mention it in terms of bundles and baskets of fuels consumed per week. Obviously, the weight of a bundle of fuelwood varies with the age of the wood, type of tree species and the physical strength of the person carrying it. A bundle of crop residues also differs with the type of crops and the physical strength of the person carrying it. Similarly, the weight of a basket of dung differs with the size of the basket and the type of livestock which produce it as well as the way the dung is stacked in it. Therefore, attempts were made to find out the average weight of a bundle of fuelwood and crop residues as well as a basket of dung. Hence, the average weights of a bundle of air dried fuelwood, a bundle of crop residues and a basket of dung fuel were 26kg, 20.5kg and 17kg respectively. Both men and women were involved in estimating the average weekly amount of consumption by fuel type. Charcoal was not used as household energy in the area. Regarding the number of trees and/or shrubs planted by each household, the interviewees were requested to count or to have counted their trees and/or shrubs and provided the information for the day arranged. The aforesaid techniques of acquiring data about the households' weekly amount of biomass fuel consumption and number of planted trees and/or shrubs were not innovative. They were employed at least in a similar research conducted by Woldeamlak (2003:110).

[1] The market price of each grain type was surveyed for four market days at Dejen town during the last quarter of January and the first quarter of February, 2007. Thus, the average market price of each grain type which was taken into account while considering income levels of the surveyed households was as shown in Appendix I.

Commonly getting accurate information about very sensitive issues like income of the households is challenging. Having this problem in mind, looking for appropriate technique for eliciting accurate information is definitely mandatory. To this end, it was absolutely essential to get the trust of the interviewees on the objectives of the study. In other words, persuading them as the study had no other hidden objectives at its back was fundamental. Therefore, in addition to what one was normally expected to say at the beginning of interviewing, it was found essential for having as much as possible a person, a friend or a relative, from the locality to accompany and introduce the interviewer. This is because, firstly, people normally trust and are more transparent to whom they know than a stranger. Secondly, the respondents feel ashamed to tell something far from the reality before the person familiar to them. In the case of the two enumerators who were involved in interviewing, as they were development agents, interviewees might feel as well that development agents knew who was who. Hence, a feeling of "am not known" would not work. Though development agents were not as green as grass for data collection, they were given the necessary training.

1.6.2.2 Key Informant Interview

Key informant interviewees included: six local elders (two from each sample village), former biogas technology beneficiary, four former leaders of producers' cooperatives (two from Inewonta and two from Subshengo villages), three development agents (one from each sample village), woreda forestry and agro-forestry expert, woreda rural energy resource development expert, zonal administrative level rural energy resource development expert, regional level biomass energy expert, biogas technology expert from FBRTPC and Biomass Technology Study and Development Team Leader at EREDPC.

The identification of farmers who know the area best is a very critical point to know a community and physical characteristics in detail. Usually elderly people have a deep rooted experience and knowledge about the community and their environment. Hence, interview with elderly people served to collect information such as change of biomass fuel sources, change in livestock population and size of grazing lands, change of vegetation cover and tree planting practices of the people in the area. Interview with former biogas beneficiary and leaders of former producers' cooperatives helped to acquire information about model biogas plants of the area. The involvement of development agents, woreda forestry and agro-forestry expert and woreda rural energy resource development expert was of crucial importance to acquire information concerning to the extent of fuelwood scarcity, measures being taken against fuelwood scarcity and the like. However, with reference to biogas technology in the area, development agents and woreda rural energy resource development expert provided no input data because they didn't have any information and follow up about the plants.

Informants at zonal or above administrative levels helped to generate information about why the area was selected for installation of model biogas plants, original intentions of the installation, responsible body for maintenance of biogas plants in the case of failure, estimation of the construction cost of polyethylene biogas plant (a type of plastic biogas plant).

1.6.2.3 Personal Observation

Personal observation was important to know the area well and generate ideas helpful to prepare leading questions for both key informant interview and focus group discussions. It also helped to acquire information about the physical setting of the area, conditions of natural vegetations and planted trees, the type and quality of biomass fuels gathered, current conditions of the model biogas plants and the like, some of which were supported by photographs.

1.6.2.4 Focus Group Discussion

Focus group discussion served to triangulate data gathered through other techniques. Moreover, as the discussants argued and negotiated on issues raised, it allowed new and valuable thoughts to emerge. For discussion, leading questions were raised for heterogeneous groups, heterogeneous in age and sex. There were three groups, one in each village, having 6-8 discussants in a group.

1.6.3 Sampling Techniques and Procedures

The study area covers three rural kebeles. Each kebele comprises of two villages. From each kebele, a village was selected purposefully to include sites where model biogas plants had been installed. The selected villages were Koncher, Inewonta (Yetnora) and Subshengo. Next, for each sample village, lists of household heads were obtained from the respective administrations. Then, using proportionate random sampling technique, 90 (3.9%) sample households were selected from a total of 2302 households in the three villages.

Obviously, sample size for a given study is determined by a number of factors such as time, cost, homogeneity of the population, nature of the problem, etc. Accordingly, the aforementioned size of the sample was determined, among others, by taking into account the following facts. Firstly, it took into consideration the sum total time expected to be taken by the actual primary data collection process using the different instruments employed. Specifically, it took into account:

- the length of interview questionnaire;
- the length of checklists prepared for different key informants, number of key informants involved; and
- the length of checklists prepared for focus group discussion and number of groups intended to be made.

Secondly, it took into consideration the time estimated to be wasted to reach each potential sample household and interviewee at different levels of administration. For instance, in the case of the household survey, it was absolutely essential to look for the most appropriate times when the respondents were at rest or at least less busy. Otherwise, information given in a hurry might involve error. The most appropriate times were, therefore, early evening at working days, early morning and late afternoon at holidays. Moreover, the interview schedule as much as possible required the presence of both woman and man, if exist at all, to be involved in estimating weekly amount of biomass fuel consumption. Hence, the indicated times were suitable. Thirdly, the sample size determination took into account the homogeneity of the population in the study site. The study area lies in a single agro-ecological zone, 'woina dega' and has more or less uniform topography. Hence, the area is homogenous in terms of at least cultural practices, types of crops and vegetations grown and in turn in terms of biomass fuel sources. Moreover, the majority of the households in the site dwell in formally villagized places, which could have some resemblance with urban areas. Sample size of about 3% of the total population is supposed be sufficient for urban areas (Clark and Hosking, 1986:153). As a result of all the aforementioned facts, the sample size taken was supposed to be reasonably sufficient representative of the total population.

1.6.4 Methods of Data Analysis

The study involved both quantitative and qualitative data analysis techniques. The quantitative data were analyzed using various statistical techniques such as means, ranges, percentages, cumulative percentages, frequencies, rank frequencies, Pearson's product moment correlation and tables. To ease the computations of quantitative data, the statistical package for social science (SPSS) was employed. The qualitative data analysis involved description, logical presentation and narration.

1.7 Limitations of the Study

1. Owing to government and structural changes, there was no any recorded data pertaining to the model biogas plants at all levels of administration.
2. Yield for 1997/98 E.C. production year was taken to analyze yearly income and expenditure of the sample households. This was because firstly, yield for the 1998/99 E.C. production year was not collected wholly during the time of data gathering. Secondly, even had the yield been collected during data gathering, it would have been technically impossible to ask the respondents about the expenditure of the year.
3. Crop residues are not used all year round. Rather they are used since when crops, which their residues serve as fuel, are harvested to about one to nine months long depending on the size of the fuel sources each household has. Hence, it is very difficult to conclude about the consumption amount of each biomass fuel on yearly bases. Because at times when crop residues collected for fuel are used up completely, the proportions of dung and fuelwood are expected to rise up as they will be the mere sources of biomass energy.

1.8 Organization of the Paper

This paper comprises of six chapters. The first chapter, introduction, includes background of the problem, statement of the problem, objectives of the study, research questions, significant and scope of the study, research methodology and limitations of the study as well this specific part. The second chapter consists of literature review. The third chapter encompasses background of the study area. The fourth and fifth chapters present analyses and discussions. The last chapter is devoted to summary, conclusions and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Sources of Energy in Ethiopia

The current energy sources of Ethiopia can be categorized into two: modern and traditional. Modern sources of energy encompass electricity and petroleum while traditional sources of energy include fuelwood, charcoal, dung and crop residues. According to Lemma (1995:4), modern sources of energy account about 5% of the total energy demand of the country. In the household sector, its contribution is even much less than what is indicated for the entire sectors. For instance, as per Asress (2002:86), in 1999, modern sources of energy accounted merely 1.1% of the total household energy consumption.

Ethiopia is well endowed with variety of energy resource potentials such as hydropower, geothermal, coal and natural gas. However, much of the energy resources available are either untouched or not harnessed to economically optimal level (ENEC, 1987:9; EREDPC/MoRD, 2002:4; TGE, 1994:1). As a result, most of its modern energy demand is met through importing petroleum products from abroad (EEA, 1990:B-2). Hydro electricity is virtually the only indigenous modern source of energy which has been developed so far. Even this source of energy has not been harnessed to the economically optimal level yet.

The underdevelopment of hydro electricity is evidenced by the relatively small proportion of the energy developed vis-à-vis the country's huge potential and the proportion of population who has access to the resource. The hydropower generation potential of Ethiopia is estimated in the range of 15,000 to 30,000MW. But what has been developed so far is merely 663MW which is 2 to 4% of the total potential (FDRE, 2005:41). Of the total population of Ethiopia, merely 13% has access to electricity (FDRE, 2002:63). The use of electricity is concentrated almost wholly in urban areas. While 75.3% of the urban population has access to electricity, only 0.4% and 0.8% of the rural population respectively have private and shared electricity connections basically for lighting purpose (FDRE, 2005:28).

Traditional fuels are, therefore, the primary sources from which the country meets about 95% of its energy demand (Asress, 2002:82; Lemma, 1995:4). Biomass fuels can be utilized either in modern or traditional forms. However, in Ethiopia, they are almost wholly utilized in traditional form (Asress, 2002:91; TGE, 1994:1).

Among the various biomass fuels, wood has been and is still the most important and preferred source of energy (Asfaw, 1996:4; Gebremarkos, 2002:125; Helen, 1990: 86). The sources from which households obtain fuelwood include own farmlands, communal bush lands, communal forests and state forests (WBISPP, 2002:60).

According to Million (2001), trees outside the forest which include roadside scattered trees, trees planted in and around fields, trees around homestead and windbreaks around agricultural fields are the major sources of fuelwood. Similarly, WBISPP (2002:98) stated that trees in agricultural areas constitute the major source of wood for fuel and construction. In the agricultural areas, they are found as indigenous trees remaining in the individually owned fields, trees in the community areas and trees planted by farmers. For example, in Chemoga Watershed, about 65% of the households of the area meet more than 50% of their fuelwood demand from own planted trees (Woldeamlak, 2003:116-117).

However, in many parts of the country, fuelwood is desperately in short supply. As per EFAP (1992:1), nearly three-fourth of the areas in the country experience fuelwood scarcity. In the Amhara region, for instance, the demand of wood is higher than the sustainable supply in all of its ten administrative zones. More importantly, even in eight of its zones, demand is twice greater than that of the sustainable supply (AMRERDPD, 2005: 3).

With increasing scarcity of fuelwood, households are forced to increasingly rely on lower quality combustible materials such as dung and crop residues. Barnard and Kristofferson, (1985:12) described the options that the majority could face when woodfuel is difficult to obtain as follows. "For many, 'the woodfuel crisis' is essentially over. What they have entered is a new phase in the evolution of fuel scarcity where the struggle is not to find wood, but to obtain enough dung, straw and crop stalks to cook their food and heat their homes." Even worse, in areas experiencing shortages of grazing lands, most of the crop residues has to be devoted for animal feed (EEA, 1990:A-2). Likewise, ENEC/CESEN (1986:108) stated that in parts of Ethiopia where land is exhaustively cultivated for variety of crops, wood lands are hardly available. In these areas crop residues are basic food for livestock. Women spend much of their time gathering cow dung from the fields and stacking it for current use or rainy seasons. Thus, dung is increasingly used for fuel as the availability of woodfuel is getting more and more questionable.

The usual type of dung used by households in Ethiopia is cattle dung. The use of dung from smaller livestock like goats, sheep and pigs is not widely practiced. Dung from pack animals like donkeys, horses and mules is fragile which makes it difficult to be collected as well as formed into cakes (EEA, 1990:A-2).

2.2 Energy Consumption Patterns in Ethiopia

The household sector is the major consumer of energy in Ethiopia. While the household sector makes up 89.2% of the total national energy consumption, the remaining 10.8% is shared among agriculture, transport, industry and service sectors (EREDPC/MoRD, 2002:5).

Biomass constitutes the lion's share of the total energy consumption in the country. It accounts about 94% of the total national energy consumption (Gebremarkos, 2002:125; Konemund, 2002:137; TGE, 1994:1). More than in any other sector, biomass fuel is important in the household sector. It makes up 98.6% of the total energy consumption. Specifically, fuelwood, dung, crop residues and charcoal account 81.4%, 8.1%, 7.8% and 1.3% respectively whereas electricity and petroleum together contribute 1.4% of the total household energy consumption (EREDPC/MoRD, 2002:5). The contribution of biomass fuels is still greater in the rural households as compared to the urban counterpart. According to EREDPC/MoRD (2003:1), biomass fuels constitute 99.9% of the total energy consumption of the rural households.

At local levels, the relative proportions of fuelwood, dung and crop residues in the total biomass fuel consumption of the households highly deviate from the national average. For instance, in Bure-Wonbera woreda, crop residues, fuelwood and dung accounted 44%, 40% and 16% of the total biomass fuel consumption respectively (Amare, 1997:3). In Chemoga Watershed, dung fuel and fuelwood accounted 34% and 66% of the total biomass fuel consumption of the households respectively (Woldeamlak, 2003:107).

The pattern of energy consumption 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, type of stoves used, the kind of food usually cooked, the food taste of the family, the availability of fuelwood, etc (EFAP, 1993:10). As per ENEC/CESEN (1986:6), the level and pattern of energy consumption are strongly determined by the local availability of natural resources. In other words, demand for different fuels is in part a function of supply.

The type of stoves used is one of the various factors affecting amount of energy consumption. In traditional three stone stoves, the end-use efficiency of biomass fuels is as low as 5 to10%. Hence, 90-95% of the biomass energy content is wasted (Hailu, 1983:74; Hailu, 2002:19; Konemund, 2002:141). However, with the use of improved stoves, the end use efficiency of biomass fuels can be doubled or even tripled. For instance, according to AMRERDPD (2004:55), the end use efficiency of biomass fuels in 'mirt' and mud made closed 'injera' stoves range from 18 to 23% and 11 to13% respectively. As 'injera' baking alone accounts about 50% of the total household energy consumption in Ethiopia (AMRERDPD, 2004:54; Konemund, 2002:142), the shift from open fire stove to 'mirt' stove can save more than half of the biomass fuels devoted to 'injera' baking. In addition to saving significant amount of biomass fuels, the use of improved stoves reduces smoke emissions and fire hazard, keeps the kitchen clean and saves time. Moreover, improved biomass stoves are affordable to many people (AMRERDPD, 2004:54-55; Konemund, 2002:142).

Despite its endowments with vast energy resources, Ethiopia has one of the lowest levels of per capita energy consumption in the world. The annual per capita energy of Ethiopia in the year 1999 was 279 kilograms of oil equivalent (Asress, 2002:88). Expressed in a different way, according to EREDPC/MoRD (2002: 4), annual per capita energy consumption is merely 0.8 tons of biomass, 20 kilo watt hours of electricity and 20 liters of petroleum fuels. Yet in a different style, EEA (1990: B-2) estimated that the daily per capita energy consumption for the household sector was 2.1kg of fuelwood equivalent. The source also indicated that the daily per capita energy consumptions of the urban and rural households were roughly 1.4kg and 2.2kg fuelwood equivalents respectively.

2.3 Traditional Biofuels and Environment in Ethiopia

People, one way or another, are dependent on the earth's natural resources for their survival. To acquire basic resources such as food, water, shelter, energy, etc, people always interfere with the physical environment. Indeed, the degree of interference of human beings with the physical environment varies greatly depending on a number of factors. As per Miller (1996:12), the environmental impact of people depends on three factors: the number of people living in a given area, the average number of units of resources each person uses, amount of environmental degradation and pollution produced per each unit of resource used (technological qualities applied to extract, process and consume resources).

Ethiopia is one of the least developed countries characterized by rapid population growth and low level of technological development. Based on the argument indicated, the average number of units of resources each person uses may be low in Ethiopia. But population pressure coupled with inefficient exploitation of the natural resources with rudimentary technologies definitely deteriorates its natural resource base. According to Nigussie (1996:xii), the population of Ethiopia has grown without resource development through technological development. As a result, the growth of the Ethiopian economy has long remained environmentally constrained. And, thus, the country is striving to achieve sustainable development in the face of many problems such as degradation of land, water and forest resources, poor infrastructure and low technology. Similarly, Girma (1996:26-27) stated that over population and increased demand for agricultural land and energy without parallel improvement in the economic performance by and large lead to problems of deforestation, soil erosion, desertification and loss of biodiversity.

Deforestation is, therefore, one of the major environmental problems facing Ethiopia. Pertaining to the causes of deforestation, there seems a controversy whether or not woodfuel production is among major causes for deforestation. FDRE (1997:1) indicated that deforestation has accelerated in Ethiopia mainly due to expansion of rain fed agriculture. In support of this, Barnard (1987:359) stated that in many countries, the main cause of deforestation is not woodfuel collection but expansion of farmland. Similarly, Smith (1981:6) also stated that though some environmental costs have resulted from fuelwood gathering, clearing land for crops and lumber trade are the major culprits for deforestation.

But Lemma (1995:6) argued that though not the only reason, woodfuel production is a major element causing deforestation and environmental problems in Ethiopia. Since the whole society heavily relies on woody biomass as a source of energy. Similarly, Grainger (1990:95) stated that fuelwood previously gathered mainly from dead wood. But now large scale fuelwood cutting has become a norm. Hence, the main causes of deforestation and degradation are agricultural clearance, fuelwood cutting, livestock browsing and burning due to bush fire.

However, what should be noted here is that as long as most wood produced in the country goes to the stoves; fuelwood gathering would not be free from the blame to be considered as among major causes for deforestation. This is because, according to EFAP (1992:19), the primary consumer of wood in Ethiopia is energy. While woodfuel accounts 90.95% of the total wood produced in the country, construction, poles and others constitute 4.2%, 4.2% and 0.63% respectively. Besides, it should also be remembered that while wood is cut for industrial or construction purpose, always some part of it goes to the stoves. For instance, during construction of houses, as some unwanted part of construction wood left for fuel, that time, with no doubt, the respective household members wouldn't go to the forest or any other wood sources available to fetch wood for fuel.

According to Fisseha B. (1996:95), deforestation has far reaching direct consequences. Some of the major consequences include acute shortage of wood for construction and fuel; drying up of permanent rivers, streams and water wells; change in the micro climate; shrinking of biodiversity and removal of top soil contributing to loss of soil fertility and productivity. Grainger (1990:103-104) also contended that deforestation is the first step leading to desertification. When trees are removed, the soil will be exposed to different agents of erosion and is as well baked by the sun. Hence, the whole area becomes more arid and villages and towns will be bare to frequent dust storms.

Deforestation and the subsequent scarcity of fuelwood cause also multiple environmental problems. Due to acute shortage of fuelwood, people are forced to increasingly use dung and crop residues as alternative sources of energy that could have been utilized directly as organic enrichment for the soil and/or as feed to livestock. Clearly, this leads to a decline in agricultural productivity (EFAP, 1992:25; Teka, 1995:1). Instead of using them as soil fertilizers and conditioners, due to the burning of dung and crop residues it is estimated that the country is losing 1 to 1.5 million tones of food grains annually (EFAP, 1992:25). The World Bank also estimated that one ton of dung would increase grain yield by 50-60kg if it was applied to the field instead of being burnt as fuel (Bernard and Kristofferson, 1985:18-19).

Moreover, the scarcity of fuelwood has another harmful effect. It poses additional burdens on the rural poor. People who are responsible for collecting fuelwood, commonly women and children, must spend more time and must often walk long distances in search of fuelwood. For instance, in northern, eastern and central Ethiopia where there is severe shortage of fuelwood, the average hours required to collect one donkey load is about 4 hours. Wood collectors are also required to travel a distance of about 5 to 12 kilometers (EFAP, 1993:19). Furthermore, crop residues and dung produce inferior fire, less heat and more smoke. There by pose health risk and make cooking task time consuming and less pleasant. The scarcity of fuelwood as well may force people to have fewer hot meals and adopt meals often less nutritious but can be cooked more quickly (Wright, 1993:20-21).

2.4 Towards Developing Renewable Biomass Energy Sources in Ethiopia

Renewable energy sources which include solar, geothermal, wind, tidal, and biomass are often also called alternative energy sources or clean and green. Nevertheless, these terms may be used differently. The term 'alternative' normally denotes "not fossil fuels and not nuclear". While "clean and green" are terms generally connote environmental benefit and 'are rarely, if ever, defined'. Hence, they have no any agreed meaning. The term "renewable" is generally used in state and federal legislations and programs. As it includes land fill gas, it doesn't usually mean 'clean and green'. It is not necessarily cleaner than non renewable (Ewall, 2000). However 'all renewable energy sources are given the benefit of the doubt to be cleans, environmentally friendly, socially fair and pro-poor' (Kaupp, n.d:1).

Biomass is one of the renewable energy sources. Biomass, be it in its traditional or modern form, can play important roles for sustainable energy supply, socio-economic development and cleaner environment (UNESC, 1996). For instance, the use of biomass fuels in traditional form is sustainable provided that biomass resources are plentiful and the rate of fuelwood utilization in a given area does not exceed the regeneration capacity of the forest. In situations when traditional biomass fuels are exploited sustainably, they give not only cheap energy to the individual consumers but also have positive impact on the national economy. They can serve as a source of income and employment opportunities for those who involved in fuel collection and selling as well as save hard currency that would otherwise be spent on importing alternative energy supplies (Konemund, 2002:137).

However, the use of biomass fuels is abused in Ethiopia. They are commonly utilized beyond their regenerating capacities.

To solve the problem of biomass fuels, there are three general technical solutions that policies and programs have addressed with varying degrees of efforts and successes. These are supply side intervention-increase the supply of biomass fuels, demand side intervention-reduce the demand of users by improving the end-use and encouraging fuel substitution away from biomass fuels (Meyers and Leach, 1989). In this regard, in Ethiopia, various attempts have been made so far at different levels from individual to community and local to national levels towards the development and use of renewable energy sources and technologies. Among the various attempts, promotion of tree planting practices and biogas technology is a case in point.

2.4.1 Tree Planting Practices in Ethiopia

Farmers do plant trees and have done so far a long period of time in Ethiopia. They have not only the experience of tree planting but also a deep knowledge of how to plant, propagate, and manage trees (Lucia and EEA, 1990:A-30-31). As a result of consolidated private planting of trees, vegetation cover may increase in some specific localities. For instance, according to Woldeamlak (2002) as cited in Woldeamlak (2003:108), forest cover has increased slightly in Chemoga Watershed over the last 40 years owing to tree planting practices of the households. In this area, households are found having an average of 307 planted trees, in fact, with a range of nil to more than 2500 trees per household.

Farmers often plant trees not for a single purpose but for multiple purposes. In this regard Arnold (1991) argued that at the time when people feel scarcity of fuelwood, they may not deem planting of trees is a rational response to alleviate the problem. Switching to cow dung and crop residues nearly always provides lower cost options for maintaining fuel supplies than tree planting. Planting of trees, to be justified, has to provide a grater return than household fuel can do. Where fuelwood is scarce, wood for construction or other purposes is likely to be even scarcer and motivates people to plant trees.

Many rural people do not consider fuelwood production as separate from growing wood for other uses. Hence, the most successful projects combine plantings for food, fodder, fuel and sale (Field, 1993). Thus, the problem of rural fuelwood needs to be tackled within the wider perspective of the diverse roles of trees (Arnold, 1991; Eckholm et al., 1984:47). However, there are a number of barriers for farmers to practice planting of trees. Some of the barriers are land tenure insecurity, shortage of land, lack of incentives and seasonal competition for labour (Amare, 1997:4; Eckholm et al., 1984:55-59).

Forestry policy, among others, is one of the major factors affecting tree planting practices. Large scale reforestation and afforestation programs have been practiced in Ethiopia since as early as the last quarter of the 19th century. As said by Field (1993), the need for making Addis Ababa the permanent seat of the government demanded the creation of eucalyptus fuelwood plantations around the capital during the reign of Menelik II. During this time, as Gebremarkos (2002:126) stated, various forest development initiatives were undertaken. Some of the major initiatives were importation of seeds of eucalyptus and few other tree species into the country, the appointment of foreign forestry expert, the award of financial incentives and land grant for those who would like to participate in eucalyptus tree plantation. Hence, the establishment of the first large scale peri-urban eucalyptus fuelwood plantations around Addis Ababa which later introduced into other urban centers like Harar, Debre Markos, Dessie, Assela, Nekemte were successful.

In rural Ethiopia, however, as stated by Jagger and Pender (2000:4), until the 1974 revolution, there was only limited planting of eucalyptus in the homesteads. Thus, the sources for most forest products were limited into natural forest exploitation. During the Derg regime, rural afforestation and reforestation were introduced into national forestry policy. Nevertheless, as Bruce, Hoben and Rahmato (1994) cited in Jagger and Pender (2000:5-6) stated, the Derg's forestry policy strongly favoured state and community forestry and highly discouraged private level tree planting. After the end of the Derg regime, one of the major shifts made in the Ethiopian forestry policy has been encouragement of private tree planting. This is substantiated by Proclamation No. 94/1994 which states "---the Ministry or each region shall facilitate conditions and provide technical assistance towards the development of private forestry". FDRE (1997:8) also consolidate the idea by stating that the environmental policy recognizes the complementary roles of communities, private entrepreneurs and the state in forestry development.

However, despite the various attempts made, the total area covered with tree plantations, which established through both 'causal' and planned tree planting activities, over the last hundred years have not reached more than 200,000 hectares (EFAP, 1994:25). This puts the average rate of planting trees at 2,000 hectares per annum. Hence, the rate of tree planting is incomparably far below the annual rate of deforestation which is estimated to range from 163,000 to 200,000 hectares (Melaku, 2003:8).

Irrespective of the controversial issue of planting eucalyptus from ecological and economic point of view, the most popular and widely planted tree species in Ethiopia is eucalyptus (FAO, 1988:20-21; Jagger and Pender, 2000:1). In some parts of the country, eucalyptus may be the only species planted by the majority of households. For instance, in Chemoga Watershed, of the total surveyed households who possessed planted trees, 80% of them had only eucalyptus species (Woldeamlak (2003:117). Though eucalyptus is blessed for its fast growing and other characters, several charges are attached to it such as deplete soil nutrients, lower the water table and produce inhospitable chemicals for other crops (Eckholm et al., 1984:66).

2.4.2 Towards Promoting Biogas Technology in Ethiopia

Biogas technology is one of the renewable energy sources that help to improve rural lives. While methane in biogas burns more cleanly than coal (Wikipedia, 2006), the slurry effluent from a biogas plant provides quality fertilizer. The slurry contains more valuable form of nitrogen than fresh manure. Crop yield can be increased by 5-15% if fields are fertilized with slurry effluent rather than fresh manure (SEPK, 1987:23). Cooking with biogas is more pleasant, non smoky, no soot on utensils, save time and cleaner than traditional energy sources. Biogas lamps provide better illumination than traditional lamps. Moreover, using biogas lamps unlike traditional lamps causes no eye irritation (Fisseha T., 1996:6). "The utilization of biogas is just a cleaver way of exploiting nature without destroying it because the ecological cycle is kept in order" (Getnet, Asmamaw and Fentahun, 2004:14).

Biogas burns more efficiently as compared to fuelwood and dung. While biogas burns at an efficiency of about 60%, fuelwood burns at 5-8% efficiency in open fire place and dung burns at 60% of that of fuelwood (FAO, 1997; UNESCO, 1982 cited in Senait, 1988:2). One meter cube of biogas can give light for about 6 hours with a power of 60-100 watt bulb; can cook three meals for a family size of 5-6; can replace 3.47kg of fuelwood, 0.61 litres of diesel oil, 0.62 litres of kerosene oil or 13.0kg of dung fuel (Guidotti, 2002 cited in Getnet, Asmamaw and Fentahun, 2004:18).

Basically, there are two major categories of biogas plants: batch type and continuous flow plants. In batch type plants, gas is not continuously available unless a big gasholder is incorporated. They are particularly established in coffee farms and are, thus, periodical. Continuous flow plants are useful where organic materials are available daily. There are many different models of continuous flow type. Nevertheless, three simple models of continuous flow type can be distinguished. These are balloon plants, also called plastic plants, fixed dome plants and floating drum plants; each of which has its own advantages and limitations over the others (Gitonga, 1997:11-12; Sasse, 1988:13).

Biogas technology was introduced in Ethiopia in 1962. The first plant was constructed at Ambo College of Agriculture (Ephram, 1978:3). The kind of biogas model installed at Ambo College of Agriculture was batch type. To date the total number of digesters constructed in the country is about 450-500. The size of the digesters installed range from 2.5-200m^3. Digester types installed yet in the country include all the models indicated earlier. In fact, about 50% of the digesters constructed in the country are floating drum plants (EREDPC, 2006:2).

In Ethiopia, there are compelling reasons to promote biogas technology. First, the country has large livestock population particularly cattle. Second, dung is increasingly used as household fuel. Third, the soil structure and fertility has negatively been affected as it is deprived of its natural fertilizer-dung (Lucia and EEA, 1990:A-35). As there are about 35.4 million cattle in Ethiopia, 10.6-14.2 million m^3 of biogas could be utilized for household cooking and lighting. Besides, about 78,000m^3 of slurry can be available at best after generating useful biogas energy (EREDPC, 2006:1). Despite this opportunity, however, there are a number of barriers that hinder the expansion of the technology in the country, among which construction cost deserves mentioning.

In fact, the expense varies greatly with the type of model required, capacity of the plant, availability of local materials and the like. For instance, among the continuous flow type biogas models, floating drum digester is the most expensive while balloon digester is the cheapest one (EREDPC, 2006:1; Gitonga, 1997:11-12; Sasse, 1988:13).

Once biogas plants are installed, they may fail to function for a number of factors. Some of the most important ones are technical problems, availability of water supply, decline of number of cows owned, change in mode of stock keeping, mismanagement, clumsy operation and absence of demand and interest. For example, due to one or more of these factors, of the 73 plants surveyed by EEA, only 17% of them were found operating adequately (Lucia and EEA, 1990:A-35). Similarly, out of the total 22 biogas plants installed in the western part of Amhara region-Gojjam and Gonder, 86.4% are not functioning for different reasons such as lack of continuous monitoring and maintenance, shifting of the families to other places, reduction of cattle, imprisonment and death (Getnet, Asmamaw and Fentahun, 2004:9).

Success or failure of a model biogas plant installed in a given area can positively or negatively affect its further promotion in that area. According to Gitonga (1997:26) where the first installed plants performed well, words of mouth from satisfied users encourage other potential users to install their own plants. Where plants failed, failure creates a negative impact on the dissemination of the technology, discouraging potential users in the process. Thus, social influence created by successfully operated biogas plants is a necessary condition for wider dissemination and acceptability of the technology.

CHAPTER THREE

BACKGROUND OF THE STUDY AREA

3.1 Physical Background

3.1.1 Location and Size

The study site, Koncher-Tik-Subshengo area, is found in Dejen woreda, East Gojjam zone, Amhara region. It is located approximately 230 kilometers north away from the capital-Addis Ababa. It occupies more or less the west central part of the woreda (Figure 3.1). The site has a total area of about 7885 hectares (DWARDO).

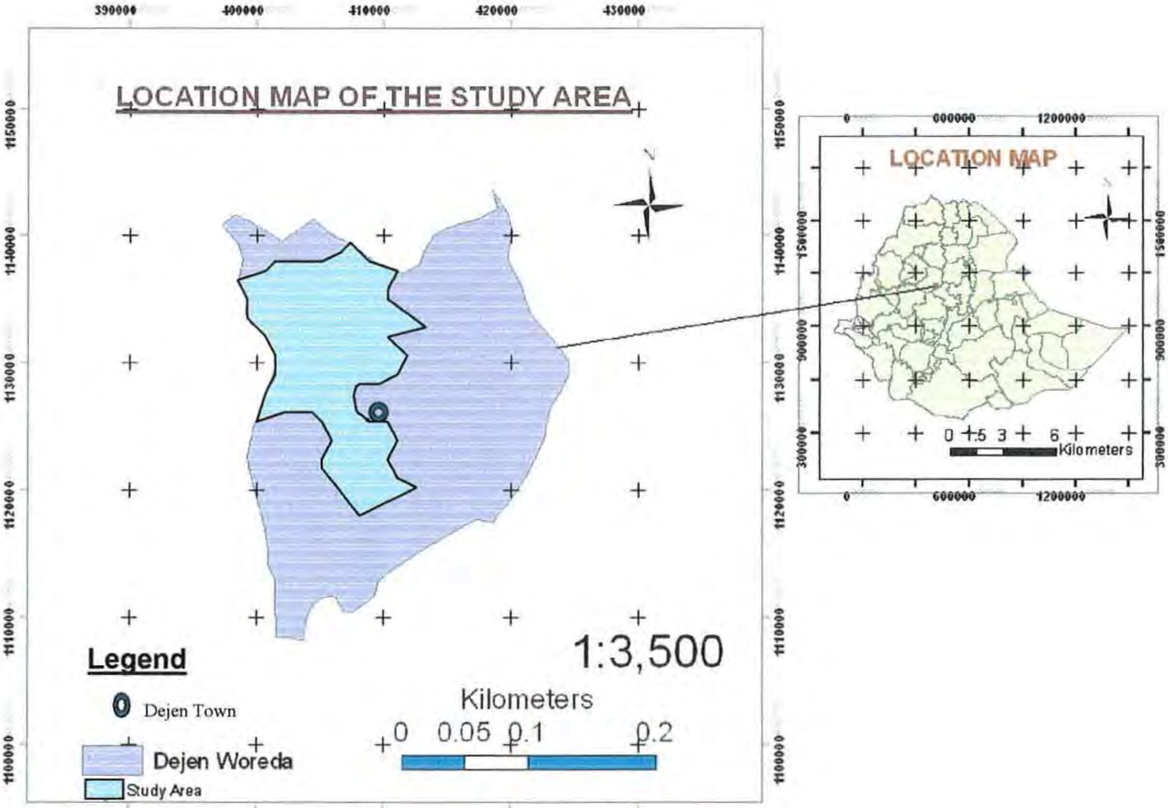


Figure 3.1 Location map of the study area

3.1.2 Topography and Drainage Systems

The study site has altitude which ranges from 2,250 to 2,510 meters above sea level. Needless to say, the site is part of the North Central Massifs of Ethiopia. Roughly, 82% of the area is flat whereas the remaining part is characterized by rugged terrain. The slightly elevated central part of the study area serves as a watershed and makes the existing streams and surface runoff of the area flowing either into eastern, western or southern directions. Hence, the site generally lies within three drainage basins, namely, Adewadeb, Muga and Bechet. Adewadeb basin occupies the southern part while Muga and Bechet occupy the eastern and western parts of the site respectively. All of these are certainly contained in the Abay (Blue Nile) drainage system.

3.1.3 Climate

Though there is first class national meteorological station established in the study site at Enewonta (Yetnora) village, the station has started functioning since a year ago. Moreover, there are no other meteorological stations with complete records of meteorological information in Dejen woreda. Consequently, it is not dependable to show the trends of major climatic elements of the site using only a one year records of meteorological data. Nevertheless, the temperature and rainfall distributions for the year 2006 were as shown in figure 3.2 and figure 3.3 respectively. The average minimum and maximum air temperatures of the station (Yetnora) at 1.5 meters height were 15.0 and 22.4 Degree Celsius respectively, with an average of 18.7 Degree Celsius. The total rainfall amount of the year for the station was 1004.5 millimeters (Appendix II). Indeed, these figures are not much different from the information obtained from DWARDO. According to this source, the average annual air temperature and average annual total rainfall of the station, the compound of DWARDO, are 19 Degree Celsius and 954.6 millimeters respectively. Considering the altitudinal ranges of the site as well as the average temperatures indicated earlier, in accordance with the local climatic classification of Ethiopia, the study site lies within 'woina dega' agro-ecological zone.

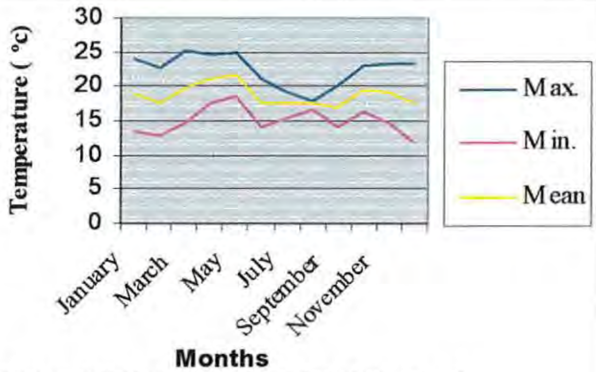


Figure 3.2 Temperature Distribution of the Study Site (2006)

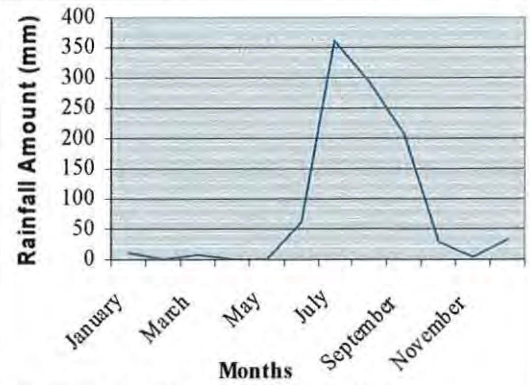


Figure 3.3 Rainfall Distribution of the Study Site (2006)

3.1.4 Soil

In broad sense, according the Ethiopian soil classification system, the study area's soil type is grouped under nitisol which often develops on a flat and sloppy terrain. It is fertile soil (EMPDA, 1984:23). However, according to DWARDO, the soils of the study area are differentiated into four types by their colours. These are black, brown, red and gray soils which account 52%, 17%, 26% and 5% respectively.

3.1.5 Vegetation Condition

Matured naturally grown trees are only observed in the aged church compounds and in some homesteads. In the rest part of the site, natural vegetations are very much degraded. However, some of the major indigenous tree and shrub species which still survive in the area include: "Warka" (Ficus vasta), "Bisana" (Croton macrostachyus), "Cheba" (Acacia species), "Digitta" (Calpurnia aurea), "Girawa" (Vernonia amygdalia), "Koshishila" (Acanthus species), "Agam" (Carissa spinarum) and "Woira" (Olea europaea). Whereas important exotic tree and shrub species commonly observed in the area encompass: "Nech Bahir Zaf" (Eucalyptus globulus), "Key Bahir Zaf" (Eucalyptus camaldulensis), "Yeferenge tid" (Cupressus lusitanica), "Shiwshiwe" (Casuarina equisetifolia) and "Sesbania" (Sesbania sesban).

3.1.6 Land Use Type

Land is a critical resource particularly for people residing in the rural areas. Hence, to acquire the maximum possible benefit from the existing size of land, it should be categorized and devoted into purposes to which every plot is best suited to. However, the land use type of the study site presented below does show merely the current purposes to which a given size of land is devoted to. According to DWARDO (2006), area coverage and land use types of the study site are as shown in table 3.1.

Table 3.1 Land Use Type of Koncher-Tik-Subshengo Area

S. No.	Land use classes	Area (ha)	Percent
1	Land devoted for annual crops	5477	69.46
2	Land devoted for perennial crops	82	1.04
3	Grazing land	803	10.18
4	Forest and bush/scrub land	586	7.43
5	Currently unproductive land	198.5	2.52
6	Land devoted for settlement and infrastructures	738.5	9.37
Total		7885	100.00

Source: DWARDO, 2006

3.2 Demographic Characteristics and Economic Activities

3.2.1 Demographic Characteristics

Based on the 1994 population and housing census of Ethiopia, a more reliable source, the population size of the study area was 15,806. Of this total, females constituted 51.2% while males accounted 48.8% (OPHCC/CSA, 1995:298). Family size, based on the surveyed households, varied from 2 to 11; where the average size was 5.1 persons per household.

The age structure of a given population is commonly portrayed either in the narrow age groups-five years interval (Appendix III) or broad age groups: 0-14, 15-64 and >64. Based on the latter age grouping system, the ages of 39.30% of the total population included in the survey lied within the age interval of 0-14. The remaining 57.21% and 3.49% of the population lied in the age groups 15-64 and >64 years old respectively. These provided a dependency ratio[1] of 74.14%. The median age lied in the age interval 15-19. The survey result also gave the sex ratio, the ratio of the number of males to females, of 97.41%.

[1]Dependency ratio refers to the ratio of the number of population in the combined age groups 0-14 and >64 to the number of population in the age group 15-64.

Of the total population in the surveyed households, 38.21% and 9.83% of them were illiterate and able to read and write respectively. The rest 51.96% had formal education ranging from elementary to tertiary levels (Appendix IV). In the case of the sample household heads alone, 47.78% and 25.56% of them were illiterate and able to read and write. The remaining 12.22%, 11.11%, 1.11% and 2.22% had elementary first cycle, elementary second cycle, secondary and preparatory levels of education respectively.

3.2.2 Economic Activities

The major economic activity of the people in the study area, as most highland people of Ethiopia do, is mixed farming, i.e., production of crops and rearing of animals. Here, crop production is almost entirely dependent on the mercy of rainfall. Only some vegetables such as green pepper, carrot, cabbage, onion and garlic and cash crops particularly 'gesho' (Rhamnus prinoides) are being grown with irrigation water from hand dug wells and small intermittent streams before they dry out. The most common crop types grown in the study area are 'teff' (Eragrostis tef), maize, wheat, sorghum, barley, beans, peas, vetch, chick pea and nigger seed.

A complimentary economic activity to crop production in the site is livestock rearing. The survey result revealed that the size of livestock has been increasing to meet the growing demand for draught animals. However, it is paradoxical to hear that the size of grazing land has diminished from time to time while the size of livestock has increased which resulting in over grazing.

In addition to mixed farming, some people carry out off-farm/non-farm economic activities such as carpentry, pottery, waving, smithing, trade and hiring labour.

CHAPTER FOUR

SOURCES AND CONSUMPTION PATTERNS OF BIOMASS ENERGY

4.1 Sources of Biomass Energy

The types of biomass fuels utilized in the study site include fuelwood, dung, crop residues, caster bean and cotton seed. The proportions of sample households who were utilizing fuelwood, dung, crop residues, caster bean and cotton seed were 100%, 96.67%, 67.78%, 4.44% and 2.22% respectively.

4.1.1 Fuelwood

Fuelwood was utilized by the entire sample households. This is probably because it is indispensably important to get other biomass fuels burn steadily and properly. The respondents were requested to prioritize the sources from which they obtained fuelwood. Accordingly, the top six vital sources from which the households obtained fuelwood in descending order of importance were own planted trees and/or shrubs, purchasing tree stands and preparing them for fuel, naturally grown wood stands protected in one's own homestead, communal scrub/bush lands, pulling up roots and stumps and cutting naturally grown wood stands from one's own farmlands away from the homestead and sharing from community forests (Table 4.1).

Table 4.1 Sources of Fuelwood for the Sample Households

S. No.	Fuelwood sources	Ranks of fuelwood sources and frequencies						Sum of the frequencies of the first three top ranks	Rank order
		1	2	3	4	5	6		
1	Collecting from communal scrub/bush lands	9	14	3	1			26	4
2	Own planted trees and/or shrubs	62	6	4	3			72	1
3	Naturally grown wood stands protected in one's own homestead	2	23	8	3			33	3
4	Pulling up roots and stumps and cutting remnant naturally grown wood stands from own farmlands away from homestead	1	3	14	2	4		18	5
5	Purchasing tree stands and preparing them for fuel	15	16	5				36	2
6	Purchasing from fuelwood carriers		1					1	8
7	Sharing from community forests		11	2	3	1		13	6
8	Collecting eucalyptus leaves and shaded branches	1	1					2	7

As can be seen in table 4.1, number one source of fuelwood for the majority of the sample households was own planted trees and/or shrubs. Planted trees and shrubs are grown primarily in and around the homesteads, in the borders of farmlands and in small plots in the farmlands. Amongst the total sample households, 75 (83.33%) of them had planted trees and/or shrubs. The heads of these households were requested as how much percent wood from own planted trees and/or shrubs covered their total fuelwood demand. Hence, 42 (56%), 10 (13.33%), 9 (12%) and 14 (18.67%) of them correspondingly met 75-100%, 50-74%, 25-49% and less than 25% of their fuelwood demand from this source.

The total number of trees and shrubs planted by all the surveyed households was 18,402, with an average of 204.47 trees and shrubs. This average is less than by about one-third from the average of Chemoga Watershed which is 307 (Woldeamlak, 2003:116). Even when the four outliers, households who possessed more than 1500 trees and/or shrubs, were excluded, the indicated average dropped nearly by half (107.90). Thus, there was a great variation in the number of planted trees and/or shrubs among the sample households; it ranged from nil to 2893. Of the total sample households, while 16.67% had no planted trees and/or shrubs, the other 21.11%, 10%,16.67% and 35.56% of them had trees and/or shrubs ranged 1-25, 26-50 and 51-100 and >100 respectively. Hence, nearly two-third (64.44%) of the surveyed households had none or less than 100 planted trees and/or shrubs (Table 4.2). As per the respondents, households plant trees and/or shrubs not for a single objective but for a combination of two or more of the following major objectives: for fuel, construction, life fence, sale and fodder.

Table 4.2 Number of Trees and/or Shrubs Planted by the Sample Households

Number of trees/shrubs	Frequency	Percent	Cumulative percent
0	15	16.67	16.67
1-25	19	21.11	37.78
26-50	9	10.00	47.78
51-100	15	16.67	64.44
101-200	13	14.44	78.89
201-300	7	7.78	86.67
301-400	3	3.33	90.00
401-500	3	3.33	93.33
>500	6	6.67	100.00
Total	90	100.00	

Of all tree and shrub species planted by the sample households, eucalyptus was by far the predominant one. It constituted 91.54% of the entire number of trees and shrubs planted by the sample households. The explanations given as to why households preferred eucalyptus to other species were due to its fast growth excellence, trunk quality for construction and survival quality. The next important species planted in the area was Sesbania sesban. This species accounted 6.05% of the total number of planted trees and shrubs while all the remaining tree and shrub species made up less than 3% (Appendix V). The reason behind Sesbania sesban being a second important species planted by the sample households could be related to its increasing recognition as a source of fodder particularly by households who had better hybrid milk cows.

Purchasing tree stands was the second most important means by which sample households met their fuelwood demand. This implies the exhaustion of free sources of fuelwood. Free sources of fuelwood can either hardly be available in the communal lands or the opportunity cost of time to be spent in collecting fuelwood from common resources may be greater than the money spent on purchasing fuelwood.

The third important source of fuelwood for the sample households was naturally grown wood stands protected in one's own homestead. According to the local elders, the contribution of this source in meeting fuelwood demand of the households had declined dramatically during the time of villagization in the ex-regime. They revealed that during this time, firstly, all sorts of shelters were constructed at once which caused extensive destruction of both natural and planted wood stands in the area. In support of this, Helen (1992:62) revealed that villagization has increased the shortage of wood. This was because, among others, many reserves of wood were exhausted in the building of new houses. Secondly, naturally grown wood stands which used to be protected in the previous homesteads were no more to be looked after. As a result, owners were forced to cut away all the remaining wood stands particularly naturally grown ones at a time. Even worse, after-all people were gathered in the new villages, people started to consider that any regenerated naturally grown wood stands and matured stumps in the previous homesteads were no more private. As a result, some people commenced to split matured stumps and pull up roots publicly in the previous homesteads irrespective of the former ownership. Following this, the previous owners with great fury and obstinacy determined to pull up roots and split stumps massively at a time. Nowadays, however, some households have gone back to the previous homesteads. Hence, the said source of fuelwood started to recover. Because the households are able to protect the regenerating naturally grown wood stands found in and around their homesteads.

The fourth most important source of fuelwood for the sample households was communal bush/scrub lands. Had there been some more wood in this source, households would have preserved their own wood stands. This is because normally, people tend to use the common resource first in the sense that "If I don't use this resource, somebody else will" (Miller, 1996:9). However, despite this logic, merely 10% and 15.56% of the sample households were utilizing this source as their first and second most important alternative to meet their fuelwood demand respectively. The respondents, who used communal bush/scrub lands as a source to met part or whole of their fuelwood demand, were requested to estimate the time spent to fetch a bundle of fuelwood. Hence, the average time spent to fetch an average bundle of fuelwood, most probably wet wood, was about 5:30 hours.

The fifth most important source of fuelwood for the sample households was own farmlands away from homesteads. This source of fuelwood may not strictly be considered as private one. Nevertheless, there seems to be more opportunity to use this source by the land holders themselves than the rest. Because by the time when landholders expand their farmlands, if at all existed, to the neighboring hills, communal grazing lands or unused patches of lands in the middle of farm plots, simultaneously households might pull up roots and cut wood stands that could serve for fuel. In addition, land owners might get more fuelwood from this source during the early autumn season while they try to remove away all which they feel unwanted shade to their crops. This is to say that there may be newly regenerated wood stands during the rainy season and create shade to crops around farm borders or patches of unused lands in the middle.

Though shared every fourth or fifth years among the village households at the time when the forest ripe to be harvested, community forest held the sixth place in the rating of fuelwood sources by the respondents.

Concerning the scarcity of fuelwood, the heads of the sample households were requested to evaluate whether the overall availability of fuelwood of the area was 'sufficient', 'moderate' or 'below sufficient'. Accordingly, 94.44% of the respondents perceived it as 'below sufficient' whereas the remaining 5.56% evaluated it as 'moderate'. Respondents who evaluated fuelwood availability of the area as below sufficient were requested to prioritize the causes that led to the scarcity in the area. Hence, the causes for the scarcity of fuelwood in the area, according to the opinion of the respondents, in descending order of importance, were expansion of farmlands, increasing demand of fuelwood for home consumption, increasing number of woodfuel sellers, over grazing, increasing demand of wood for construction and increasing number of local bear sellers (Table 4.3). Therefore, all the aforementioned causes for the scarcity of fuelwood could be related to the prevalence of population pressure and the subsequent depletion of resources.

Table 4.3 Causes of the Scarcity of Fuelwood in the Study Site as Perceived by the Respondents

S. No.	Causes of fuelwood scarcity	Rank frequencies						Sum of the frequencies of the first four top ranks	Rank order
		1	2	3	4	5	6		
1	Increasing demand of fuelwood for home consumption	26	48	5	2	4		81	2
2	Increasing number of woodfuel sellers		1	27	41	14	2	69	3
3	Increasing number of local bear sellers					9	17	0	6
4	Increasing demand of wood for construction	3	10	16	14	13	1	43	5
5	Deforestation to expand cropping land	56	22	6		1		84	1
6	Deforestation due to over Grazing		4	31	28	20	2	63	4

The respondents realized various problems prevailing as a result of fuelwood scarcity in the area. Some of the problems pointed out included: wasting more precious time for fuel collection; increasing of health problems related to using more dung and crop residues as fuel; declining of soil fertility due to growing use of dung and crop residues as fuel; increasing shortage of animal feed with increasing use of crop residues as fuel; exacerbating the destruction of the remnant natural vegetations; increasing temperature of the locality; increasing incidents of females abduction while walking long distance in search of fuelwood and declining of biodiversity.

As a result of widespread destruction of the natural vegetations for various reasons, as local elders and group discussants revealed, some species of trees and shrubs which were previously relatively abundant are now hardly found in the area. If not totally, they are on the verge of extinction from the locality. These include 'Kitkita' (Dodonea viscosa), 'Tungit' (Otostegia fruticosa), 'Embus' (Allophyllus abyssinicus), 'Qega' (Rosa abyssinica) and 'Koshim' (Dovyalis vemeosa). The existence of misuse of the natural vegetations of the area can substantiate the perception of the informants pertaining to the possibilities of degeneration of some tree and shrub species from the locality. Because the use of immature wood, roots and stumps as fuels are most likely to cause degeneration of some tree and shrub species. In this case, firstly, the writer observed immature wood kept for fuel in the compound of some households (Figure 4.1). Secondly, among the total sample households, 23.33% of them used stumps and roots for fuel which were collected from communal bush/scrub lands and own farm plots.

Figure 4.1 Immature Wood Kept for Fuel

When asked as to what the lasting solutions could be for the problem of scarcity of fuelwood, consolidating tree planting was suggested to be a lasting solution by 100% of the respondents. Indeed, in addition to tree planting, 23.33%, 5.56%, 7.78% and 1.11% of the respondents respectively suggested saving fuels using fuel saving stoves, conservation of the remnant natural vegetations, introducing hydro electricity and promoting biogas technology. The other 10% suggested the need for integrating tree planting with the use of fuel saving stoves and conservation of the remnant natural vegetations (Table 4.4).

Table 4.4 Suggestions of the Respondents as Lasting Solutions for the Problem of Fuelwood Scarcity

S. No.	Suggested solutions	Count	Percent
1	Tree planting	47	52.22
2	Tree planting and using fuel saving stoves	21	23.33
3	Tree planting and conservation of the remnant natural vegetations	5	5.56
4	Tree planting and introducing hydro electricity	7	7.78
5	Tree planting and promoting biogas technology	1	1.11
6	Tree planting, using fuel saving stoves and conservation of the remnant natural vegetations	9	10.00
Total		90	100.00

The suggestions given by informants at different levels of administration were not as such different from what were already indicated. They revealed with emphasis that increasing wood supply through promoting tree planting both at household and community levels and reducing demand through the use of improved stoves were more feasible at the current socioeconomic conditions of the people in the rural areas.

Tree planting as community forest was, therefore, suggested to be an important option towards minimizing fuelwood problem of the area. There are possibilities for the development community forests in the site. Firstly, there exist currently unproductive parcels of lands (Table 3.1). Secondly, the area is traversed by dry and all weather roads along which community forest can be established. Thirdly, planting trees as community forest, managing and protecting as well as sharing its products are not new experiences in the study area.

4.1.2 Dung Fuel

Among the sample households, 96.67% of them utilized dung fuel, the remainder 3.33% didn't. The reason given for not using dung fuel by the latter was that they had neither livestock nor the labour input that could collect dung fuel from communal grazing lands. Those sample households who did use dung fuel obtained it from one or more of the following sources: from own livestock, communal grazing lands and purchasing (Table 4.5).

Table 4.5 Sources from where Sample Households Obtained Dung Fuel

S. No.	Source type	Frequency	Percent
1	Communal grazing lands only	8	9.20
2	Own livestock only	37	42.52
3	Purchasing only	2	2.30
4	Communal grazing lands and own livestock	31	35.63
5	Purchasing and own livestock	2	2.30
6	Communal grazing lands, own livestock and Purchasing	5	5.75
7	Communal grazing land and purchasing	2	2.30
Total		87	100.00

As could be anticipated, the primary source of dung fuel for the sample households was own livestock. Among dung fuel users of the surveyed households, 42.52% exclusively relied on their own livestock to meet their dung fuel demand while the other 43.68% had additional sources. Communal grazing lands played second leading role as a source of dung fuel. Of the total dung fuel users of the sample households, communal grazing lands were a mere source for 9.2% and an alternative for the other 43.68%. Purchasing was another means by which the sample households acquired dung fuel. It was a mere source for 2.3% and an alternative for the other 10.34% of the dung fuel users of the sample households.

Households might be forced to purchase dung fuel for one or more of the following reasons:

- lack of enough or no livestock;
- lack of enough or no labor input to collect it from communal grazing lands;
- when the cost of dung fuel is cheaper than other fuel types; and
- when dung fuel is wanted for some specific purposes than other fuel types.

In the literature review, it was described that dung fuel from smaller livestock like goats and sheep and pack animals is not widely used (EEA, 1990:A-2). But in the study area, even if cattle dung was still the primary source , dung from goats, sheep, donkeys and horses was used for fuel by more than half (55.56%) of dung fuel users of the surveyed households. The author also observed people in the area were making dung cakes by mixing dung of cattle and other livestock (sheep, goats, donkeys and horse) with the help of water. Hence, it is common to see a huge heap of dung cakes at the residence of many households in the site as shown in figure 4.2.

Of the total dung fuel users, 44.44% of the respondents replied that they did not use dung other than cattle's. The reasons given were the following:

- not possessing any livestock;
- not possessing livestock but cattle;
- difficulty of the fuel to be collected from the field;
- not comfortable to be used as fuel; and
- having enough number of cattle as a source of dung fuel and, thus, preferred to use the dung of other livestock as fertilizer.

Figure 4.2 Heap of Dung Cakes under the Shade

4.1.3 Crop Residues

Amongst the surveyed households, 67.78% of them did use crop residues for fuel. All of these households utilized stalks of maize and/or sorghum for fuel. Hence, the most important types of crop residues utilized for fuel were stalks of maize (including its cobs) and that of sorghum. The roots and bottom parts of these cane crops, parts not edible by livestock, were kept for fuel in many residences in the study site as shown in figure 4.3. To a lesser degree, stalks of nigger seed, beans and rape seed were also used. Even straws of 'teff' (Eragrostis tef), wheat and barley that were left over by the livestock were utilized too, after mixed with fresh dung and baked into dung cakes.

Figure 4.3 Stalks of Maize Collected for Fuel

The rest 32.22% of the surveyed households did not use crop residues as a source of fuel. A major reason provided for not using this fuel type by 25.56% of the respondents was having not cane crops in 1998/1999 E.C. production year. Here, it could be pointed out that the proportion of users and non users of this fuel type varies with the types of crops each household decides to cultivate every year. In a nutshell, the availability of crop residues as a source of fuel varies with the types of crops grown in each year as the residue of different crops are not equally important for fuel. Other reasons given by the remaining 4.44%, 1.11% and 1.11% of the respondents were selling residues of cane crops for animal feed, devoting the residues wholly for animal feed and having enough wood and dung fuel sources respectively.

4.1.4 Caster Bean and Cotton Seed

Caster bean and cotton seed were utilized by 4.44% and 2.22% of the sample households respectively. The users revealed that such biomass fuels used only occasionally. They are utilized for lighting purpose. According to the local elders these fuel types including food oil, 'kitkit[1]' and 'chibo[2]' were used widely for lighting purpose during the Imperial regime and even as late as the early years of the Derg regime.

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[1] 'Kitkit'- is an Amharic term which refers to thin long wood crushed while wet and exposed to sun's heat for drying. Once dried, it is used for lighting. It is preferably prepared from 'digitta' (Capumia aurea).

[2] 'Chibo'- is also an Amharic term which refers to bunch of dried stick tied together in elongated manner and used for lighting purpose.

Though caster bean and cotton seed are used only occasionally and in negligible amount, describing how they are utilized is assumed to be important as the experience may be foreign to other areas. In fact, Denkneh (1984:40) indicated that cotton seed and nigger seed cakes were one of the important sources of domestic energy in the city of Addis Ababa. But how the cakes were utilized and for what end uses were not described.

Caster bean is commonly grown in the homesteads as life fence. Once a certain amount of caster bean seed is collected, the exocarp of the seed is removed. Then the inner whitish part will be crushed and exposed to sun's heat. Exposing the oil for 20 to 30 minutes will make it, to some extent, melt and become sticky. Then the oil will be fastened around a thin dry wood. The time duration the fuel serves while lighting is determined by thickness of the oil made sticking around thin dry wood and the length of the stick covered with the oil. The bottom part of the thin dry wood will be left free so that one holds this part during lighting as shown in figure 4.4.

Households obtain cotton seed by the time when they purchase cotton for spinning. The preparation of cotton seed for lighting purpose is not as such different from that of caster bean. What makes it different from caster bean is that its exocarp is not easy to be removed. Consequently, the seed is crushed well with the exocarp and then the same procedure will be followed as that of caster bean.

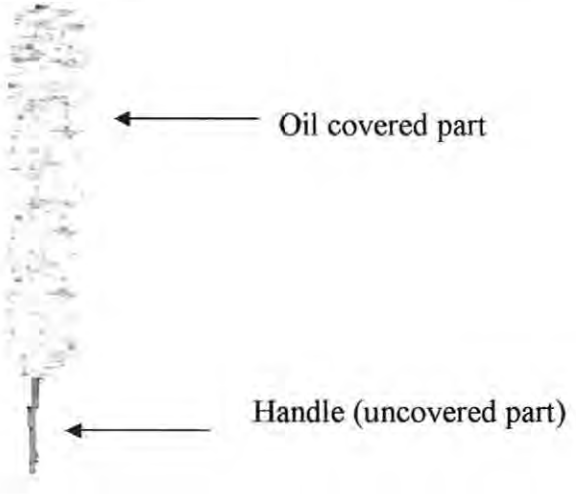


Figure 4.4 Caster Bean and Cotton Seed Prepared for Lighting

4.2 Consumption Patterns of Biomass Energy

Consumption quantity of a given fuel type can be expressed in any convenient unit of measurement. The unit can be unit of weight such as kg, tone; unit of volume such as cubic meter (m^3), litre, barrel, or unit of energy like joule, caloric, British thermal unit (Btu). But the units matter when one attempts to compare consumption amounts of different fuel types. In this case, the gross weight or volume of each fuel type consumed needs to be changed into its heat value expressed commonly in basic energy units like joule, caloric, Btu, or standard units such as tonne of oil equivalent, tonne of coal equivalent. This is because, indisputably, the energy contents (heat values) of per unit weight or volume of different fuel types are quite different (Appendix VI).

For instance, compared in terms of simply their gross weights consumed, fuelwood and dung accounted 43.52% and 45.19% of the daily total biomass fuel consumption of the sample households respectively. But when compared in terms of their energy contents (heat values), fuelwood slightly exceeded that of dung fuel, constituting 44.14% and 43.62% of the daily total biomass fuel consumption of the surveyed households respectively (Table 4.6). In fact, the gaps among per unit weight heat values of fuelwood, dung and crop residues are not as wide as that of charcoal and fuelwood or fuelwood and kerosene (Appendix VI). However, for better precision, one prefers to compare these fuel types using their heat values to their simple gross weight consumed. Therefore, the weight of each biomass fuel type consumed was changed into equivalent heat values. Conversion factors employed are shown in Appendix VI.

4.2.1 Consumption by Fuel Type

The types of biomass fuels regularly consumed in the site, similar to many other rural areas, are fuelwood, dung fuel and crop residues. The daily total biomass fuel consumption for the entire surveyed households was 9626.63MJ. Of this total, fuelwood, dung and crop residues accounted 44.14%, 43.62% and 12.24% respectively (Table 4.6).

Table 4.6 Daily Total Biomass Fuel Consumption by the Surveyed Households

	Fuel type	Fuelwood	Dung	Crop residues	Total biomass fuels
Consumption	In kg	293.05	304.32	75.99	673.36
	% as of total biomass fuels	43.52	45.19	11.29	100.00
	In MJ	4249.20	4199.56	1177.87	9626.63
	% as of total biomass fuels	44.14	43.62	12.24	100.00

The proportion of fuelwood (44.14%) in the total biomass fuel consumption of the surveyed households is much less than the national level, which is 81.26 % (Asress, 2002:85). In contrast, the shares of dung fuel (43.62%) and crop residues (12.24%) in the total biomass fuel consumption of the surveyed households are greater than the national levels, which are 9.14% and 8.35% respectively (Asress, 2002:85). The result implies the existence of fuelwood scarcity and the increasing use of its substitutes-dung fuel and crop residues.

The prevalence of household energy problem in the area can also be evidenced by the relatively lower daily per capita biomass fuel consumption amount of the sample households as compared to the national average. The average daily per capita biomass fuel consumption for the surveyed households was 21.93MJ (1.51kg of fuelwood equivalent) while the national average was 2.1kg (EEA, 1990: B-2).

4.2.2 Household Size and Biomass Fuel Consumption

For the surveyed households, daily biomass fuel consumption ranged from 50.43MJ to 198.94MJ, with an average of 106.96MJ. Household size, inter alias, was a major factor affecting the amount of domestic energy consumption of the sample households. This is because for surveyed households, there was a statistically significant positive correlation (+0.766) between household size and amount of daily biomass fuel consumption at 99% level of confidence. Hence, amount of daily biomass fuel consumption increases with the size of the household. But household size and daily per capita biomass fuel consumption were inversely related, The Pearson's product moment correlation coefficient of the two variables was -0.485 at 99% of level of confidence. The result implies that cooking large meal is more energy efficient than smaller meals.

4.2.3 Household Income and Biomass Fuel Consumption

The daily averages of biomass fuel consumption for poor, medium and rich income groups of the surveyed households were 94.23MJ, 107.79MJ and 139.89MJ respectively (Table 4.7). The outcome shows that as income of a household increases, amount of energy consumption also increases. Considering the average daily per capita biomass fuel consumption of the three income groups, the result as well proves that household energy consumption amount rises with income level. The daily averages of per capita biomass fuel consumption for poor, medium and rich income groups were 20.19MJ, 20.46MJ and 30.00MJ respectively.

Even if the mean daily per capita biomass fuel consumption for poor income group is nearly the same as that of medium income group, the trend is very clear due to an outlier value of the rich income group. Among others, the reason for the slightly equal values for poor and medium income groups is expected to be the result of the latter's greater mean household size; where, as discussed before, larger meal cooking is more energy efficient than a smaller one. The average household sizes of poor, medium and rich income groups were 4.90, 5.44 and 4.80 respectively (Table 4.7).

Table 4.7 Average Daily Biomass Fuel Consumption by Income Groups of the Surveyed Households

Income Group	Number of households	Average household size	Annual average income (Br)	Mean daily consumption				Per capita biomass fuel consumption (MJ)
				Fuelwood (MJ)	Dung (MJ)	Crop residues (MJ)	Total biomass fuel (MJ)	
Poor	41	4.90	5,080.49	47.38	34.86	11.99	94.23	20.19
Medium	34	5.44	11,012.62	43.16	50.68	13.95	107.79	20.46
Rich	15	4.80	18,481.84	55.94	69.82	14.12	139.89	30.00
Grand mean	-	5.09	9,555.08	47.21	46.66	13.09	106.96	21.93

As displayed in table 4.7, mean daily consumptions of dung and crop residues increase with income group levels. The mean daily consumption amounts of dung fuel for poor, medium and rich income groups were 34.86MJ, 50.68MJ and 69.82MJ respectively. While for crop residues, the mean daily consumption amounts for poor, medium and rich income groups were 11.99MJ, 13.95MJ and 14.12MJ correspondingly. Among income groups, differences in the mean daily dung fuel consumption amounts are higher than that of crop residues. These differences could be the result of the variations in the average numbers of cattle among income groups. The average numbers of cattle for poor, medium and rich income groups of the surveyed households were 1.85, 4.18 and 7.07. Hence, having more number of cattle does mean more dung fuel but at the same time devoting more crop residues for feed and lesser for fuel.

The mean daily fuelwood consumptions for poor, medium and rich income groups were 47.38MJ, 43.16MJ and 55.95MJ respectively. Hence, the mean daily fuelwood consumption of the poor income group is relatively higher than the medium income group. The reason for this seems a bit confusing because the average number of planted trees and/or shrubs still increases with the level of income groups. The average numbers of planted trees and/or shrubs for poor, medium and rich income groups were 112.88, 194.65 and 477.07 respectively. However, the possible reasons for poor income group consuming slightly higher fuelwood than the medium income group could be the following. Both income groups may be forced to sell more of their planted trees and shrubs to gain cash. But the poor income group may have more time to collect fuelwood from free sources than the medium income group. On the contrary, the medium income group had more number of cattle and, thus, more dung fuel than the poor income group. In deed, as long as the poor income group has more free time, they could also collect more dung fuel but preference of fuel types may matter.

4.2.4 Type of Stoves Used and Biomass Fuel End Uses

The type of stove used is one of the various factors affecting the amount of consumption. As per Konemund (2002:137), the utilization of biomass fuels in traditional three stone stoves leads to unnecessary high levels of consumption. However, in the study area, among the total surveyed households, 70 (77.78%) of them used traditional three stone stoves. The rest 19 (21.11%) and 1 (1.11%) utilized mud made closed 'injera' stoves and 'mirit' 'injera' stoves respectively. The latter two respondents were asked to mention the advantages they obtained as a result of the stove types being used. Consequently, the major advantages of using improved stoves as per the respondents were: protect the cooks from smoke and fire flame, secure children from fire accident and prolong the life of 'mitad'. Most (89.47%) of the mud made closed 'injera' stove users, however, did not recognize whether the stoves could save energy. This is probably because as the mud made closed stoves are built with no any molding devices, which could maintain their efficiency at a certain levels, the efficiency of mud made closed stoves may not be much better than traditional open three stone stoves.

The users of improved stoves pointed out as well some draw backs. The draw backs of improved stoves were: they require wider kitchen; not comfortable for human warming during the cold time and mud made closed stoves have short life spans, not more than six months.

Of the total respondents, 45.6% of them revealed that they got some informal education, i.e., orientation given about the use of improved stoves commonly at the end of public meeting. But users of improved stoves were about half less than those who got education.

With reference to type of biomass fuel end uses, as per the respondents, while fuelwood and crop residues were utilized for cooking, lighting[3] and heating purposes, dung fuel was used only for cooking and heating. Hundred percent of the sample households used fuelwood for cooking and heating purposes while 26.67% of them used it for lighting. In the case of crop residues, while 100% of its users utilized it for cooking and heating purposes, only 5.56% its users used it for lighting. With regard to dung fuel, hundred percent of its users utilized it for cooking and heating. Moreover, though used occasionally, caster bean and cotton seed were utilized for lighting purpose by 4.44% and 2.22% of the sample households respectively.

[3] It was revealed that in the evening time, while food is being cooked, light is also obtained in open three stone stoves particularly from fuelwood and crop residues. During this time diesel or kerosene light is not used in many cases so as to minimize their costs. In fact, all the sample households revealed that they used kerosene or diesel or electricity for lighting purpose. Note that hydro electricity has been introduced at Inewonta (Yetnora) village. Of the total 41 sample households taken from the village, 27 (65.85%) of them had electricity connection for lighting purpose.

CHAPTER FIVE

CONSTRAINTS AND OPPORTUNITIES FOR DEVELOPING RENEWABLE BIOMASS ENERGY SOURCES

5.1 Constraints and Opportunities for Consolidating Household Level Tree Planting Practices

5.1.1 Constraints for Consolidating Household Level Tree Planting Practices

Among the sample households, 69 (76.67%) of them had either none or insufficient number of trees and shrubs to meet their wood demand for fuel and other purposes. While 15 (16.67%) possessed no planted trees and/or shrubs, the remaining 54 (60%) reported as having insufficient number of planted trees and/or shrubs.

Both of these respondents were asked to prioritize the major constraints hindering their tree planting activities. Hence, limiting factors affecting their tree planting practices in descending order of importance were as shown in table 5.1.

Table 5.1 Constraining Factors Affecting Tree Planting Practices of the Sample Households

S. No.	Constraints	Rank frequencies				Sum of the frequencies of the first two top ranks	Rank order
		1	2	3	4		
1	Land ownership insecurity	1		2		1	8
2	Shortage of land	51	12	1		63	1
3	Seasonal competition for labour	8	18	1		26	2
4	Preference for 'gesho' (Rhamnus prinoides) to eucalyptus as the two do not go together	3	1			4	4
5	Discouraged with destruction of the newly regenerating shoots following harvesting by livestock	2	1	1		3	5
6	Discouraged, with price fall of wood at a time in comparison to grain and destroyed part or all of their trees once and for all	3	6			9	3
7	Discouraged with the destruction of their trees at the time of producers' cooperatives		2	1		2	6
8	Landlessness	1				1	8

As seen in table 5.1, shortage of land was the primary constraint for planting sufficient number of trees and/or shrubs. The average landholding size of the surveyed households was 1.6 hectares. This is less than the average of the respective regional level which is 1.8 hectares (WBISPP, 2002:ii). However, the correlation between landholding size and number of trees and/or shrubs for the sample households was not statistically significant (0.025). In contrast, there is statistically significant positive correlation (+0.303) between educational status of the surveyed household heads and that of the number of trees and/or shrubs planted at 99% level of confidence. Hence, one can conclude that despite the existence of shortage of land, through up grading the educational status of the people, the tree planting practices of the households can be ameliorated.

Seasonal competition for labour was believed to be the second most important constraint that restrained sample households from planting sufficient number of trees and/or shrubs. It was pointed out that the times for preparation of the land for crops and growing seedlings of trees at the nursery site are the same. Managing of tree seedlings particularly at the nursery site is a routine toil which involves, among others, watering the seedlings two times a day-morning and late afternoon. Hence, handling preparation of land for crops and managing tree seedlings at the nursery site at a time was pointed out to be very challenging particularly when the nursery site is away from homestead. It was also discussed that, nowadays, the majority of the young in the family are students. Thus, it is difficult to push the young in the family to carry out such labour intensive activities of the nursery site, unless the young themselves are determined to do so for their own source of income.

Price fluctuation of wood was mentioned as the third most important factor constraining tree planting practices of the sample households. In the review literature, it was mentioned that there is general trend of rising price of wood over time. But vis-à-vis the price of grains, there may be temporal fall or stagnation of wood price at local levels. In situation where there is shortage of farmlands, households who have particularly large plots of tree plantations may react to such temporal price fall or stagnation by hastily changing the plantation sites into farmlands. But when the price of wood rises once again, obviously, replanting is not as easy as destruction.

5.1.2 Opportunities for Consolidating Household Level Tree Planting Practices

Tree planting was suggested to be a lasting solution for the problem of fuelwood scarcity by hundred percent of the respondents (Table 4.4). Hence, one can say that such positive attitude of the people towards tree planting is an important springboard for further consolidating tree planting practices of the households. Regarding tree planting habits, a question was posed for various informants as how they evaluate the overall tree planting performance of the people. Accordingly, it was revealed that there is relatively slight improvement mainly because of the increasing scarcity of wood in the communal lands and the subsequent rise of its price. But the improvement is vividly seen in a few households. It was also pointed out that on average, people are not still able to plant trees at least at the same rate as they do destroy the trees for various reasons.

As per group discussants and key informants, there are various fast growing indigenous and exotic tree and shrub species known in the area. Some of the fast growing indigenous tree and shrub species mentioned were 'Bisana' (Croton macrostachyus), 'Girawa' (Vernonia amygdalia), 'Warka' (Ficus vasta), 'Sesa' (Albizia gummifera), 'Wanza' (Cordia africana) and 'Birbira' (Millettia ferruginea). The exotic tree and shrub species indicated as fast growing were 'Nech Bahir Zaf' (Eucalyptus globulus), 'Key Bahir Zaf' (Eucalyptus camaldulensis), 'Shiwshiwe' (Casuarina equisetifolia) and 'Sesbania' (Sesbania sesban). The presence of such known fast growing tree and shrub species is an opportunity by itself for further consolidating of tree planting in the area. Because looking for new other fast growing tree or shrub species suitable to the area and introducing and familiarizing the new species with the local people are not easy tasks.

Though not unique to the area, it was also pointed out that the price of wood is generally increasing from time to time. Hence, a few households who have many numbers of trees but less sensitive to wood price fluctuation are seen improving their life from the sale of their trees. Therefore, this trend together with the accessibility of the area for vehicles can be used as a point of entry to encourage the households to plant more trees.

Institutional factors, definitely, can either promote or retard tree planting practices of a given society. As indicated in the literature review, the forestry policy of the country does encourage private tree planting (Proclamation No. 94/1994). Heads of the sample households were asked whether they had ever got any institutional support about tree planting. Consequently, while 78.89% replied that they did not get any support; the remaining 21.11% revealed that they did get institutional support. As per the latter, the types of support given included: free provision of some seedlings; education about the importance of forest and planting multipurpose trees as well as the consequences of deforestation; and borrowing some instruments necessary for nursery site activities freely.

Free provision of tree seedlings may not be practically possible to undertake at a wider scale owing to limited capacity of the government. However, it is important from at least two points of view. Firstly, it can help to familiarize the farmers with some important exotic tree and/or shrub species, particularly with multipurpose tree species. Secondly, it can serve as an incentive for exemplary farmers with which others can follow the footsteps.

5.2 Constraints and Opportunities for Promoting Biogas Technology

To promote biogas technology in a given area, certain basic requirements need to be met. Among others, the basic requirements include: availability of sufficient source of dung and water, presence of positive attitude or interest towards the technology and availability of sufficient source of income to be able to finance its construction cost. Hence, being basic ones, these points were considered under here.

5.2.1 Availability of Sufficient Sources of Dung

Biogas can be produced from all types of dung (Buren, 1989:22)[1]. However, as conversion factors were not able to be obtained for the other animals, only cattle dung was taken into account.

[1] The type and number of livestock for the surveyed households were as displayed in Appendix VII.

As per SEPK (1987:18), in zero grazing units, the ideal number of cows required to produce enough biogas to meet the cooking and lighting requirements of 8 to 10 family members is 2 to 5. Hence, in a non-zero grazing system, doubling the aforesaid number of cows, i.e., 4 to 10, is assumed to be sufficient for the purpose indicated. Therefore, on average, 4 and 7 cows and/or cow equivalents[2] were supposed to be minimum requirements for the production of enough amount of biogas in zero and non-zero grazing systems respectively.

Based on this assumption, 34.44% and 10% of the surveyed households had sufficient number of cows and/or cow equivalents to be able to feed a family size biogas plant in zero and non-zero grazing systems respectively (Table 5.2).

Table 5.2 Number of Cows and/or Cow Equivalents Possessed by Sample Households

Range of cows and/or cow equivalents	Sum of cows and/or cow equivalents	Average of cows and/or cow equivalents	No. of SHHs	Percent of SHHs	Cumulative percentage	Range of household size	Total persons	Average household size
≥7	72.76	8.08	9	10.00	10.00	4-11[3]	57	6.33
4-6.99	107.41	4.88	22	24.44	34.44	4-10	139	6.32
<4	91.15	1.54	59	65.56	100.00	2-8	262	4.44
Total/Grand mean	271.31	3.01	90	100.00	-	-	458	5.09

In the study area, people commonly use non-zero grazing system. In such system, therefore, only 10% of the sample households could have enough sources of dung to feed a family size biogas plant. Here, it should be remembered that the use of additional waste matter from other livestock types, including human beings', may increase the proportion of the sample households who could have enough sources of dung for biogas production.

[2] Conversion factors of live weights into equivalent cows: ox=275kg, cow=200kg, heifer=125kg, bull=150kg and calf=50kg (Jahnke, 1982 cited in Amare, 1996:115).

[3] Though there was a sample household with 11 members, a size which was greater than the indicated assumption, the household as well had 8.08 cows and cow equivalents which is greater than what was recommended. Hence, as the larger household size can be compensated by larger number of cattle owned, the household wouldn't be out of the game.

Interestingly, however, there is an emerging tendency towards intensification of livestock rearing. As the informants revealed, better hybrid milk cows are mostly handled in zero grazing system. Moreover, some households who specifically have the intention to change their oxen are observed selling them after fattening. With the help of development agents and animal science experts, still a few other households start to fatten at least an ox or a few sheep as an off farm activity.

In connection to this, heads of the sample households were requested to rate whether the available grazing lands were 'enough', 'moderate' or 'not enough' vis-à-vis the livestock size in the area. Thus, 87.78% of the respondents replied that the available grazing lands were not enough while the rest 10% and 2.22% respectively rated them as moderate and enough. On the basis of the opinions of sample household heads as well as key informants, the promising solution for the problem of over grazing is intensification of livestock rearing. Other solutions suggested included strictly controlling illegal expansion of farmlands towards grazing lands, proper use of the existing grazing lands and reducing the size of livestock.

Thus, one can say that the tendency towards intensification of livestock rearing is an opportunity by itself to promote biogas technology in the area. This is because, as already pointed out, less number of cattle is required to be able to feed a given size of biogas plant in zero grazing system than in a non-zero grazing system. Hence, more households can be accommodated for biogas production.

5.2.2 Availability of Sufficient Water Supplies

The type of supplies from which the sample households obtained water for home consumption included community hand pump water, private water wells, spring water and pond water. Among the total surveyed households, 41.11%, 22.22% and 5.56% of them utilized community hand pump water, private water wells and spring water respectively. The remaining 31.11% of the surveyed households used two or more of the aforementioned water supplies (Table 5.3). The principal supplies of water were community hand pump water and private water wells from which 66.67% and 43.33% of the surveyed households met part or the whole water demand for home consumption respectively. The average distance of the sources from which the sample households fetch water for home consumption was about 6 minutes' walk.

Table 5.3 Water Supplies of Surveyed Households for Home Consumption

S. No.	Type of water supply	Count	Percent
1	Private water well	20	22.22
2	Community hand pump water	37	41.11
3	Private water well and community hand pump water	16	17.78
4	Spring water	5	5.56
5	Spring water and community hand pump water	6	6.67
6	Private water well and spring water	3	3.33
7	From other's private water well	2	2.22
8	Spring water, community hand pump water and pond	1	1.11
Total		90	100.00

Asked whether or not the water supplies were sufficient and reliable, 47 (52.22%) of the respondents replied that they had sufficient water supplies while the rest 43 (47.78%) responded that their water supplies were not sufficient. Among the latter, the majority 34 (79.07%) used community hand pump water wells as their sole water supply. In contrast, among 39 surveyed households who had private water supplies, 35 (89.74%) of them reported that they had sufficient water supply. Hence, from these, it is possible to say that common properties, community hand pump water wells in this case, are neither efficiently utilized nor managed whereas the opposite is true for private properties.

As to the suggestions of heads of the sample households and different key informants, the problem of water supply can be minimized through digging additional community hand pump water and private water wells deeply, strengthening and managing spring water supplies and digging ponds (water harvesting). It was also indicated that the area has sufficient ground water. Hence, water supply is not as such a major problem in the area.

5.2.3 Attitude of the People towards Model Biogas Plants

Attitude of the people towards biogas technology is one of the pertinent factors affecting its promotion in a given area. Attitude, in turn, among others, can be affected by knowledge of that people about the technology. How much people of the area know about the advantages and limitations of biogas technology is of course a difficult question.

However, to know the attitude of the heads of the surveyed households towards the technology, they were requested whether they have some knowledge about the biogas plants installed in the area. Accordingly, among the sample household heads, 31 (34.44%) replied that they had some knowledge about it while the rest 59 (65.56%) replied that they had little or no any knowledge. The former were further requested to give their attitude about the technology. Consequently, in brief, while 28 (90.32%) had positive attitude towards the technology, the remaining 3 (9.67%) perceived it as its limitations outweigh its advantages.

The latter were all among sample household heads from Koncher village. As discussed in the literature review, failure or success of a new technology introduced into a given society can positively or negatively affect its further promotion. Hence, the indifferent perception of these a few respondents from the village towards biogas technology could be related to the influence of the failure of the model biogas plant within one year service time (Appendix VIII).

However, as per the majority of the sample household heads who had positive attitude towards the technology together with key informants, biogas has a number of advantages. These include: it is quicker and, hence, saves time; it is smokeless; its slurry is effective fertilizer; it has no running cost except the initial capital and it is more promising to solve the problem of shortage of cooking fuels than the introduction of that of grid extension of hydro electricity to the area. With regard to hydro electricity, the respondents revealed that the rural people would not be able to withstand electricity tariff to use it for cooking. Indeed, this is true for the majority of the urban dwellers too.

Pertaining to the limitations of the technology, in addition to its high initial cost, it was disclosed that the technology requires frequent attention; it is labour intensive; and needs to maintain the number of livestock not to be less than from a certain level.

5.2.4 Availability of Sufficient Income

The dissemination of biogas technology, among other factors, is constrained by its high cost of construction. However, for a given capacity of biogas digester, among others, construction cost varies greatly with the type of model. As discussed in the literature review, floating drum is the most expensive model whereas plastic plant is the cheapest one. As per an informant from the Biomass Technology Study and Development Team in the Ethiopian Rural Energy Development and Promotion Center, the maximum total construction cost of polyethylene biogas plant with a capacity of $7m^3$ digester, roughly 1.5 to $2m^3$ of which serves as gasholder[4], is about 900Birr[5]. This cost does include the cost of wire mash for protection. Wire mash helps to secure the digester particularly from explosion that might result from extreme gas pressure as well as from mechanical damage. According to the informant, the maximum cost for the polyethylene tube alone which is enough for the capacity indicated is about 320 Birr.

However, including contingency, assume that households who have more than 1000 Birr annual surplus income, be it in kind or cash, from yearly expenditure can afford the construction cost of polyethylene biogas plant for the size aforesaid. Thus, the financial condition of the sample households was as shown in table 5.4.

Table 5.4 Range of Surplus Income of the Sample Households from their Yearly Total Expenditure

Surplus income range (Br)	>3000	2501-3000	2001-2500	1501-2000	1001-1500	501-1000	1-500	0	Total
Number	6	1	2	3	1	23	11	43	90
Percent	6.67	1.11	2.22	3.33	1.11	25.56	12.22	47.78	100.00
Cumulative percentage	6.67	7.78	10.00	13.33	14.44	40.00	52.22	100.00	

[4] As per the informant, a biogas plant with a capacity of 1.5 to $2m^3$ of daily biogas production is sufficient for household level domestic energy requirement. This can be substantiated by the following facts. The heat value for $1m^3$ of biogas is about 20MJ (FAO, 1997; Senait, 1988:3). Biogas burns at an efficiency of about 60% (FAO, 1997; UNESCO, 1982 cited in Senait, 1988:2). Hence, the useful energy which can be obtained from $1.5m^3$ of biogas is about 18MJ (1.5x20x0.60). In chapter 4, it was indicated that daily biomass fuel consumption of the surveyed households ranged from 50.43MJ to 198.94MJ. It was also pointed out that 77.78%, 21.11% and 1.11% of the sample households used traditional three stone stoves, mud made closed stoves and 'mirt' stoves respectively. As indicated in the literature review, traditional biomass fuels burn at average efficiencies of 7.5%, 12% and 20.5% in traditional three stone stoves, mud mad closed stoves and 'mirt' stoves respectively. Thus, the average efficiency that the sample households utilized traditional biomass fuels is about 8.6% (77.78x0.075+21.11x0.12+ 1.11x0.205). Hence, the amount of useful energy that the surveyed household with daily maximum biomass fuel consumption obtained is about 17.11MJ (198.94x0.086). Therefore, from these facts, one can understand that the useful energy acquired from $1.5m^3$ of biogas is slightly greater than the useful energy that the indicated household obtained from its daily consumption.

[5] Though earlier in time and lesser in capacity, based on a study conducted by Senait, ILCA, Livestock Economics Division, the total construction cost of a polyethylene plant for a capacity of $1m^3$ gasholder was estimated to range 87-108 Birr only (Senait, 1988:3).

Hence, as can be seen from table 5.4, ignoring other factors, 13 (14.44%) of the sample households could be able to afford the construction cost of polyethylene biogas plant. But it is essential whether at least to see the coincidence of financial affordability of the households with that of the availability of sufficient sources of dung. Thus, among those sample households who were financially capable, 10 (76.92%) and 6 (46.15%) of them had enough sources of dung to feed family size biogas plant in zero and non-zero grazing systems respectively. But the remaining 3 (23.08%), though they were financially capable, they had no enough number of cattle to feed a family size biogas plant. In other words, of all the surveyed households, only 11.11% and 6.67% of them had enough sources of income and dung to have a family size polyethylene biogas plant in zero and non-zero grazing systems respectively.

5.3 Reasons for the Failure of Model Biogas Plants and the Possibilities for Making them Functional Again

5.3.1 Reasons for the Failure of Model Biogas Plants

In the study area, though they are no longer functioning now, four biogas plants have been installed so far. Three of them were installed in the ex-regime, two at Inewonta and the other one at Subshengo villages. They belonged to producers' cooperatives of the time in the respective villages. The fourth one was established in the present government at Koncher village and it belonged to an individual household. The first three plants served for 4 to 7 years for both cooking and lighting purposes whereas the fourth one gave a one year service for cooking only (Appendix VIII). In the fourth case, the 'injera' stove failed functioning within the first two weeks of service time. Though gas transforming tube was stretched and made ready, light bulb was not installed from the beginning[6]. Hence, only the smaller stove which used to make coffee, boil tea, cook 'wot' and the like served for about a year.

[6]An informant from the FBRTPC revealed that there was problem of supplies of biogas light bulbs and 'injera' stoves. Consequently, many of the biogas plants installed by the center did not have these parts.

The biogas plant found at Koncher village was built by the former Bahirdar Rural Technology Promotion Center, which has been structurally transformed into Bahirdar Agricultural Mechanization Research Center since the year 2000. As per the informant, the center built model biogas plants in different woredas of the region which were believed to be fuelwood scarcity areas between 1994 and 2000. During this time, more than 20 model biogas plants were constructed in the western part of Amhara region alone; one of which was located at Koncher village. The major objective of the installations of these biodigesters at different woredas and kebeles in the region was to familiarize and further promote the technology.

The criteria for selection of beneficiary kebele in the already selected woredas were relative severity of fuelwood scarcity and nearness from towns and main roads to minimize transport and time costs as well as for easier monitoring activities. The criteria for selection of the individual household beneficiaries encompassed: possession of sufficient number of cattle, presence of enough labour power in the household, interest to the technology and willingness to dig the biodigester installation site to help them develop sense of ownership. However, though the beneficiary of the technology at Koncher was convinced at first to dig the site, it was revealed that the person refused after digging few centimeters depth. Thus, the government covered the cost of digging the digester site too.

The reasons behind the failures of model biogas plants installed in the area were different depending on the regimes in which they were constructed. For the biogas plant established at Subshengo village, the reason for its non-functioning was related to change in the economic policy of the ex-regime at the eve of its downfall. As per the informants, when the majority of the members of producers' cooperative of the village withdrew from the cooperative following the declaration of mixed economy, the plant was abandoned. In the case of those biogas plants installed at Inewonta village, they were abandoned following the removal of the Military Junta from power.

Regarding the biogas plant constructed at Koncher village, as per the owner, firstly, the main gas controlling valve near the digester became loose. Then the gasholder was no more able to rise up as high as usual-meaning gas accumulation started declining. Consequently, the gas burner was not giving heat as good as before. After a few days, the gas burner stopped functioning completely. Hence, on the basis of this information, one can say that the owner did not internalize the use of biogas technology. This is because the problem that led to the failure of the plant was so simple that it could have been rectified by changing or fastening the gas value with the help of even a junior plumber.

However, even if the owner applied the problem to the DWARDO repeatedly for maintenance, no one could give him solution. Though DWARDO, in turn, led the problem to the respective department at regional level, the response given was no further budget for maintenance as well as transport cost and expert's per diem. As per the beneficiary, there was no any expert who visited the plant after its installation. Consequently, no one could help him even when the 'injera' stove failed functioning as early as within the first two weeks of working time. The major problem with the 'injera' stove was that the 'mitad' was not able to be heated uniformly. An informant from FBRTPC also revealed that there was monitoring problems due to the scattered locations of model biogas plants and budget constraints. As a result, immediate solutions were not able to be given whenever there was call for maintenance and technical assistance.

5.3.2 Possibilities for Making Biogas Plants Functional Again

Making the biogas plants serviceable again, among others, demand willingness of the owners to use them again, presence of financial sources for maintenance and presence of readily available technical assistants at the institutional or private levels.

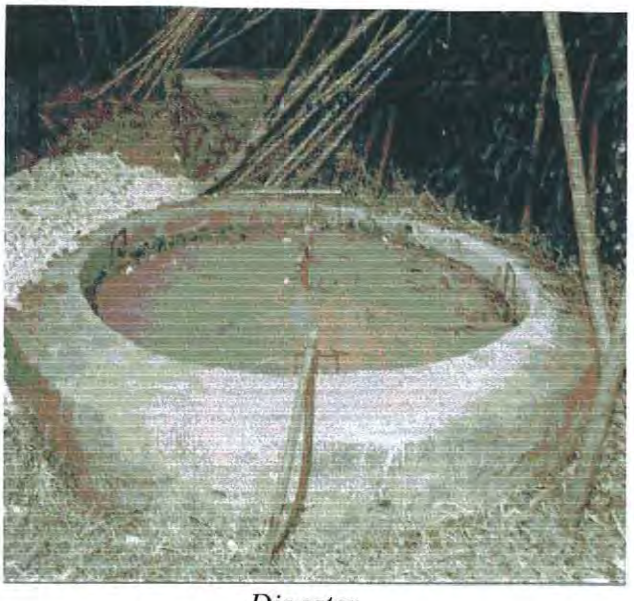
As described at Appendix VIII, though other parts are either damaged or totally lost, the digesters and gasholders of two of those biogas plants installed in the previous regime are seemingly observed yet undamaged (Figure 5.1 and Figure 5.2). For the third one, the digester and gasholder were almost obscured from sight as stones were piled on them. The digester may probably be undamaged while the gasholder though may get deformed it can work with some repairing. Hence, ignoring other factors, all of the three plants can be recovered with incomparably much lower cost of maintenance as compared to the construction cost of a new plant. However, to make them functional again, there are some ownership related questions that need to be answered. Firstly, there is a question of who should benefit from plants to be recovered. Secondly, who should pay for the cost of maintenance is another question. Thirdly, all of the digesters are currently found within individual households' home compounds and hence, what compensation should be made to these individuals is still another question.

Figure 5.1 Status of Biogas Digester Found at Inewonta (Yetnora) Village

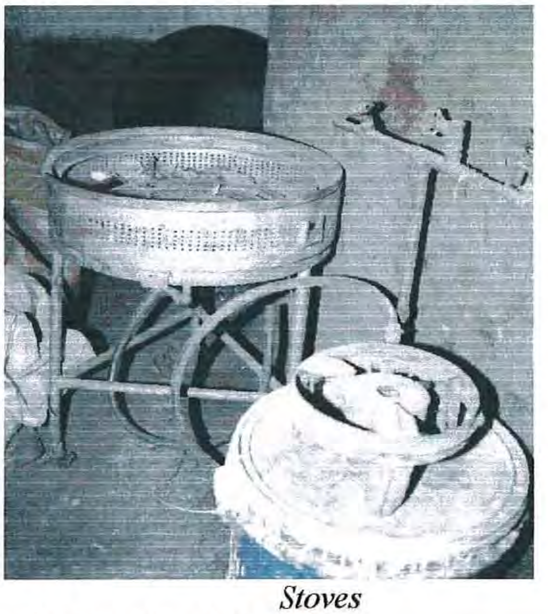
Figure 5.2 Status of Biogas Digester Found at Subshengo Village

In the case of the biogas plant found at Koncher village, except break on gas transforming plastic tube, damage on gas valves and 'injera' stove, the rest parts do seem undamaged (Figure 5.3). Hence, maintenance cost would not be much. However, even if the owner revealed as he worried much about the failure of the biogas plant and would be glad if government repaired it for him, he did not want to cover the cost of maintenance by himself. The reason given for not ready to pay the cost of maintenance were the following. Firstly, the biogas energy did not totally replace traditional biomass fuels. 'Injera' stove failed functioning immediately after installation. Hence, the biogas energy was used only for cooking 'wot', making coffee and the like. Secondly, as there is no any expert on biogas technology nearby, he disclosed his fear that paying the cost of maintenance would be a simple loss of money in case the plant fails once again.

Even in case when the owner of biogas plant is convinced to cover the cost of maintenance by himself, it is possible to say there is no readily available technical expert. Informants at zonal and regional administrative levels were asked whether there is individual expert or team of experts assigned to give technical assistance in case when an individual biogas owner is ready to pay the cost of maintenance. Accordingly, it was revealed that the individual is expected to cover not only the cost of materials needed for maintenance but also all expenses of the expert. Given that experts do not live nearby, this seems to be unaffordable for an average Ethiopian farmer.



Digester



Stoves

Figure 5.3 Status of Biogas Digester and Stoves Found at Koncher Village

CHAPTER SIX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary and Conclusions

Energy is an indispensable requirement, among others, for cooking, lighting and heating purposes in any society. For these end uses, people may utilize a wide variety of energy sources ranging from traditional to modern and renewable to non renewable energy types. Diversity of energy sources (options) by and large decline from the most developed to the least developed counties and from metropolis to rural areas. Because whatever a given area is endowed with abundant energy resources, unless the resources are able to be developed to the required levels and forms, that area will continue to suffer from limited energy options. Ethiopia, as many scholars reveal, is endowed with abundant energy resources. But as much of the resources are either untapped or not developed to optimal levels, its citizens continue to depend heavily on a single source of energy-biomass in its traditional form. What is currently worrying more to some areas is not even the heavily dependence on traditional biomass fuels but rather their scarcity and the related environmental problems.

However, there are always great spatial variations in energy sources, consumption amounts, energy related problems and energy resource endowments or potentialities within the country. As the study on the topic under discussion reveals, the situations to Koncher-Tik-Subshengo area can be comprehended as presented here under.

The primary sources of energy for the people of the study area are fuelwood, dung and crop residues. Caster bean and cotton seed are other types of biomass fuels which are used only occasionally by a few households in the area. The use of caster bean and cotton seed as sources of energy rarely appear on literature. Hence, they may probably be unique to the area and its environs. Caster bean, probably with some better methods of exploitation, can serve as an option towards improving the energy problems of the area in the future.

The principal sources from which households in the area obtain fuelwood in descending order of importance include privately planted trees and shrubs, purchasing, naturally grown wood stands protected in the homesteads, communal scrub/bush lands and private farmlands.

Free sources of fuelwood are exhausted very much in the area. People spend an average of about 5:30 hours to fetch a bundle of fuelwood from these sources. Even the ways these sources of fuelwood are utilized can further diminish their importance. Roots and stumps are pulled up and/or split and immature wood stands which sprout as a result of the rainy season are cut away competitively following the end of the season for fuelwood. Hence, such method of exploitation, in addition to exacerbating fuelwood problem, if not already happens, can inevitably lead to local extinction of some tree and shrub species.

Hence, due to the exhaustion of wood in the free sources, the fuelwood demand of the majority of the households in the area is met basically from own planted trees and/or shrubs and through purchasing. Among the total households, about 68.83% of them meet more than half of their fuelwood demand from privately planted trees and/or shrubs, predominantly eucalyptus, in the area. On average, households have about 204 planted trees and shrubs which is less than by about one third from that of Chemoga Watershed. There is even quite great variation in the number of planted trees and shrubs possessed among households. Hence, only some enlightened households have sufficient number of planted trees and shrubs.

As a result of the scarcity of fuelwood, households in the area widely use dung and crop residues as fuel. While fuelwood constitutes about 44.14% of the total biomass fuel consumption of the households, dung and crop residues roughly account 43.62% and 12.24% respectively. Hence, the relative contribution of fuelwood in the total biomass fuel consumption of the area is much smaller whereas dung fuel and crop residues are higher than the national averages. Households obtain dung fuel not only, if any at all, from own livestock but also commonly through collecting from grazing lands and to some extent through purchasing. Though cattle are the primary source of dung fuel, dung from goats, sheep, donkeys and horses is also widely used in the area. The types of crops which their residues commonly used as fuel are maize and sorghum. The wide use of dung and crop residues as sources of energy, among others, indirectly adversely affects the fertility of the soil, exacerbates soil erosion, negatively affects the health of the cooks (as perceived by the respondents) and aggravates shortage of animal feed.

Household size and income, among others, are identified to be major factors affecting fuel consumption. While household size increases, total amount of biomass fuel consumption also increases but per capita biomass fuel consumption decreases. As income of the households' increases, amount of biomass fuel consumption as well increases. Daily average of biomass fuel consumption rises from about 94.23MJ for poor income group to107.79MJ and 139.89MJ respectively for medium and rich income groups.

Efficient utilization of biomass fuels is one important option towards lessening energy problem of an area. However, the majority (77.78%) of the households in the study site use inefficient traditional open stoves. The remaining 21.11% and 1.11% use mud made closed stoves and 'mirt' stoves respectively.

As can be understood from the conclusion made so far, the study area has serious energy problem. Towards solving the energy problem of the area, developing household level tree planting and biogas technology as options, the existing constraints and opportunities can be comprehended as follows.

Concerning tree planting, the major obstacles adversely affecting tree planting practices of the households in the area include shortage of land, seasonal competition for labour and temporal wood price fluctuation. However, despite these limiting factors there are opportunities for further consolidation of households' tree planting practices. Firstly, as the educational status of household heads increases, the number of planted trees and shrubs of the households also increases. There is a statistically significant positive association between educational status of the surveyed household heads and that of the number of planted trees and/or shrubs. Secondly, promotion of tree planting is suggested to be a lasting solution by all the respondents. Hence, such positive attitude towards tree planting is an opportunity by itself for its further consolidation. Thirdly, the people in the area have the knowledge to identify which trees and shrubs do grow fast. Hence, the need for identifying and choosing fast growing tree and shrub species in the area would not be a problem. Fourthly, people in the area have the observation that a few households in the area, who have many number of planted trees and shrubs but are less sensitive to temporal price fall, have improved their lives from selling their trees. Fifthly, though covers yet about 21.11% of the households in the area, the presence of institutional support like free provision of some seedlings, informal education, and moral support is an opportunity by itself.

With regard to the possibilities for developing biogas technology in the area, biogas is not a technology to be adopted by every household as it needs some basic requirements to be fulfilled. One of the indispensable requirements is availability of sufficient sources of dung. About 34.44% and 10.0% of total households of the area have enough number of cattle to feed a family size biogas plant in zero and non-zero grazing systems respectively. Even if households in the area currently commonly practice non-zero grazing system, there is opportunity to encourage households to practice zero grazing system. This is because, firstly, in the area there is overgrazing problem. Intensification of livestock rearing was suggested to be number one solution to the problem. Secondly, there are some beginnings of practicing non-zero grazing system. Households who possess better hybrid milk cows as well as those who fatten one or more heads of livestock as an off-farm/non-farm activity practice non-zero grazing system. The other requirement, water is not a major problem in the area. Ground water can easily be obtained. The average distance of water sources from residences is about 6 minutes' walk. Still the other requirement, with regard to attitude, about nine tenth of the people who have some knowledge about the technology have positive attitude towards it while the remaining one-tenth estimates the limitations outweigh its advantages. However, the perception of the latter is more likely influenced by the failure of the biogas plant installed in the area. In terms of income, 14.44% of the households can afford the construction cost of polyethylene biogas plant. Nevertheless, while considering the coincidence of availability of enough sources of dung and income, about 11.11% and 6.67% of the households can have family size polyethylene biogas plant in zero and non-zero grazing systems respectively.

Reasons for the failure of model biogas plants embrace lack of internalization of the use of the technology on the side of the beneficiaries, change in economic policy and government as well as absence of regular maintenance and follow up. However, as long as the major components of the biogas plants-digesters and gasholders, which account most of the construction cost of a biogas plant, do exist and have no or lesser damage, the costs of repairing the plants are most likely much lower than constructing new ones. Hence, repairing is possible if the other problems such as interest, source of fund, technical assistance and ownership related problems are solved.

6.2 Recommendations

Based on the findings and conclusions made the following points are identified for further consideration to solve energy related problems of the households in the area and other similar rural areas.

1. Cutting of immature wood, digging up roots and stumps are found to be some of the major misuses of communal wood resources which inevitably lead to the extinction of some species. Therefore, in order to raise the general awareness of the people about the consequences of vegetation misuses and depletion and of the need to conserve and protect the existing natural vegetations, the concerned bodies, among others, woreda forestry and agro-forestry experts should give proper and continuous education to the public. Various social assemblies such as gatherings at worshipping places, at 'idir' (burial associations), at local conflict resolving places and the like can be used to deliver continuous education to the people.
2. To arrest unnecessary high wastage of energy through the use of traditional open three stone stoves and, hence, reduce energy demand, the concerned bodies particularly rural energy resource development experts should give due attention to the promotion of improved stoves. To this success, comparative demonstrations between the energy efficiencies of improved stoves and traditional open three stone stoves which involve the community members should be carried out.
3. Shortage of land is indicated to be a major constraint for household level tree planting. However, the study reveals no statistically significant correlation between number of planted trees and/or shrubs and landholding size. But there is statistically significant positive correlation between educational status of household heads and number of planted trees and/or shrubs. Hence, improving educational status of the people in general and household heads in particular may help to promote tree planting activities.
4. The study site is crossed by all and dry weather roads and has also some unused public lands. Hence, planting trees along road sides, foot paths and on marginal lands as community forests could be used as an option to minimize fuelwood scarcity problem. The use of these public lands for the development of community forests could lighten the restraining power of the shortage of land on household level tree planting activities.

Hence, the concerned bodies specifically woreda forest and agro-forestry experts in collaboration with kebele administrations should mobilize the community to plant trees and shrubs on them. Households should be given user rights. The user rights could be secured through proper sharing of the ripe trees among the households or selling for them at a reasonable price.

5. The use of caster bean as a source of fuel particularly for lighting purpose could be used as an option towards minimizing the energy problems of the site. Therefore, households should be encouraged to plant and utilize the species widely.
6. To minimize pressure on wood resources, to reduce or stop direct burning of dung and crop residues as fuel and the related problems and increase resource recovery, attention ought to be given for promotion and dissemination of biogas technology. The construction costs of biogas plants should be weighted against the long term social and environmental costs and risks which stem from direct burning of dung and crop residues. In order to include more households in biogas production and utilization, households firstly, should be encouraged to practice zero grazing system and secondly, all sorts of dung including human wastes should be encouraged for use. To address the expected households' resistance towards the use of human wastes for biogas production and subsequent utilization for cooking, continuous education supported by demonstration could be the way forward.
7. Long term loans should be facilitated for those households who have enough sources of dung to feed biogas plant but can't afford the construction cost of biogas plant. The cheapest biogas plant model such as polyethylene which is relatively affordable at household level could be promoted.
8. To avoid or minimize biogas failures, proper training for users should be given. Periodical maintenance and follow up should also be carried out following biogas plant installations. And proper institutional arrangements should be set up to avail accessories.
9. Repairing the non functioning biogas plants is not only important to recover the resources wasted but also would have a positive impact in promoting positive attitude for would be users. Therefore, support for funds from non-governmental organizations or other sources should be sought to recover the plants.

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Glossary

Agro-forest: Trees and shrubs grown in close association with crops. They may be planted along borders of farmland, in one side of a plot of farmland or interspersed among crops.

Balanced ecosystem: An ecosystem in which there is healthy and self sustaining association between plants and animals and with their environment.

Biogas: A gas produced by anaerobic fermentation of organic matter-including manure and other biodegradable materials.

Biomass energy: A type of renewable energy which can be derived directly or indirectly from biological sources.

Communal bush land: A public land covered more or less with woody biomass, usually with more of shrubs and scattered tree stands, from which the community obtained wood for fuel and other purposes.

Communal scrub land: A public land with much degraded shrubs and trees from which the community gathers wood for fuel or other purposes. When bush lands become so degraded, they are called scrub lands.

Community forest: Forest grown on communal or public lands. This may be established to rehabilitate or stop the degradation of public land. Both the establishment and management of community forestry may belong to the public.

Deforestation: A process of indiscriminate cutting or over harvesting of trees either for wood products such as lumber, fuelwood, charcoal or to clear the land for farming, settlement, etc.

Energy end use: The purpose of energy that its users decide to perform something with it or have already done something with it. The purposes include cooking, heating and lighting.

Energy end use efficiency: The ratio of units of energy which actually go to the intended purpose, say to the cooking pot, to the total units that certain energy input comprises of.

Fuelwood: All parts of a tree or shrub which is ready to be used as fuel.

Gezim/Timad: A system of local land measurement where one gezim/timad is equivalent to 0.25 hectare.

Household: A group of people, whether with blood relations or not, who live together and share a single meal.

Improved stoves: At times when there is shortage of energy, the problem can be relieved either by increasing its supply or reducing its demand. Energy demand can be reduced through improving its end use efficiency. Improved stoves are, therefore, stoves that help to increase the end use efficiency of energy. 'Mirt' is an example of improved stove. It is an Amharic term which means best or chosen.

Injera: A pan-cake like Ethiopian bread which is commonly prepared from flour of 'teff'(Eragrostis tef) or a mixture of 'teff' and other cereal crops.

Kebele: The lowest administrative organization in the administrative hierarchy of Ethiopia.

Mitad: A circular flat device which is made of clay and is used to bake 'injera'.

Non-zero grazing: A system of livestock management in which the livestock are allowed to graze in the open fields during the day time and confined at home during the night time.

Over grazing: A process by which vegetations are destructed as a result of keeping a large number of animals that exceed the carrying capacity of the resource.

Renewable Energy resources: Energy resources which replenish themselves if they are used in a sustainable ways. They are, therefore, infinite and locally available resources.

Renewable Energy Technologies: Technology refers to an innovation by which human beings create tools and machines that help them to increase their control and understanding of the material world. Renewable energy technologies are, therefore, innovations that have the potential to supply renewable energy service. They can help to generate renewable energy where demand is created.

Shrub: A woody plant with typically multiple stems which arise from just beneath or above the earth's surface. It is generally shorter than a tree.

Sustainable resource exploitation: A system of resource utilization at a rate less or equal to the regeneration capacity of the resource so that it can be utilized for indefinite time.

Traditional biofuels: Types of energy sources that are locally available and produced, and require no high level of conversion. They include fuelwood, charcoal, cow dung and crop residues. They may simply be called traditional fuels or biomass fuels.

Tree: A woody plant commonly with single stem and definite crown. A matured tree is often the tallest plant.

Unbalanced ecosystem: An ecosystem has certain resistance and resilience capacity for disturbances beyond which it may get permanent damages. Hence, unbalanced ecosystem refers to an ecosystem in which the normal relations within biotic components and between biotic and abiotic components have been greatly disturbed.

Unsustainable resource exploitation: A system of resource utilization at a rate faster than its regeneration capacity. Or it is simply system of resource utilization beyond its carrying capacity.

Useful energy: During cooking or doing some other purposes, the entire units of energy in a certain energy input may not go to the intended objective. Some units of energy may be wasted in the form of smoke which dissipates into air or in the form of heat through convection or so. While some other units of energy directly go to the purpose sought. These latter units of energy that go to the objective required are called useful energy.

Vegetation: Vegetation in this paper does refer to trees and shrubs. It is interchangeably used with woody biomass.

Woina dega: An agro-ecological zone in Ethiopia which is equivalent to temperate type of climate.

Woreda: The second lowest administrative organization in the administrative hierarchy of Ethiopia.

Woodfuel: A term that denotes fuelwood and charcoal together.

Woodfuel Plantation: Tree plantation established with the primary objective of supplying sustainable woodfuel resources. Woodfuel plantation can be established either by individuals or by the public.

Wot: Ethiopian sauce.which is mostly eaten with 'injera'.

Zero grazing: A system of livestock management in which livestock are confined at home and given the necessary feed and water regularly.

Appendices

Appendix I: Average Market Prices for Different Grain Types (Br/Qt)

-'Teff'(Eragrostis tef)=365.00 -Barley=315.00 -Chick pea= 425.00

-Wheat=292.50 -Maize=160.00 -Peas=455.00

-Sorghum=160.00 -Beans= 408.00 -Vetch=333.00

-Nigger seed=380.00 -Rape seed=360.00

Appendix II: Temperature and Rainfall Distributions of the Study Site in 2006

Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean/ Total
Temperature (°c)	Max	23.9	22.6	25.1	24.7	24.9	21	19.3	18	20.1	22.9	23.3	23.2	22.4
	Min	13.5	12.8	14.7	17.7	18.5	13.9	15.4	16.7	13.9	16.2	14.6	11.8	15.0
	Mean	18.7	17.7	19.9	21.2	21.7	17.5	17.4	17.4	17	19.6	19	17.6	18.7
Rain Fall (mm)		12	0	6	0	1.7	61.1	359.3	293.4	208	28.8	2.3	31.9	1004.5

Source: Yetnora Meteorological Station

Appendix III: Age-Sex Composition of the Population in the Surveyed Households

Age Group	Females		Males		Total	
	Number	Percent	Number	Percent	Number	Percent
0-4	18	3.93	19	4.15	37	8.08
5-9	35	7.64	29	6.33	64	13.97
10-14	38	8.30	41	8.95	79	17.25
15-19	31	6.77	25	5.46	56	12.23
20-24	21	4.59	27	5.90	48	10.48
25-29	16	3.49	14	3.06	30	6.55
30-34	10	2.18	4	0.87	14	3.06
35-39	17	3.71	10	2.18	27	5.90
40-44	13	2.84	8	1.75	21	4.59
45-49	9	1.97	14	3.06	23	5.02
50-54	12	2.62	9	1.97	21	4.59
55-59	5	1.09	7	1.53	12	2.62
60-64	2	0.44	8	1.75	10	2.18
65-69	2	0.44	5	1.09	7	1.53
70-74	3	0.66	2	0.44	5	1.09
75+	1	0.22	3	0.66	4	0.87
Total	233	50.87	225	49.13	458	100.00

Appendix IV: Educational Status of the Population in the Surveyed Households

S. No.	Educational Status	Frequency			Percent		
		Males	Females	Total	Males	Females	Total
1	Illiterate	70	105	175	15.28	22.93	38.21
2	Read and write	27	18	45	5.90	3.93	9.83
3	1st cycle elementary (1-4th grade)	51	46	97	11.14	10.04	21.18
4	2nd cycle elementary (5-8th grade)	50	39	89	10.92	8.52	19.43
5	Secondary level (9-10th grade)	13	18	31	2.84	3.93	6.77
6	Preparatory	10	5	15	2.18	1.09	3.28
7	Tertiary	4	2	6	0.87	0.44	1.31
Total		225	233	458	49.13	50.87	100.00

Appendix V: Type and Number of Trees and Shrubs Planted by the Entire Surveyed Households

S. No.	Type of trees and shrubs		Number
	Local name	Scientific name	
1	Bahir zaf	Eucalyptus species	16846
2	Yeferenje tid	Cupressus lusitanica	79
3	Shiwshiwe	Casuarinia eqisetifolia	29
4	Suspania	Sesbania sesban	1114
5	Woira	Olea europaea	46
6	Girawa	Vernonia amygdalia	94
7	Shefere	Calocedrus decurrens	88
8	Wanza	Cordia africana	38
9	Graviillia	Grevillea robusta	51
10	Bisana	Croton macrostachyus	14
11	Birbira	Millettia ferruginea	1
12	Sesa	Albizia gummifera	2
Total			18402
Average			204.47

Appendix VI: Heat Values of Different Fuels

Fuel type	Standard unit	Quality	Heat value (MJ/standard unit)
Crop residues	Kg	Air dried	15.50
Charcoal	Kg	Air dried	29.00
Dung	Kg	Air dried	13.8
Fuelwood	Kg	Air dried	14.50
Diesel	L	-	42.70
Kerosene	L	-	43.10

Source: EREDPC, 1994

Appendix VII: Type and Number of Livestock Possessed by Surveyed Households

Livestock type	Cattle						Goats	Sheep	Donkeys	Horses	Chickens
	Cows	Oxen	Heifers	Bulls	Calves	Sum					
Total Number	76	118	36	39	55	324	57	341	69	6	151
Average	0.84	1.31	0.40	0.43	0.61	3.60	0.63	3.79	0.77	0.07	1.68

Appendix VIII: Some Additional Information about the Model Biogas Plants Installed in the Study Area

Location (village)	Functioning years	Type of model	Ownership	Giving service to	Application	Source of fund	Present status (Author's observation)
Subshengo	1986-1990	Floating drum	Farmers' producer cooperative	kindergarten of the producers' cooperative	-Cooking (2 stoves) -Lighting (4 lamps)	UNICEF	The gasholder and digester seem undamaged. Mixing pit has some damages. The rest parts are absent.
Enewonta (Yetnora)	1984-1991	Floating drum	Farmers' producer cooperative	kindergarten of the Producers' cooperative	-Cooking (4 stoves) -Lighting (6 lamps)	UNICEF	Stones are piled on the gasholder while it is in the digester for the reason to prevent accident on livestock due to the space between the gasholder and digester wall. Hence, it is almost obscured from sight. Other parts are absent.
	1985-1991	Floating drum	Farmers' producer cooperative	Recreational center of the producers' cooperative	-Cooking (2 stoves) -Lighting (2 lamps)	Producers' cooperative it self	The gasholder and digester seem undamaged. Mixing pit has some damages. The rest parts are absent
Koncher	1996-1997	Floating drum	Private	Household	-Cooking (a stove)	FBRTPC project fund	Except break on gas transforming tube, damages on gas vales and 'injera' stove, the rest parts do seem undamaged.

Appendix IX: Interview Questionnaire Prepared for Sample Households

Date of interview_______________

Interview starting time ________

Dear Respondents,

The main purpose of this interview questionnaire is to acquire information relevant for synthesizing a research entitled "Use of Biomass Energy and the Need for Developing Renewable Biomass Energy Sources, the Case of Koncher-Tik-Subshengo Area". The questionnaire is particularly helpful to gather data pertaining to the socioeconomic conditions of the households, sources of biomass fuels, amount of biomass fuels consumption and the like without which the objectives of the study cannot be achieved. Therefore, your genuine answer to the interview questionnaire is a necessary condition for the reliability of this research outputs. The findings of this study will help different stakeholders and policy makers in the process of solving the energy problems of the area.

I honestly assure you that your personal information will be kept confidentially. The questionnaire has no any objective other than the one stated. Hence, in no way the study affects anybody negatively. Thank you for your responsible cooperation in advance.

Sample Identification

1. Name of the village___________________
2. Code of the sample household_________________
3. Enumerator's name ___________________

Part I: Demographic Characteristics of the Sample Household

1. Household head's age ___________

2. Household head's sex : a. Male ☐ b. Female ☐

3. Household size _______________

4. Household head's educational status ___________

5. Age-sex characteristics and educational levels of household members, except the head

Household list	Age	Sex	Educational status
1			
2			
3			
4			
5			
6			
7			
8			

Part II: Sample Household's Income, Assets Possessed and Availability of Some Resources

1. Number of animals owned and income from selling animals and/or their products (Birr)

Animal type	Cattle					Goat	Sheep	Donkey	Mule	Horse	Chicken	Apiary (hives)
	Cow	Ox	Heifer	Bull	Calf							
Number												
Yearly income from selling animals												
Monthly income from selling their products												Annual

2. If any, of the total income you got from selling your animals, how much percent of money do you spend?____________ What about from selling their products?_______________

3. Income from production of cereals, oil seeds and pulses for 1997/98 E.C. production year

Crop type	Cereals					Oil seeds			Pulses			
	Teff	Maize	Wheat	Barley	Sorghum	Flax	Nigger seed	Rape seed	Peas	Beans	Chick peas	Vetch
Total yield (Qt)												
Transferred to next year (Qt)												
Sold (Qt)												

4. Of the total money gained from the sale of crops indicated in Q.No.3, how much percent do you spend? ______________

5. Income from other crop types and planted trees for 1997/98 E.C. production year, if any

Crop type	Vegetables (garlic, onion, cabbage, potato, etc)	Spices (basil, rue, ginger, (fenugreek, , etc.)	Cash crops (chat, 'gesho', etc)	Planted trees	Others, if any
Total sale (Br)					

6. Of the total money gained from the sale of crops indicated in Q.No.5, how much percent do you spend? ______________

7. Income from off farm/non-farm activities and other sources per year, if any

Income sources	Trade	Smithing	Pottery	Hiring labor	Carpentry	Remittance	Pension	Selling biomass fuels	Selling crop residues	Selling local beer	Others, specify
Amount (Birr)											

8. Of the total income gained from the sources indicated in Q.No.7, how much percent do you spend? ______________

9. How many 'timads' or 'gezims' of land do you have? ________

10. How do you rate the availability of grazing lands vis-à-vis the size of the livestock?

a. Enough ☐ b. Medium ☐ c. Not enough ☐

11. If your answer is 'c' for Q. No. 10, what do you suggest to make the number of livestock in accordance with the availability of feed and grazing lands?

a. Reducing the number of livestock ☐

b. Increasing the size of grazing lands by reducing the cultivated lands ☐

c. Intensification of livestock rearing using modern system ☐

d. Other solutions, specify ______________

12. What type of water supply do you have?

a. Private water well ☐ b. Spring water ☐

c. Community hand pump water ☐ d. Others, specify ______________

13. How many minutes does your water source take to reach from home? ________

14. Is your water source sufficient and reliable? a. Yes ☐ b. No ☐

15. If no, for Q. No 14, what do you suggest to have sufficient and reliable water source?

____

____

Part III: Woodfuel Sources and Consumption Amount

1. On average human portage, how many bundles of fuelwood do you consume per week?

   ____

2. Do the household use charcoal for home consumption? a. Yes ☐ b. No ☐
3. If yes, in Q.No.2, how many sucks or baskets of charcoal do you consume per month?____________sucks or____________baskets.
4. From where does the family get woodfuel? (Please, tell in order of importance.)
   a. Collecting from communal scrublands/bush lands ☐
   b. Own planted trees and shrubs ☐
   c. Naturally grown wood stands protected in your homestead ☐
   d. Pulling up roots and stumps and cutting remnant naturally grown wood stands from own farmlands away from homestead ☐
   e. Purchasing planted tree stands and preparing them for woodfuel ☐
   f. Purchasing from woodfuel carriers ☐
   g. Others, specify____________

5. If you use communal scrub/bush lands as a source of fuelwood, on average, how many minutes do you spend to fetch a bundle of fuelwood? ________
6. Do you use stumps and roots for fuel? a. Yes ☐ b. No ☐
7. If yes, for Q. No. 6, specify from where you collect it. ____________
8. Does the household own planted trees and shrubs? a. Yes ☐ b. No ☐
9. If yes, for Q. No. 8, what was/were your primary objective/s for planting?____________

   ____

   ____

10. Types and number of trees and shrubs planted

Type of Trees	Eucalyptus species	Cupressus lusitanica	Casuarinia eqisetifolia	Sesbania sesban	Olea europaea	Vernonia amygdalia	Calocedrus decurrens	Cordia africana	Grevillea robusta	Croton macrostachyus	Milletia ferruginea	Albizia gummiferas	Others, specify
Number													

11. Do you think that the number of trees and/or shrubs you have planted is sufficient to meet your wood demand? a. Yes ☐ b. No. ☐

12. If no, for Q. No. 8 or 11, what is/are your obstacle/s for not planting sufficient number of trees and shrubs? (Please tell in order of importance, for more than one reason)

    a. Land ownership insecurity ☐
    b. Shortage of land ☐
    c. Seasonal competition for labour ☐
    d. Free wood availability in the public lands ☐
    e. Others, specify________________

13. If you use wood for fuel from your own planted trees and/or shrubs, how much percent do you think it constitutes your total woodfuel consumption? ________________

14. Have you ever got any institutional support or advice about tree planting?

    a. Yes ☐ b. No ☐

    *If yes, please state the support or advice________________

15. How do you rate the current availability of wood for fuel in your locality?

    a. Enough ☐ b. Moderate ☐ c. Not enough ☐

16. If your answer is "c" for Q. No. 15:

    i. what do you think the reasons? (Please tell in order of importance).

    a. Increasing demand of woodfuel for home consumption ☐
    b. Increasing number of woodfuel sellers ☐
    c. Increasing number of local bear sellers ☐
    d. Increasing demand of wood for fencing and construction of houses ☐
    e. Deforestation to expand cropping lands ☐
    f. Deforestation due to over grazing ☐
    g. Others, specify________________

    ii. do you realize some problems which come as consequences of woodfuel scarcity in your locality? a. Yes ☐ b. No ☐

    * If yes, please specify the major consequences________________

    ____

    ____

17. What do you think the lasting solutions for the scarcity of woodfuel? ________

____

____

Part V: Dung Fuel and Crop Residue Sources and Consumption Amount

1. Do you use animal dung for fuel? a. Yes ☐ b. No ☐
2. If no, for Q. No. 1, please justify your answer ________________

____

3. If yes, for Q. No. 1:

   i. how many baskets of dung do you consume per week? ________

   ii. from where do you obtain it?

   a. Communal grazing lands ☐

   b. Own livestock ☐

   c. Purchasing ☐

   d. Both from communal grazing land and own livestock ☐

   e. Both purchasing and own livestock ☐

   f. Communal grazing lands, own livestock and Purchasing ☐

   d. Others, specify ________________

   iii. do you use dung fuel other than cattle's? a. Yes ☐ b. No ☐

   * If yes, please specify the type of animals? ________________

   *If no, why? ________________

   ____

4. Have you ever sold extra dung fuel from home consumption?

   a. Yes ☐ b. No ☐

5. Do you use crop residues for fuel? a. Yes ☐ b. No ☐

6. If yes, for Q. No. 5, on average human portage, how many bundles of crop residues do you consume per week? ________

   - Specify the type of crops you use ________________
   - If you don't use crop residues all year round , specify the months in which you use this fuel type ________________

   ____

7. If no, for Q. No. 5, please justify your answer.____

____

Part VI: Energy End Use Type and Efficiency

1. Please specify the end uses of each fuel type which you are using.

Fuel type	Cooking	Lighting	Heating	Others, specify
Fuelwood				
Charcoal				
Animal dung				
Crop residues				
kerosene				
Others, specify				

2. What type of 'injera' stove do you have?

   a. Traditional 'three stone' stove   b. Modern ('mirt') stove

   c. Closed mud made stove   d. Others, specify________________________

   *If you have improved stove, please state your opinion about it. ________________

   ____

   ____

3. If you use charcoal, what type of stoves do you have?

   a. Traditional (iron) charcoal stove   b. 'Lakech' charcoal stove

   c. Others, specify______________________________

4. Have you ever been given any training or education about improved stoves?

   a. Yes ☐   b. No ☐

5. Do you have some knowledge about biogas technology? a. Yes ☐   b. No ☐

   *If yes, what is your attitude about it? ______________________________________

   ____

   ____

   ____

Interview ended at time______________

Thank you!

Appendix X: Key Informant Interview Checklists

A. For Local Elders

1. Is the overall vegetation cover of the area declining or increasing over time? Why?
2. If you believe that vegetation cover of the area is declining over time, do you think that some species of trees and/or shrubs are extinct or on the verge to extinct from the locality owing to devegetation?
    - Was there any critical time you know when devegetation was exacerbated?
3. How do you evaluate the tree planting habits of the people in your locality? Is there change over time?
4. How do you evaluate the overall supplies of woodfuel in your locality? Is there change over time?
5. Are there changes in the types of biomass fuels utilized for different end uses-cooking, heating and lighting overtime?
6. Are there changes in the comparative size of livestock and grazing lands in your locality?

B. For Development Agents

1. How do you evaluate the current woodfuel availability of the area?
2. If there is woodfuel scarcity:
    a. What do you think the causes for the scarcity?
    b. Are there problems prevailing as a result of woodfuel scarcity?
    c. Are there any institutional measures taken towards minimizing the problem in the area? If any, how are the measures successful?
    d. What do you suggest as lasting solutions for the problem of woodfuel scarcity in particular and energy problem of the area in general?
3. How do you evaluate the overall tree planting activities of the people in the area?
4. What favorable and constraining factors are there to further promote tree planting activities?
5. The common planted tree species observed in the area is eucalyptus. Eucalyptus is believed to have some negative ecological impact. Is there any attempt to promote other fast growing but ecologically friendly species of trees and shrubs?

6. How do you evaluate the available grazing lands vis-à-vis the size of the livestock population? If you say there is over grazing, what do you suggest to solve the problem?
7. How do you evaluate the supplies of water in the area? If you say there is problem of water supply, what do you suggest to solve the problem?

*** Additional Points for Koncher-Sasaberay Kebele Development Agent Only**

8. Do you have some idea why the area was selected for installation of model biogas plant? What were the criteria for selection of the beneficiary individual? What was the original intention for installing it there?
9. How was the initial reaction of the people living in the environs of the biogas plant?
10. What do you think the reasons for the failure of the model biogas plant?
11. Are there possibilities to make it functional again? If there are possibilities, why have they not implemented yet?
12. What favorable and constraining factors are there to promote biogas technology in the area?

C. For Woreda Rural Energy Development Expert

1. How do you evaluate the current woodfuel energy availability of Koncher-Tik-Subshengo area?
2. If there is woodfuel scarcity in the area:
   a. What do you think the causes for the scarcity?
   b. Are there problems prevailing as a result of woodfuel scarcity?
   c. Are there any institutional measures taken towards minimizing the problem in the area? If any, how are the measures successful?
   d. What do you suggest as lasting solutions for the problem of woodfuel scarcity in particular and energy problem of the area in general?
3. How do you evaluate the overall tree planting activities of the people in the area?
4. What favorable and constraining factors are there to further promote tree planting activities?
5. Do you have some idea why the Koncher village was selected for installation of model biogas plants? What were the criteria for selection of the beneficiary individual? What was the original intention for installing it there?

6. How was the initial reaction of the people living in the environs of the biogas plant?
7. What do you think the reasons for the failure of the model biogas plant?
8. Are there possibilities to make them functional again? If there are possibilities, why have they not implemented yet?
9. What favorable and constraining factors are there to promote biogas technology in the area? Is there any plan prepared to promote biogas technology at woreda level?

D. For Woreda Forestry and Agro-forestry Expert

1. How do you evaluate the current fuelwood energy availability of Koncher-Tik-Subshengo area?
2. If there is woodfuel scarcity in the area:
    a. What do you think the causes for the scarcity?
    b. Are there problems prevailing as a result of woodfuel scarcity?
    c. Are there any institutional measures taken towards minimizing the problem in the area?
    d. What do you suggest as lasting solutions for the problem of woodfuel scarcity in particular and energy problem of the area in general?
3. How do you evaluate the overall tree planting activities of the people in the area?
4. What favorable and constraining factors are there to further promote tree planting activities?
5. The common planted tree species observed in the area is eucalyptus. Eucalyptus is believed to have some negative ecological impact. Is there any attempt to promote other fast growing but ecologically friendly species of trees and shrubs?

E. For Owner of Biogas Plant at Koncher Village

1. What do you think the reason/s why you were selected for biogas technology beneficiary?
2. When was it installed? By whom was it installed?
3. For what end uses did you utilize the technology? What did you do with the slurry? How long did you use the technology?

4. What was your attitude about the technology at the beginning? What is your attitude about it now? (Please enumerate the advantages and limitations which you did experience).
5. Were you given training as how to run the plant?
6. Did you have enough labour to be able to feed the plant regularly?
7. Was there somebody who used to monitor the plant after the installation?
8. What do you think the reasons for the failure of the biogas plant?
9. Have you ever tried to get the plant repaired?
10. Are you ready to cover the cost of maintenance if somebody promises to repair the plant to you?

F. For the Former Leaders of Producers' Cooperatives

1. How many biogas plants were constructed during the producers' cooperative? When were they installed? Who did install them? What was the source of fund?
2. For what end uses did you utilize the technology? Number of gas burners and light bulbs, if any?
3. How long did the plant give service? Do you remember why they did fail functioning?
4. What did you do with the slurry?
5. What is your attitude about the technology? (Please enumerate the advantages and limitations which you did experience).
6. Do you think that it is possible to promote the technology now in your locality?

G. For Zonal and Regional Levels Rural Energy Experts

1. As many literatures reveal, nowadays there is a growing gap between demand and sustainable supply of fuelwood in the zone/region, so what do you think the lasting solutions to the problem?
2. Biogas is believed to be one alternative source of energy as a lasting solution to the problem of energy particularly in the rural areas. Is there any plan prepared to promote biogas technology at zonal/regional level?
3. Who is responsible to repair biogas plants constructed particularly by FBRTPC but failed to function in different parts of the zone/region including Dejen woreda?

4. In case if biogas owner wants to cover the cost of maintenance or somebody wants to have the technology privately, is there any assigned expert in the institution who can facilitate to avail necessary materials and give technical assistance as soon as possible?

H. For an Expert in Biogas Technology from the FBRTPC (A Member of a Team Who Constructed Biogas Plants in Different Woredas Including Dejen)

1. What were the initial objectives of constructing biogas plants including Dejen in different woredas of the region by the FBRTPC?
2. What were the criteria for selecting biogas technology beneficiaries-woredas, kebeles and individual households?
3. Were beneficiary individuals given training as how to run the plant?
4. What was the source of fund for the construction of biogas plants installed in different woredas including Dejen by the FBRTPC?
5. Was there any assigned expert who used to monitor or give technical assistance in case of failure of plants for different reasons?
6. Do you have some idea as to why the plant installed at Dejen woreda failed to function?

Appendix XI: Focus Group Discussion Checklists

1. How do you evaluate the current woodfuel availability of your locality?
2. If there is woodfuel scarcity problem:
   a. What do you think the major causes leading to the problem?
   b. Are there problems prevailing as a result of woodfuel scarcity?
   c. Do you think that some tree and/or shrub species are extinct or on the verge to extinct from your locality as a result of devegetation?
   d. Are there any institutional support given to minimize the problem in the area?
3. . How do you evaluate tree planting activities of the people in your locality? What are the factors that promote or retard planting activities of the people in the area?
4. Are there fast growing tree or shrub species in your locality?

5. Are there changes in the scale of using of dung and crop residues as fuel in your locality? Why? What problems or consequences do you see if there is increasing use of cow dung and crop residues as fuel?
6. What do you suggest as lasting solutions for the energy problems of your locality? Why haven't they practiced yet?
7. How do you see the availability of grazing lands in comparison to the size of livestock population? If there is over grazing, what do you think the solutions?
8. Are your water sources sufficient and reliable? If not, what do you suggest to solve the problem?

Declaration

I, the undersigned, declare that the thesis is my original work, has not been presented for a degree in any other university and that all sources of material used for the thesis have been duly acknowledged.

Declared by:

Candidate

Confirmed by:

Advisor