HOUSEHOLD ENERGY, COPING STRATEGIES AND HEALTH EFFECTS IN THE BONGO DISTRICT OF GHANA

By

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(B.Sc Renewable Natural Resource Management)

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DECLARATION

I hereby declare that this submission is my own work towards the PhD and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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Head of Department Signature Date

ABSTRACT

Currently millions of people around the globe rely on wood as a source of fuel for cooking. Although this situation not only pertains to impoverished rural communities, it is within these communities and in developing countries like Ghana that this is occurring the most. The burning of wood in open fires is causing a number of health problems but is also deteriorating for the rural household economy as well as for the local and global environment. Women and children are the main groups exposed to the indoor smoke produced while cooking. Illnesses as a result of this exposure take millions of lives every year. This thesis looks into the relationship between rural household energy consumption patterns, coping strategies and health effects for domestic cooking in the Bongo district in the Upper East Region of Ghana.

Several methods including household survey; focus group discussion and key informant interviews were employed to collect data at household and individual levels. The methods involved queries on several aspects of household energy consumption. The survey of household energy consumption pattern was carried out in fifteen communities comprising of 625 households between January-April 2006. The households surveyed covered heterogeneous population belonging to different income, educational and social groups. Daily average concentrations of respirable particulates and carbon monoxide from woodsmoke in 45 rural homes selected through stratified random sampling from the Bongo district in Ghana was also quantified using UCB Particle Monitors. CO was measured with Onset HOBO Loggers. Graphical, cross-tabulation and multinomial logistic regression methods are applied to data drawn from Household Survey.

The results indicated that there was more availability and utilization of solid biomass fuels as energy resources in domestic sector as compared to the commercial fuels. Crop residues, firewood and Charcoal were found to be the three main fuels used for cooking, though LPG was also used along with biomass fuels. But complete conversion to cleaner fuels has not taken place yet even in households that has been using LPG for many years. Income was an important factor determining the choice of fuel for cooking, but there were some socio-cultural factors which were equally important in making fuel preferences at household level.

The use of biomass fuels; from it collection to combustion also has impacts on the health of the user. Result from the woodsmoke monitoring shows that the values of respirable particles ($PM_{2.5}$) ranged from 0.05–6 _g.39mg/m^3 and 2.90- 45.60ppm for CO. Both $PM_{2.5}$ and CO concentrations were well above both the World Health Organisation 24-hour Guideline and Interim Targets. Observed health effects from the collection and use of biofuels included eye discomfort, headache, backache, coughing, skin irritation, stiff necks and chest pains. Extrapolation of diseases with PM concentration showed that households were in a higher risk of being infected with respiratory diseases from the use of biomass fuels. This observation confirms with the self-reported symptoms associated with biomass fuel use where respiratory diseases dominated (cough, wheezing, shortness of breath, eye irritation). Considering that traditional biomass will likely continue to be the most popular cooking fuel in rural areas of the district in the near future, and that households can achieve considerable welfare gains from improvement in stoves and kitchen ventilation, the analysis suggests that the government should consider reviving the improved stove program with a new advanced stove strategy coupled with conducting advocacy campaigns on how to improve kitchen ventilation.

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I think that even though being a Ph.D. student is stressful and difficult, every day during the last five years I have been happy to go to work. The atmosphere in the department of Planning has made all the difference. I would like to thank the entire staff at the Department of Planning for their help in many aspects during my studies. There are so many friends and colleagues to thank. I am sincerely grateful to all my colleagues especially Dr. De-Graft Owusu Manu and Dr Michael Poku-Boansi .

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ABOVE ALL, I GIVE GLORY AND HONOUR TO GOD

DEDICATION

This work is dedicated to all rural women in Ghana. Your hard work and sacrifices are much appreciated.

LIST OF ABBREVIATIONS

AFREPEN	African Energy Policy and Research Network
AGDP	Agricultural Gross Domestic Products
ALRI	Acute Lower Respiratory Infection
AQG	Air Quality Guidelines
CDM	Clean Development Mechanism
CHIED	Center for Entrepreneurship in International Health and Development
CO	Carbon monoxide
COPD	Chronic obstructive pulmonary diseases
DALYs	Disability-adjusted life years
DANIDA	Danish International Agency
DFID	Department for International Development
DME	Dimethyl Ether Gas
EPA	Environmental Protection Agency
ESMAP	Energy Sector Management Assistance Programme
FAO	*Food and Agriculture Organisation*
GAMA	Greater Accra Metropolitan Area
GDP	Gross Domestic Product
GHGs	Green House Gases
GoG	Government of Ghana
GPRS	Growth and Poverty Reduction Strategy
GSS	Ghana Statistical Service
IAP	Indoor Air Pollution
IEA	International Energy Agency
ITDG	Intermediate Technology Development Group
ISSER	Institute of Statistical, Social and Economic Research
JI	Joint Implementation (in the Kyoto Protocol)
JICA	Japan International Cooperation
KITE	Kumasi Institute of Technology and Environment
KNUST	Kwame Nkrumah University of Science and Technology

LPG	Liquefied Petroleum Gas
MDG	Millennium Development Goals
MOE	Ministry of Energy
NDPC	National Development Planning Commission
NGO	Non-governmental Organisation
PIC	Product of Incomplete Combustion
PM	Particulate matter
UNDP	United Nations Development Programme
WHO	World Health Organization
WEA	World Energy Assessment
WEC	World Energy Council
WLPGA	World Liquid Petroleum Gas Association

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CHAPTER ONE

INTRODUCTION

1.1 Background

It is evident that, throughout history, mankind's ability to live in harmony with its environment has been dependent upon the availability of energy. Human civilization, in particular, has flourished by using far greater amounts of energy extra somatically (i.e., outside the body) than required for basic survival, harnessing it for improving living conditions, agricultural productivity, industrial advancement, and health, cultural, and scientific betterment. (Masud, et al, 2007). Today, the world is an unprecedented period of growth in its human population, made possible by a technology revolution over the past 200 years that has dramatically increased mankind's ability to harness energy from nature (WEC, 2007). This has, in turn, had an enormous effect on human society, individual and communal behavior, and social evolution, with the emergence of unprecedented affluence and large-scale urbanization and industrialization leaving the world precariously perched on an increasingly unstable global energy access structure which is producing diminishing returns at ever greater economic, environmental and security costs.

All such progress depends vitally on modern energy supplies and transformation system primarily processed liquid and gaseous fuels and electricity without which it would not have been possible to move beyond fulfilling very basic human subsistence needs. Yet the oldest human energy technology, the home cooking fire, persisting as the most prevalent fuel-using technology in the world is under serious security issues, particularly for developing countries. According to the World Energy Assessment (2004), currently more than two billion people in the world cannot access energy services that are based on efficient use of gaseous and liquid fuels, or electricity. Without this access they rely on the burning of solid fuels to generate energy for essential daily activities such as cooking often in open fires or in inefficient, smoky stoves. Nowhere is this challenge more obvious than in rural areas of developing countries.

Similarly, in Ghana, the bulk of the country's energy consumption is from biomass in the form of firewood and charcoal accounting for about 60 percent of total energy consumption. Whiles the urban areas consume the bulk of charcoal produced, the rural areas are more dependent on firewood (Ministry of Energy, 2003). According to Abavana (2004), the overall family energy consumption in rural communities has a clear thermal component which is met by biomass. This accounts for almost 95% of total rural household energy consumption. Wood fuel (charcoal and firewood) accounts for more than 63% of total energy consumed in the country and charcoal consumption alone (674ktoe) is more than the total electricity generation in Ghana (Ahiataku-Togobo, 2008).

According to the World Health Organization (2008) the reliance on solid fuels for cooking purposes in inefficient, traditional open fires and stoves causes constant damage not only to the environment, but also to the economy and the health of the members of rural families. the noxious and hazardous products of combustion from stoves, particularly indoors, in poorly ventilated houses, are a major source of health problems including acute and chronic respiratory diseases, malignancies of the aero-digestive tract and lungs, burns, eye diseases, low birth weights and increased infant mortality (Bruce et al., 2002). The World Health Organization estimates that 1.6 million people die from the adverse effects of indoor air pollution each year or one person every 20 seconds. In Ghana, estimates from the WHO (2007) of the national burden of disease due to indoor air pollution from the solid fuel use for the year 2002 are quite alarming. Women and young children bear the brunt of illness as a result of their exposure in the home.

Beyond the risk to human health, inefficient and unsustainable cooking practices can have serious implications for the environment, such as land degradation and local and regional air pollution, acidification of water and soils, or greenhouse gas emissions. According to the World Bank (1984) fuel wood gathering is one of the major contributory factors to deforestation, which is already claiming about 10 million hectares of forest each year in the developing world. This excessive deforestation has resulted in fuel wood crises in many countries and hence agricultural residue and animal dung are being substituted for fuel wood. A study in Ghana found that *Celtis zenkeri*, prized as fuelwood and used by 80 percent of households in two villages during the past decade, was no longer available (Osei, 1993). In other areas, such as rural China, exhaustion of traditional fuels has prompted a switch to coal for household use with its own consequences.

Rural household energy consumption has thus become a major focus of concern in all developing countries. On one hand, rural household fuel consumption constitutes the majority of total national energy consumption in many developing countries; on the other hand, the social and economic costs of household fuel to the rural poor are high and rising rapidly. With a rural population of over 11.4 million people and a human development value of 0.553, Ghana ranks 135th among 177 countries on poverty levels (UNDP, 2007). While poverty is highest in the northern part of the country, rich and poor districts are found all over (NDPC, 2005). In this context, inequitable access to clean energy sources in the country is major impediment to sustainable development. This is amply borne out by the fact that misery of close to 37 per cent of the rural masses who do not have access to safe source of drinking water and over 58 per cent who lack access to proper health care can be addressed to a large extent through the provision of clean and efficient energy sources (GPRS I, 2003). Hence, in order to address the needs of sustainable development, it is necessary to examine the constraints related to rural energy and to find appropriate responses that have a bearing across all sectors of rural development. This thesis proposes and discusses the ways to mitigate the consequences of this complex worldwide issue.

1.2 The Problem Statement

At the centre of Ghana's development dilemma is the question of sustainable household and commercial energy demands against current supplies. Energy scarcity is one of the factors that currently threaten economic growth in Ghana. For instance, in many parts of the country, acute fuel scarcities render meaningful economic growth difficult. Worst affected are the rural communities and urban slums, where many households are unable to grow past their subsistence levels. The scarcity has also led some households to substitute lower-grade fuels that tend to burn more inefficiently, such as crop residues for fuelwood.

The use of traditional fuels, as already cited in the previous section has serious consequences for human health. In spite of the inherent disadvantages associated with traditional fuels/ stoves, majority of the rural population use them. Therefore, understanding the dynamics of inter-fuel substitution is important as more and more households get access to modern fuels in rural areas Currently, the process of fuel switching in rural areas is very poorly understood (Leach ,1992). Most of the current understanding about inter-fuel substitution comes from urban case studies that simply describe the process of moving from biomass fuels to a higher value modern fuel as a linear one-way process driven by increasing household income (Hosier and Dowd, 1988). As per capita income increases, households generally switch to cleaner and more efficient energy systems for their domestic energy needs (i.e. move up the ‘‘energy ladder’’) (Bruce et al, 2000). However, the picture is often complex as in many rural areas, households often employ a ‘‘multiple model’’ of stove and energy use in which households stretch across two or more steps of the energy ladder and fuel substitution is often partial (Balakrishnan et al, 2004). People use multiple fuels to acquire energy security (Kammen et al, 1995). Besides economic reason, there are some socio-cultural practices that influence people’s fuel choice. Such factors may include a number of household characteristics and social class, which is a function of wealth and defined by factors such as the type and ownership of the dwelling unit, money income etc. Increasing fuel shortages compels two broad reactions by households: first, some households will switch to other fuel alternatives. Second, the households that are not able to switch (for whatever reasons) may have to adjust their cooking patterns to the prevailing levels of shortages (Masera, et al., 2000). However, some of the coping techniques may entail dietary and health consequences.

To this effect, identification of the factors governing the current energy consumption patterns, coping strategies and health issues in the face of household energy insecurity and usage will be helpful to show the appropriate target variables in the attempt to influence the exiting patterns and hence bring about the envisaged transition. Knowledge about the various factors underlying the existing consumption pattern helps policy makers to prescribe measures that will strengthen the conditions that encourage use of modern fuels while opting for measures that will weaken reliance on traditional fuels. In general, formulation and implementation of energy related policy requires detailed knowledge of the existing consumption pattern, substitution possibilities among the various household energy sources and the responsiveness of household energy demand to changes in prices, income, etc.

There exist several studies on Ghana's rural energy consumption. Steckle (1972) examined the types of fuel used for cooking and found out they were mainly woodfuel, charcoal and kerosene. Ardayfio-Schandorf (1982, 1986) analysed the relationships between rural energy, women's work and family, and Amaka-Otchere (2006) analysed the relationship between charcoal production and impact on women and environment nutrition. Osei (1996) examined Rural energy technology employed in the procurement of firewood.

Several gaps however still exist, as none of the studies made rigorous quantitative studies on the levels of indoor air pollutions from the burning of biomass fuels in households, socio-economic factors and fuel consumption pattern simultaneously. The present study shows fuel use pattern at household level and factors influencing fuel choices available to households of Bongo district, and the different factors that affect a household's probability of choosing one cooking fuel against another**.** Furthermore, the paper focuses on the adverse health effects of IAP on women and children in the district. From the issues above, the research will be interested in finding answers to the following questions:

1. What is the current energy use patterns and accessibility of rural households?
2. What are the implications of household energy scarcity on the livelihoods of households?
3. What are the determinants, of household cooking fuels choices?
4. What are the heath issues related to the use of household energy fuels?

5. What are the policy implications of the observed patterns?

1.3 Study Objectives

The overall objective of this study is to assess the extent of household energy security Rural Ghana and to draw policy implications based on the study. The specific objectives of the study are as follows:

1. To examine the extent of household energy consumption and usage patterns in the Bongo district of Ghana.
2. To investigate what the implication of energy scarcity on household livelihoods are, especially with regard to women.
3. To estimate the determinant of energy choices/substitution in the study area, to help in policy formulation.
4. To examine the association among combustion of biofuels, air pollution and women health
5. To highlight the policy implications of the energy demand patterns on household energy welfare and demand.

1.4 Significance of Research

The relevance of this study lies within the dealing of a worldwide issue that implies severe social, economic and environmental problems generated through rural cooking activities and also within the overall objective of the United Nations (UN), oriented to achieving sustainable development in its Millennium Development Goals (MDGs). UN (2004) finds that improvements in the supply of cooking energy are needed in order to reach more respectable living conditions for the population. The MDGs aim to reduce the number of persons without electrical power and of those who do not have access to clean cooking fuels. LPG is mentioned as the cooking fuel which is in line with these goals, and its minimum consumption is defined as around 1 GJ/year. The sixth MDG mentions an increase in access to modern fuels as one of the interventions in order to ensure a sustainable environment. According to the UN, clean fuels will reduce the residential demand for bio-mass, in this way reducing the clearance of trees and the degradation of the earth, and as well reducing greenhouse gas emissions and indoor air pollution. The MDG guidelines require that each country institutes sustainable development policies aimed at reducing the degradation of natural resources.

These current issues frame a suitable setting for inquiring into more sustainable solutions for a problem that is currently affecting millions of people in the world (UNDP, 2002). It is therefore addressed with an intended contribution of exposing and analyzing one more of several actions that could lead towards a more sustainable rural development concerning cooking technologies. Within this thesis all three pillars of sustainability are touched, by suggesting improvements in the rural families' welfare, wealth and environment. In a country where more than 66 percent of the total population use wood fuel for cooking (Energy Commission, 2005), this study intends to target a particular group of families in rural Ghana, families for whom just a small change would have a substantial impact on their daily lives.

The result of this work may also be important in the international negotiations on the reduction of greenhouse gas emissions; given that Ghana is a signatory to the Kyoto Protocol. The Kyoto Protocol, signed in December 1997, created mechanisms to combat the emission of greenhouse gases: carbon market, Joint Implementation (JI) and Clean Development Mechanism (CDM).

The Protocol stipulated, as an overall rate, that the industrialised countries reduce their emissions of such gases by 5 percent (between 2008 and 2012), in relation to the volume emitted in 1990. In carbon emitting businesses, the industrialised countries—the greatest polluters—may invest in reducing greenhouse gases in other countries and thus gain carbon credits. In addition to reducing greenhouse gas emissions the JI and CDM projects may also diminish local pollution and reduce its impact on health, improve energy supply security, create jobs and make possible technology transfer. These secondary benefits may push the Government of Ghana to negotiate climate change projects, in the area of use of biomass for cooking, together with other outside investors or through the CDM.

It is hoped that the study would provide energy planners and policy makers with valuable insights into the impact of energy poverty on people, especially rural women and their families, in order to develop pro-poor and engender policies based on real evidence.

1.5 The Scope of the Study

Given the constraints of time and resources and a particular research agenda, the concepts, theories, actors and spatial coverage of the research have to be clearly defined. The research work is designed to provide an insight into the cooking energy situations of the rural poor and its implications on the environment and the socio-economic status of the household. A quantitative analysis is also carried out, to determine factors that contribute to the demand of cooking energy choices in households and the adoption of new technologies such as improved stoves. Cooking energy choices were limited to firewood and crop residues, since they constitute the bulk of cooking energy in the study area. The analysis is done with data collected from the Bongo District, which was selected for its peculiar spatial, socio-economic and ecological conditions.

National, regional and global issues are referred to within the framework of understanding the issues at the local level.

In the evaluation of the environmental impact of firewood collection, forest degradation rather than deforestation is emphasized because the former mainly comes from local population withdrawals from natural resources, including firewood collection but also over-grazing and fires, etc., while the latter is mostly due to forest exploitation and commercial logging (Duraiappah, 1998; Trossero 2002; Wunder , 2001). In the broader debate about poverty and the environment, forest degradation is also seen as a source for a further impoverishment of poor people who strongly depend upon forest resources (Duraiappah , 1996, 1998).

1.6 Thesis Organization

The thesis report is organised into six chapters. Chapter 1 is the introduction, while Chapter 2 provides a literature review on cooking energy in the residential sector, with the objective of analysing cooking fuels and technologies, indoor and outdoor air pollution, definition of clean cooking fuel and the determinant factors in choice of fuel.

Chapter 3 presents the current situation as regards supply of cooking energy in the rural areas of Ghana, and contains information on socio-economic characteristics, demand for and consumption of cooking energy, emission of air pollutants and initiatives for improvement in the supply and consumption of cooking energy. Chapter four defines the research methodology applied in the study. The various research methods employed in the collection of primary and secondary data are also presented.

Chapter 5 and 6 use the information developed in Chapters 2 and 3 in order to identify the health effects associated with the usage household cooking fuels. Comparisons across other studies are also presented. Possibilities for meeting the demand for cooking energy in the study area and to Quantitatively analyse the impacts of fuel substitution are also presented in the chapter. Chapter 7 presents the conclusion of the study.

CHAPTER TWO

LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK – COOKING ENERGY IN DEVELOPING COUNTRIES

2.1. Introduction

This chapter develops a framework for carrying out analyses of cooking energy in rural areas in general, and in the Bongo District in particular. This contributes towards the overall focus of this study, which is to analyze rural cooking energy consumption as far as its effect on the user and the environment is concerned. Peculiar characteristics of rural households, together with earlier models of energy consumption in developing countries are used to develop a suitable conceptual and analytical framework. This analytical framework helps to meet the study goal that is assessing the health hazard associated with the cooking energy used, and to find the alternative sustainable fuel to meet the domestic energy demand.

2.2 Overview of the Worlds Energy Resources and Consumption.

Since the discovery of fire, energy has been a major factor in development (Colombo, 1996). Fire for cooking made possible the consumption of a much wider variety of foodstuffs and greatly enhanced food safety. Fire for heating allowed man to expand the range to higher latitudes and elevations, and it fundamentally transformed our patterns of social development. According to Lofteness, (1978), only man has been able to effectively alter his environment to suit himself through the use of energy sources. The type of energy we use and the type of fuel technology we apply can have a major impact on facilitating sustainable livelihood, improving health and education and significantly reducing poverty. Access to adequate levels of energy service is a crucial prerequisite for the development of any country (Karekezi and Ranja , 1997). It is evident that, each major economic and social change in the world has been accompanied by the discovery and availability of the technology of exploitation and social demand for new energy sources and considerable increase in the rate of energy consumption.

Exploitation of animal power about 5000BC was an essential component of the advent of agriculture and the ensuing of stable settlements, with all its social and cultural consequences (Colombo, 1996). During the Renaissance the use of wind in sea transport and for churning mills had a profound influence and contribution to the expansion of culture and commerce. The windmill, which first appeared in Europe in the 12th century, was used primarily for pumping of water and the grinding of grain (Lofteness, 1978).

The major industrial development in Europe came after the invention of the steam engine that freed industry from the geographical limitations imposed by power resources and permitted location of industry either near the other primary resources or near convenient transportation (Lofteness, 1978). At the beginning of the 19th century, the European industrial revolution was made possible by the use of hydropower and coal as an energy source (Farinelli, 1997).

The use of water as the source of energy to turn water wheels for the grinding of grain dates back in to the Roman times (Lofteness, 1978). The conversion of hydraulic energy to mechanical energy for the operation of factories reached its peak during the 17th century, at which time the steam engine came into use and permitted the location of factories elsewhere other than on river banks. Hydraulic resources became important once again with the development of efficient electric generators and transmission technology that permitted location of hydroelectric plants several hundred miles from the points of energy consumption (Lofteness, 1978). Electricity stimulated new forms of industry and changed the urban environment, while, especially after World War II the availability of an abundant, flexible, easy to transport and cheap energy sources, oil and natural gas, has fueled the great transformation of the industrial society (Farinelli, 1997).

Prior to the 17th century, the productivity of man was mainly determined by his own labor and that of domesticated animals (Lofteness, 1978). Since the first use of inanimate energy that provided man with a cost far below that of animate energy sources, there has been, undoubtedly, some correlation between the use of energy and economic productivity (Lofteness, 1978). It is now more generally appreciated that inequalities in people's access to resources and the resultant ways in which they use them constitute greater challenge for sustainable development (Elliott, 1999). There is tremendous diversity in terms of peoples' access to resources of all kinds. The case of energy use illustrates how inequalities in access to resources could be considered at a number of levels. The decline in the traditional use of biomass and the increase in modern energy use are viewed as an indication of socioeconomic development (Zandbergen and Moreira, 1993; Cited in Karekezi and Ranja , 1997).

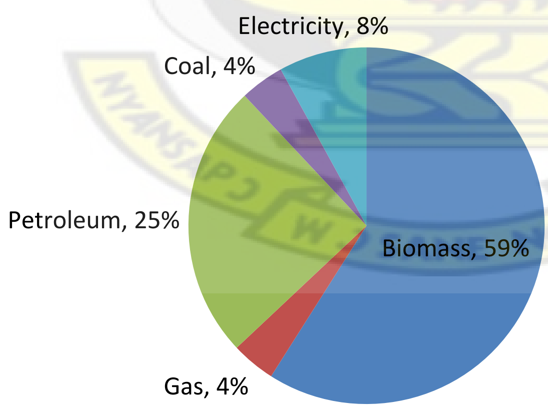
Out of the total primary energy demand in industrializing counties in 1980, 98 percent supply was met from the modern energy sector and only the remaining 2 percent from biomass, while the same pattern was 48 and 52 per cent respectively in the developing countries. Moreover, even within developing countries, there are extremes in which biomass serves as the major or exclusive energy source (Miller, 1986). On the other hand the per capita consumption of modern energy in the developing world is extremely low, relative to that in the industrial countries. For example, in the early 1990s per capita consumption of modern energy in the US was 8 tons of oil equivalent energy per year, which was 80 times more than that of Africa, 40 times more than that of South Asia, 15 times more than that of East Asia and 8 times more than that of Latin America (World Bank, 1996).

As countries grow richer, their patterns of energy consumption tend to change, and the household energy consumption share diminishes while industrial consumption grows. In the OECD countries, the two largest sectors of energy uses are industry and "others" (mainly residential), accounting for about 40 and 30 per cent respectively. Transportation comes next with about 20 per cent. In the poorest countries, the consumption for household purposes is dominant (IEA, 2006). This difference in the patterns of energy use reflects, on one hand, the inefficiency in the traditional use of biomass fuel and, on the other hand the much greater importance of the household sector, especially the dominance of the rural economy in the developing countries (Dunkerely, 1981).

Traditional fuels accounts for an estimated one-third of primary energy use in developing countries. In many developing countries, the biomass share of primary energy exceeds 70 percent. Over two billion people cook by direct combustion of biomass (UNDP, 2002), primarily in rural areas. Traditional use of biomass fuels is typically inefficient, relying largely on low-cost sources such as natural forests, which in turn contributes to deforestation (Reddy et al, 1997).

Though, it is used traditionally with low efficiency, biomass has numerous economic and environmental advantages, for the global as well as for local energy balances. Biomass fuels make no net concentration to atmospheric carbon dioxide if produced and used sustainably to allow regrowth of biomass (HABITAT, 1993). Biomass accounts for an estimated one-third of primary energy use in developing countries. In many developing countries, the biomass share of primary energy exceeds 70 percent (Kartha and Larson , 2000). A number of developed countries also use biomass quite substantially. For example the United States has some 8000 MWe of biomass-fueled electricity-generating capacity installed, primarily as combined heat and power production systems. Residues of industrial processes and logging are the principal biomass fuels used in industrialised countries (Kartha and Larson, 2000). Figure 2.1 shows the energy consumption by type in Africa entailing the dominance of biomass fuel for the overall energy demand.

Figure 2. 7: Energy Consumption by Type in Africa (2001)



Source: IEA, 2003

However there are considerable variations in energy consumption among different regions and countries of Africa. For example, the share of biomass energy of total energy exceeds 81 percent in Sub- Saharan Africa compared to only 4.1 percent in North Africa and 16.5 percent in South Africa (table 2.1).

Table 2.1 Energy consumption by Region in Percentage, 2001

Region/Country	Biomass	Petroleum Products	Electricity	Gas	Coal
North Africa	4.1	61.5	15.1	18.1	1.3
Sub-Saharan Africa	81.2	14.5	2.9	1.0	0.5
South Africa	16.5	29.3	25.9	1.6	26.8

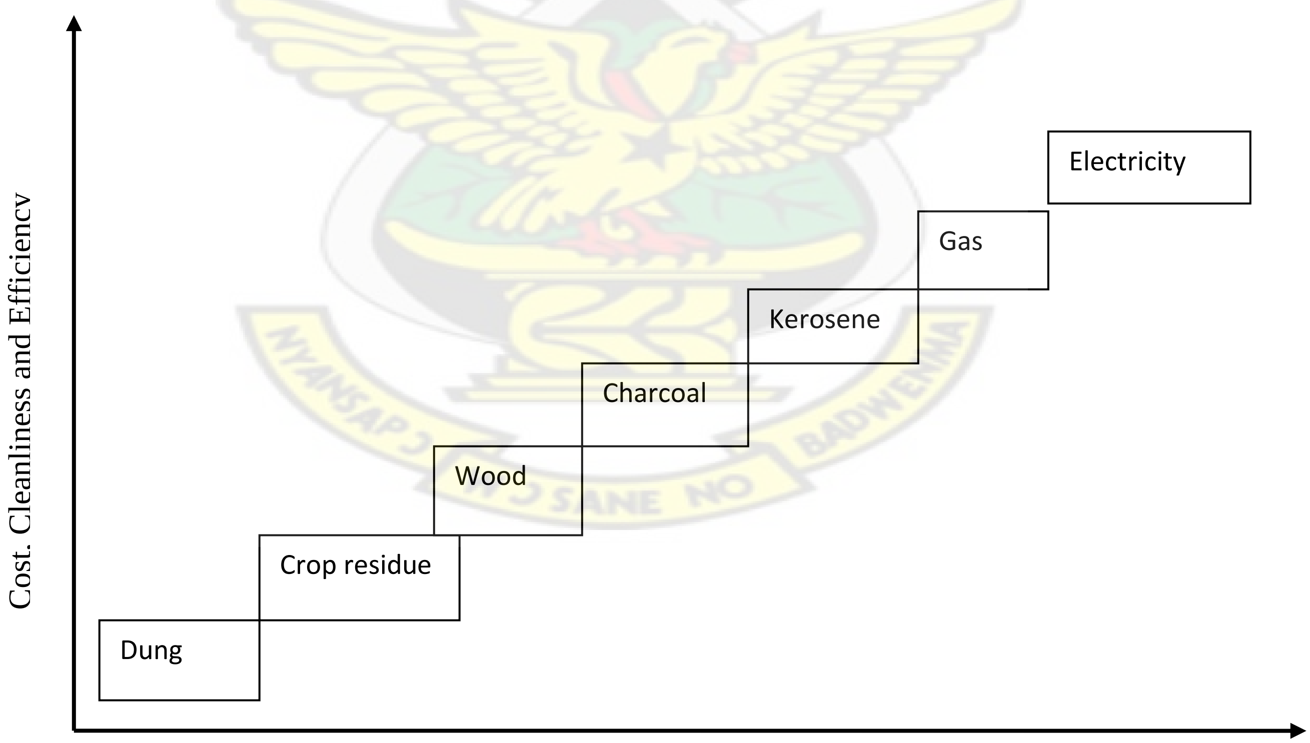
Source: IEA 2003

Table 2.1 above illustrates that South Africa and North Africa have high levels of modern energy consumption, while Sub-Saharan African countries continue to heavily rely on biomass and traditional energy. This heavy reliance on traditional energy sources means low level of energy efficiency; heavy deforestation and biodiversity loss; greater health hazards due to indoor air pollution; and reduced capacity to mitigate climate changes.

2.3 Background on Cooking Fuels

Compared to developed countries, developing nations use much less total energy per capita. However, because of their much larger populations, they still require a substantial portion of global energy. Less industrialized countries use energy differently, consuming a much higher proportion at the household level, principally for cooking and lighting, but also for heating in cooler climates. In fact, household fuel needs continue to make up more than half of total energy demands in more than 100 countries (Merson et al, 2001). Energy for cooking in less industrialized countries is provided by a heterogeneous mixture of fuels which vary in importance from country to country. These fuels are often conceptualized as forming an "energy ladder" which describes transitions in fuel use at different levels of economic development (Holdren and Smith, 2000). Figure 2.2 below gives a schematic representation of the energy ladder model adapted from Masera *et al* (2000).

Figure 2.8 Schematic Illustration of the energy ladder hypothesis: Change in fuel with increasing income level



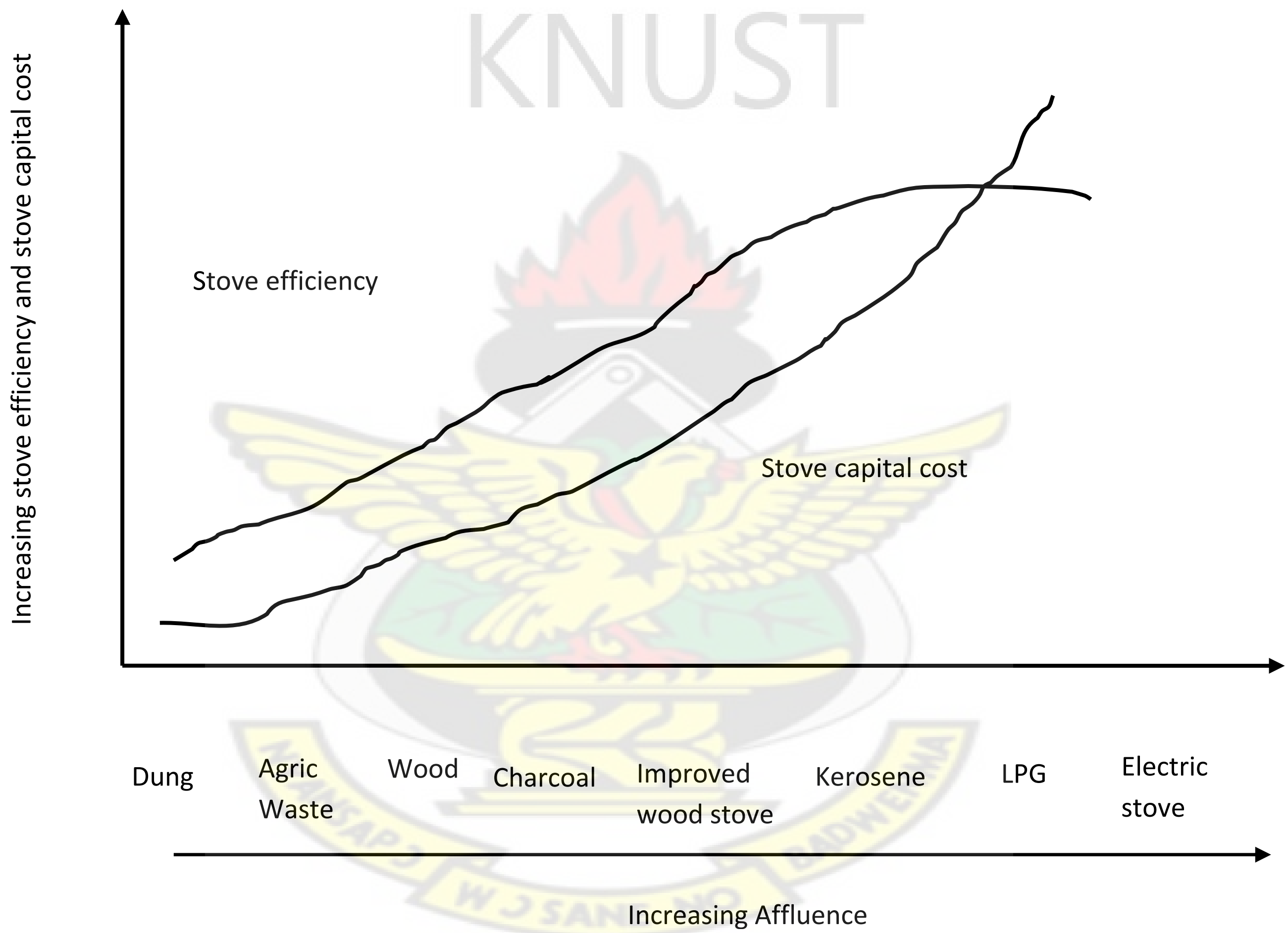
Income

Source: (Masera et. al., 2000)

Households at lower levels of income and development tend to be at the bottom of the energy ladder, using fuel that is cheap and locally available but not very clean nor efficient. According to the World Health Organization (2006), over three billion people worldwide are at these lower rungs, depending on biomass fuels – crop waste, dung, wood, leaves, etc. – and coal to meet their energy needs. A disproportionate number of these individuals reside in Asia and Africa: 95 percent of the population in Afghanistan uses these fuels, 95 percent in Chad, 87 percent in Ghana, 82 percent in India, 80 percent in China, and so forth. Coal is seen as a higher quality fuel due to its efficiency and storage, and thus is higher on the energy ladder, but as Holdren and Smith (2000) describe, coal can in fact be dirtier than wood.

As a household's economic well-being increases, it is assumed to move up the ladder to more sophisticated energy carriers and to move to less sophisticated energy carriers as economic status decreases through either a decrease in income or an increase in fuel price (Hosier and Dowd, 1987). The energy ladder model also relates the technological advancement of a fuel to the efficiency of the appliances used as shown in figure 2.3. According to this schematic, both stove efficiency and capital cost increase with energy sophistication, and the use of any type of energy is an indicator of household affluence. For example dung and crop residues require little if any investment in appliances, and they are the least efficient technologies, used by the least affluent households. Electricity on the hand, requires high investment in more efficient appliances, and is used by the more affluent households. In general, the end-use efficiencies of cooking technologies increase progressively in the following order: woodfuel, charcoal, kerosene, LPG and electrical power (Reddy *et al*., 1997) and Kammen (1995) in (WEC, 1999). Therefore, moving up the energy ladder results in declining emissions of carbon dioxide, sulphur dioxide, and particulates.

Figure 2.9 Schematic representation of the efficiency of stoves with traditional and modern fuels



Source: adapted from Masera *et al.* (2000)

The stove efficiency curve is above the stove cost below a certain level of technology, reflecting that efficiency increases at a decreasing rate as technology increases. Beyond the threshold level of technology, increasing the capital cost of the appliance does not result in substantial gains in efficiency. This is depicted by the intersection of the two curves.

However, reality is not in line with this progressive and unidirectional transition as suggested in this model. Literature confirms the fact that households use multiple fuels (Campbell et al, 2003; Kebede, 2002; Foster et al., 2000 and Masera et al., 2000). More recently other opinions have arisen to explain the trend to energy transition in homes, notably the work of Masera *et al* (2000). The authors emphasise that the energy transition is a function of four essential factors: (a) costs and accessibility; (b) efficiency and convenience of use; (c) culture; and (d) quantity of emissions per quantity of energy produced. Switching fuel, therefore, is an interactive process in which some factors push the user toward the use of modern fuels, and others pull him/her back to the use of traditional fuels. It is a bi-directional process: in the same way as the consumer can climb the energy ladder, he/she can also go down, once again using woodfuel and other traditional fuels in certain situations.

In general terms, woodfuel is rarely completely replaced, even with the availability of the modern fuels. Evidence from a growing number of countries suggests that modern fuel adoption often results in multiple fuel use, where households consume a portfolio of energy sources at different points of the energy ladder (Barnes and Qian , 1992; Hosier and Kipondya, 1993; Davis, 1998). This phenomenon has been termed fuel stacking (Masera et al., 2000). For example, Reddy (1997) shows that the use of biomass in Pakistan and Vietnam is widespread, for both the poor and rich classes, in proportions of 91.4 percent and 60.9 percent respectively. In the shanty areas of Campinas, Jannuzzi (1991) shows that woodfuel still corresponded to a significant portion of domestic consumption for cooking, despite the widespread presence of LPG. Close to 40 percent of homes used firewood, both in stoves especially built to this end, as well as in improvised stoves.

The complexities of fuel switching in the developing world suggest that there are many factors besides income that determine fuel choice. Social, economic and technological barriers all prevent the linear progression towards clean cooking fuels represented by the energy ladder. Davis (1998), citing the work of Leach (1987) in a study in south Asia, lists four of the most important factors in the choice of fuel. They are: family income, relative prices of the fuels, costs of stoves and availability of fuels. In some cases, the choice of fuel is made in such a way that it ensures the security of supply of another energy source. For example in the Philippines firewood and charcoal are kept in stock as emergency fuels, in the event of a shortage of LPG

Fuel price differences are cited by Leach (1992) as another factor determining fuel choice. Where differences are large, the cheaper the fuel, the more the fuel is consumed. For example Jannuzzi (1991) shows that the low-income population prefers to use the wood stove as a means for cooking beans and other foodstuffs with long cooking times, because it is cheaper than use of the gas or electric stove. In some cases, however, price is not a determinant in the choice of fuel. In a town in Sierra Leone, two-thirds of the families do not switch from firewood to other fuels, due to the ease with which the wood stove offers in preparation of the meals which are typical of the region (WEC, 1999).

Leach and Gowan (1987) in Davis (1998), reviewing various research efforts on cooking energy, summarise the factors which influence the supply and demand of a given fuel, in table 2.2

Table 2.2 Determinant factors in the choice of fuel

Supply	Demand
• Fuel price and availability	• Household income
• Time and work required in the collection and use of the fuel	• Number of persons in the family
	• Climate
• Location	• Culture (diet , way of preparing meals)
• Fuel characteristics and preferences	• Stove cost and efficiencies

Source: Leach and Gowen (1987), in Davis (1998)

2.4 Traditional Biomass cooking Fuels.

According to the IEA (2006), over 2.5 billion people, or 52 percent of the population in developing countries, depend on biomass as their primary fuel for cooking. By far the biggest source of biomass energy is woodfuel (firewood and charcoal) but agricultural residues and animal wastes are used where woodfuel is unavailable. The reliance on traditional biomass fuels is magnified in rural areas, where more than 90 percent of the populations in many countries depend on these fuels.

2.4.1 Firewood

Firewood[1] occupies an enviable place for providing many people, especially the poor and rural households, with a primary source of energy (Anderson and Fishwick, 1984; Leach and Mearns, 1988; Eberhard, 1990; Hall, 1994 cited in (Dovie et al, 2004). Firewood remains the most

[1] Firewood is wood in rough obtained from the trunk and branches of tress to be used for fuel purposes such as cooking, heating or power generation.

common fuel for cooking in most African countries. It is estimated that daily fuelwood consumption in Africa, for example, is approximately 500,000 tonnes per day (Schirnding et al., 2000). Table 2.3 shows the use of firewood as a household cooking fuel in selected sub-Saharan African countries

Table 2.3 Use of firewood as household cooking fuel in selected sub-Saharan African countries

	Percentage of total population living in rural and urban areas		Percentage of rural, urban and total population dependent of firewood.		
Country	Rural	Urban	Rural	Urban	Total
Tanzania	76.9	23.1	95.6	26.7	77.4
Uganda	87.7	12.3	91.3	22.1	81.6
Senegal	59.3	40.7	89.1	15.9	54.7
Zambia	65.4	34.6	87.7	10.1	60.9
Malawi	85.6	14.4	98.5	69.0	94.3
Kenya	64.1	35.9	88.4	9.6	68.8

Source: Schlag and Zuzarte , 2008

In rural settings, the predominance of firewood as the dominant source of cooking energy is attributed to its availability as a “free” source of energy. In most cases firewood is collected and not purchased. On the other hand, in urban areas, use of firewood as the primary fuel varies according to factors such as differences in price and availability of alternatives. However, this low or non-existent immediate cost does not reflect the lost opportunities and external costs associated with its collection and combustion. Use of firewood as fuel is also a gender issue, as women spend by far the most time collecting the wood (see section 2.7).

Firewood is often burned in open stoves (traditional three-stone stove, mud stove) resulting in low energy density and low total energy efficiency on combustion, often between 10 percent and 20 percent (Bailis, 2004). Furthermore, the difficulty of controlling heat levels in an open stove means that large masses of fuel must be burned. The tragedy of this dependency on firewood is that it is being depleted more rapidly than any fossil fuels, and that its consumers have little political power. A FAO study shows that an estimated 60 percentage of households in Africa, nearly 80 percent in Asia, and nearly 40 percent in Latin America and the Caribbean suffer an acute firewood scarcity and are consuming amounts below the minimum required for heating and cooking (Human Development Report, 1995 cited in Reddy, 1997)

2.4.2 Charcoal

In developing parts of the world, such as Africa, charcoal is often made in simple temporary earth-mound kilns with low efficiency and high pollution emissions (Pennise et al., 2001). But the production process requires 1 - 3 times as much wood to deliver the same amount of energy for cooking. It thereby exacerbates the demand for wood. When burned in inefficient stoves, losses are further multiplied. In general the efficiency of charcoal stoves commonly found in urban households is approximately 25 percent, so the overall system efficiency is quite low: about 5 percent of the energy in the original biomass is converted to useful energy for cooking (Davidson, 1992). In Nairobi, for example, it is estimated that a household that relies exclusively on charcoal will consume between 240 kilograms and 600 kg of charcoal annually. Between 1.5

and 3.5 tons of biomass is required to produce this amount of charcoal (Kammen, 2006). Thus, encouraging a shift to charcoal could lead to even more severe environmental degradation and fuel scarcity, as more wood is needed per meal using charcoal compared to firewood.

Even so, charcoal is a preferred cooking fuel in many urban areas in developing countries (Schlag and Zuzarte, 2008). There are a number of reasons why people in dense urban settlements favour charcoal over wood: it has a higher energy density, it burns more cleanly (which reduces exposure to harmful pollutants), and it is easier to transport, handle, store, resists attack by insects, burns in a controlled fashion without much smoke or flame, (FAO, 1983; van der Plas, 1995). Charcoal can be purchased in small amounts, making it flexible and affordable even for the poorest households. Similarly, charcoal-burning stoves are quite inexpensive, making it a more attractive fuel for the urban poor than other fuels available in urban markets such as LPG and electricity. Moreover, it can be made locally and contributes to the national economy. Representing advancement along the energy ladder above wood, charcoal probably has lower respiratory health risks to the user than some other traditional fuels. Therefore, demand for charcoal can be quite high.

2.5 Modern Cooking Fuels

Modern cooking fuels are considered to be those that have a high energy density, high combustion efficiency and high heat-transfer efficiency with sufficient heat control characteristics. They include Liquefied Petroleum Gas (LPG), Kerosene and other non-conventional technologies

2.5.1 Kerosene

As consumers climb the energy ladder, kerosene which is a colorless flammable hydrocarbon liquid obtained from the fractional distillation of petroleum is usually the first modern fuel to be used, because it is more easily transported and stored than LPG. With a lower heating value of around 44.75 GJ/tonne (Schlag and Zuzarte, 2008)) its greatest use, however, is in lighting, mainly in the countries with poor access to electricity. This leads to its penetration in the rural areas being greater than that of LPG. Because it produces soot and other particulates when burned it is not considered a clean cooking fuel; nevertheless, it is potentially an improvement over woodfuel. Quality varies widely; to the point that the worst kerosene stoves are just as bad as some solid fuel stoves and the best are as good as the worst LPG stoves.

Two types of stoves are used for cooking with kerosene: wick stoves and pressurised stoves. Both have high total energy efficiencies of between 40 percent and 60 percent and are simple to use (Bailis, 2004). However, there are numerous hazards associated with the household use of kerosene because of its toxicity and flammability. In 2000 in South Africa, kerosene ingestion was cited as the cause of death of 4,000 children; in addition, there were at least 46,000 fires resulting from household kerosene use (Bizzo and de Calan , 2004). Such hazards make kerosene less desirable than other options.

2.5.2 Liquefied Petroleum Gas, LPG

Of all the modern fuels available today, LP.Gas, which consists mostly of propane and butane, is particularly well suited to domestic cooking and heating because of its clean-burning attributes and practical advantages over traditional fuels and kerosene. These gases have the unusual property of becoming liquid at room temperature if moderately compressed and reverting to gases when the pressure is sufficiently reduced. This gives them a considerable advantage over other fuels because they can be easily transported and stored in the liquid state. They can be economically provided in small amounts in tanks at relatively low pressure far from pipelines, unlike natural gas (methane), which does not liquefy unless compressed at high pressures (CNG, compressed natural gas), raising cost and safety issues (Belguedj and Chantelot 2002 cited in Smith et al., 2005). LPG burns very cleanly in simple devices, such as household stoves and furnaces, for two principal reasons. Firstly, its properties make it easy to produce in a highly purified state without such intrinsic contaminants, such as sulfur, that would produce health-damaging air pollution. Secondly, being a gas when burned, it is relatively easy to pre-mix with air (oxygen) in simple devices, thereby achieving high combustion efficiency, i.e., nearly complete conversion of the carbon and hydrogen in the fuel to carbon dioxide (CO_2) and water (H_2O) with few products of incomplete combustion (PIC), many of which are health damaging. This is not easily done with solid fuels in simple devices, as has been discussed above.

Households recognise these advantages and are usually prepared to pay a premium for LP. Gas over other fuels, if their incomes are high enough. For example, in Africa consumption of LPG grew from 1,898 thousand tonnes in 1980, to 5,424 thousand tonnes in 1995, giving an increase in residential consumption of 5.2 percent to 14 percent (FAO, 1995). World LPG demand in 2000 was around 200 million tonnes, with an expectation of it increasing to 237 million tonnes in 2005, according to the World Liquid Petroleum Gas Association (WLPGA, 2004). Average growth in the consumption of LPG is around 5 percent per year. According to WLPGA (2004), Asia is the largest consumer of LPG in the world. In 2003 the continent used 60 million tonnes, with 65% of consumption directed to the residential and commercial sectors.

In Africa and in the poor countries of Asia, the lack of distribution infrastructure and the high costs for LPG and gas stoves, impede its greater penetration in the rural areas. Floor and Groove (1990), in Baranzini and Goldemberg (1996), show that the majority of the poor families do not save enough, thus making impossible the spending of a lot of money, for example in the purchase of gas stoves. Table 2.4 presents rates of penetration of LPG in various developing countries.

Table 2. 4: Percentage penetration of LP Gas and Kerosene

Country	LPG(%)	Kerosene(%)
Brazil	92.3	0.1
Nicaragua	29.0	1.8
South Africa	7.9	43.2
Vietnam	22.3	8.0
Guatemala	44.9	5.5
Ghana	5.4	1.1
Nepal	1.6	7.1
India	61.0	7.9

Source: World Bank, 2003

2.6 Non-conventional technologies: Biogas, Producer Gas and Dimethyl Ether

2.6.1 Biogas

Biogas is a good source of cooking fuel, which can be produced in digesters through anaerobic digestion of biodegradable material. Biogas can be produced using cow dung, poultry droppings agricultural residues or even human excreta, which are renewable raw materials. Biogas is inflammable, and is a mixture of several gases consisting of 40- 70 percent methane gas, 30- 60 percent carbon dioxide and a low amount of other gases[2]. Like those of any pure gas, the characteristic properties of biogas are pressure and temperature-dependent. They are also affected by the moisture content. According to GTZ and ISAT (undated), the calorific value of biogas is about 6 kWh/m^3, which compares to the energy content of about half a liter of diesel oil. The volume of 1m^3 of gas can provide energy for the preparation of three meals for a family of five to six persons, operate 60 -100 watt bulb for 6 hours, run a one horse power motor for 2 hours and generate 1.25 kilowatt hours of electricity (Kristoferson 1991, in ITDG 2003).

In communities where there is availability of inputs like manure and water, the use of biodigestors has greater potential for domestic use. China and India are the countries known for having the largest programs for dissemination of this technology. Over the period from 1973 to 1978, the biogas program in China had built seven million biodigestors for domestic use, and in 1994, five million biodigestors were operating satisfactorily (UNDP, 2002). Biogas experience in Africa has been on a far smaller scale and has been generally disappointing at the household level. The capital cost, maintenance, and management support required have been higher than

[2] Other constituents and their proportions by volume, include hydrogen (0-1%), hydrogen sulphide (0-3%) and other gases (1-5%) (GTZ and ISAT undated)

expected. According to the UNDP (2002), the experience in dissemination of biodigestors for cooking shows that in the short term, the expectation is very low for expansion of its domestic use.

2.6.2 Producer gas

An alternative to biogas is producer gas, a mixture consisting largely of carbon monoxide, hydrogen, and nitrogen. Producer gas derived from the gasification of biomass has been used for domestic and industrial heating purposes, for cooking, for stationary power, and for motor vehicle applications (UNDP 2002). During the Second World War, this gas was the principal fuel driving stationary and automobile motors in Europe and Asia. Following the war, there was an increase in the supply of fossil fuels, which were cheaper, and interest in the use of the gas declined. The lower heating value of producer gas is 5.2 MJ/Nm3, less than that of natural gas (34.6 MJ/Nm3) and of LPG (86.4 MJ/Nm3) (FAO, 1986). Despite the low heating value of producer gas, the quantity of emissions from its use is relatively less than that of LPG or kerosene. Producer gas is also known as an alternative gas to biogas, and has been used as a fuel for the cooking of foodstuffs in many European and Asian countries since the seventeenth century (UNDP, 2002).

Recently, interest has grown in the producer gas produced from coal and biomass, as an intervention to reduce air pollution from the burning of unprocessed biomass and mineral coal. The systems range from small-scale (5- 100 kW), suitable for the cooking or lighting needs of a single family or community, up to large grid connected power or combined heat and power facilities consuming several hundred kilograms of woody biomass per hour and producing 10-100 MW of electricity (UNDP 2002) . Biomass gasification is not yet fully commercialized, though many projects of different scales have been attempted and have yielded valuable lessons (Larson, 2000 ; Reed and Gaur, 2000).

For example in China, domestic use of producer gas for food cooking has now been relatively developed since 1996, when research programs began which drove the development of this technology. In the Shangdong region, twenty gasifiers already exist which produce gas and supply homes through a system of piped gas. In 1996, there were 216 homes in Tengzhai in the Shangdong region which were benefiting from this technology (UNDP, 2002). It is estimated that in China, with the use for energy purposes of 60% of the available agricultural residues, it will be possible to generate energy to meet the demand for cooking in all rural areas of the country (UNDP, 2002). However, research efforts are being carried out aimed at reducing environmental impacts from the tar produced during production of the gas. The tar produced with producer gas may contaminate and pollute the water on the surface and in the soil. These research efforts also aim to avoid accidents which may take place due to CO leakage during burning of the gas, given that 20 percent of the gas is composed of CO.

2.6.3 Dimethyl Ether Gas (DME)

Dimethyl ether gas (DME) has characteristics similar to those of LPG and is used as a cooking gas, in addition to other energy and industrial uses. It is produced from any carbonaceous feedstock by catalytic synthesis from syngas (a gaseous mixture consisting largely of carbon monoxide and hydrogen). DME is super clean, non-toxic cooking fuels that are gaseous at ambient conditions but can be stored and delivered to consumers as liquids in moderately pressurised canisters. These fuels can be produced from crop residues or other biomass feedstocks through thermo chemical gasification to produce the needed syngas (UNDP, 2002). In addition to the toxicity advantages offered, DME fuels could be readily transported in canisters by truck or donkey cart to remote, scattered households.

However the technological development and production of the gas on a large scale are in the initial phases. World production of the gas is around 150,000 t/year and it is foreseen that the technology will be ready in commercial terms to enter the market between 2010 and 2015 (Larson and Tingjin , (2003) and UNDP (2002)). DME has also been identified as an especially promising clean cooking fuel (Chen and Niu, 1995 cited in UNDP 2002). Its wide availability in developing countries could dramatically mitigate the horrendous air pollution health impacts from burning biomass and coal for cooking..

2.6.4 Solar cooker

Solar cookers cooks' food using direct sunlight as its only source of energy, therefore no smoke is produced. However solar cookers have limitations within their operation. They must be placed in an outdoor area with direct sunlight exposure. Thus they cannot be used on cloudy days, in shady areas, in the early morning or at night. To merit consideration for solar cooking promotion, monthly insulation[3] should exceed four kilowatts per hour per square meter (kWh/m²) per day on average (Curtis, 2006). "Cooking with the sun" also allows the use of a free, effectively inexhaustible source of energy, relieves the workload on women, and reduces the harmful effects on health arising from cooking. Moreover, fewer trees are chopped down, thus stopping

[3] Insolation is a measure of solar radiation energy received on a given surface area in a given time. It is measured by [kWh/m²] per day

deforestation and the advance of desertification, while at the same time guarding against global warming. It has to be said, though, that decades of efforts have not helped solar cookers to achieve a breakthrough. So far it is only on the treeless plateaus of Tibet that solar cookers have truly become established; roughly half of the million or so solar cookers in the world are used in China**.** Each of this cookers saves about 600 to 1000 kg of firewood a year (GTZ, 2007).

2.7 Consumption of traditional fuels and its side effects

As mentioned at the beginning of this chapter, and as demonstrated by the selected examples, biomass consumption is the dominant household fuel in Sub -Saharan Africa ranging from 55 percent in Senegal to 92 percent in Tanzania (IEA, 2003). With most households in South Africa and North Africa using relatively cleaner energy forms such as electricity, LPG and kerosene, the more serious household energy challenge is in sub-Saharan Africa which still relies on inefficient and environmentally unsustainable traditional biomass. The key challenges facing the household sector in sub-Saharan Africa are discussed in the next section.

2.7.1 Indoor air pollution.

With proper stoves and good fuel burning practices, fuelwood and charcoal as well as other biomass can be burned cleanly, producing mostly carbon dioxide (CO_2) and water (Smith, 2006). Such conditions are difficult to achieve in poor rural and urban areas where small-scale inexpensive wood-burning stoves are used, however. Woodfuel that is not properly burned to carbon dioxide is diverted into Products of incomplete combustion (PIC) posing health hazards. Table 2.5 below lists a few health-damaging products of incomplete combustion (PIC) in wood smoke. Leading the list of PIC in terms of total mass and number of carbon atoms is carbon monoxide (CO), an invisible odorless but nevertheless toxic gas with a number of potential short-term and long-term impacts on health. Following are dozens of simple and complex hydrocarbons and organic compounds, some in gaseous and some in solid form. In addition, a portion of the PIC is released as elemental carbon, or “soot,” in the form of small particles (PM). The quantity of each pollutant released is dependent on combustion conditions such as energy density, combustion temperature and air flow, and pollutant emission rates which vary with time and stove geometry (Ballard-Tremeer and Jawurek , 1999; Ezzati *et al*. 2000; Ezzati .and Kammen , 2002).

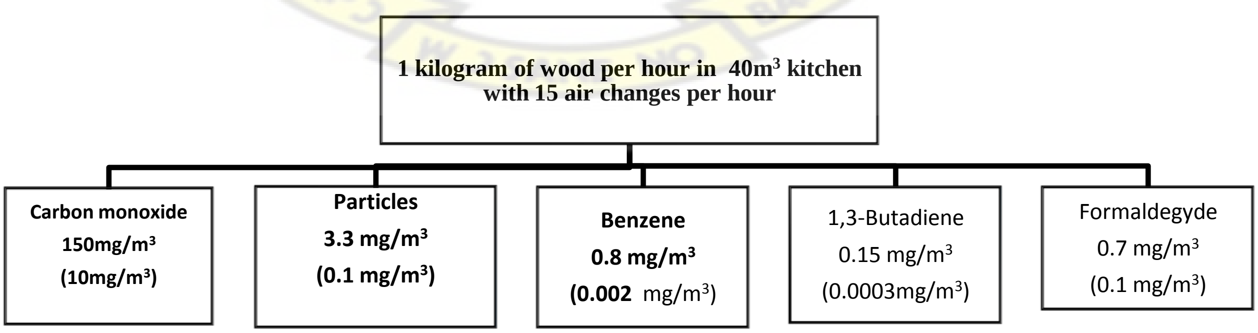
Table 2. 5: A few health – damaging products of incomplete combustion (PIC) in wood smoke

Chemical	Emission Factor (g/kg)	Chemical	Emission Factor(g/Kg)
Carbon Monoxide	80 - 370	Methyl chloride	0.01 – 0.04
Methane	14 – 25	Napthalene	0.24 – 1.6
VOCs (C2-C7)	7 – 27	Substituted Napthalenes	0.3 – 2.1
Aldehydes	0.6 – 5.4	Oxygenated Monoacromatics	1 – 7
Substituted Furans	0.15 – 1.7	Oxygenated PAHs	0.15 – 1
Benzene	0.6 – 4.0	Polycyclic Aromatic Hydrocarbons (PAHs)	$7*10^{-3}$ – $4.3*10^{3}$
Alkyl Benzenes	1 – 6	Elemental Carbon	0.3 – 5
Toluene	0.15 – 1.0	Particulate Organic Carbon	2 – 20
Acetic Acid	1.8 – 2.4	Chlorinated dioxins	$1*10^{-5}$ – $4*10^{-5}$
Formic Acid	0.06 -0.08	Particulate Acidity	$7*10^{-3}$ – $7*10^{-2}$
Nitrogen Oxides (NO, NO2)	0.2 -0.9		

Source: United States Environmental Protection Agency (USEPA) cited in (Smith et al , 2005).

Ventilation characteristics, unique to each dwelling, also add temporal and spatial variation to pollutants, and as such, the level of exposure to occupants in the dwellings is varied and often unpredictable. Past and current literature illustrates this point: while mean averages of particulate matter (PM) are generally higher for solid coal or biomass fuels when compared to cleaner fuels, there is still a high degree of variance and overlap in the distribution of values across fuel groups (Brauer and Saksena, 2002). Studies have even found that although paraffin is less polluting than biomass fuels, women using paraffin had similar exposure to respirable particles as women using wood for cooking (Raiyani et al., 1993; Saksena et al., 2003). Consequently, levels of IAP from fuel burning, exposure levels and potential health risks to individuals can vary greatly amongst dwellings. It is instructive to see what a kilogram of wood will generate. On a typical three stone wood-fired stove, about 18 percent of the energy goes into the pot, 8 percent into the smoke and 74 percent is waste heat (Warwick and Doig, 2004)). But it is the pollutants that are of more concern. A kilogram of burning wood can produce significantly harmful levels of gases, particles and dangerous compounds. Figure 2.4 shows the Pollutants generated from burning one kilogram of wood are well beyond World Health Organization guidelines

Figure 2. 10: Pollutants generated from 1kilogram of wood burned



Source: Smith and others, 2000 cited in UNDP 2000.

Note: Dozens of other health-damaging pollutants are known to be in wood smoke. Mg/m3 stands for milligrams per cubic metre. Numbers in parentheses are typical standards set to protect health.

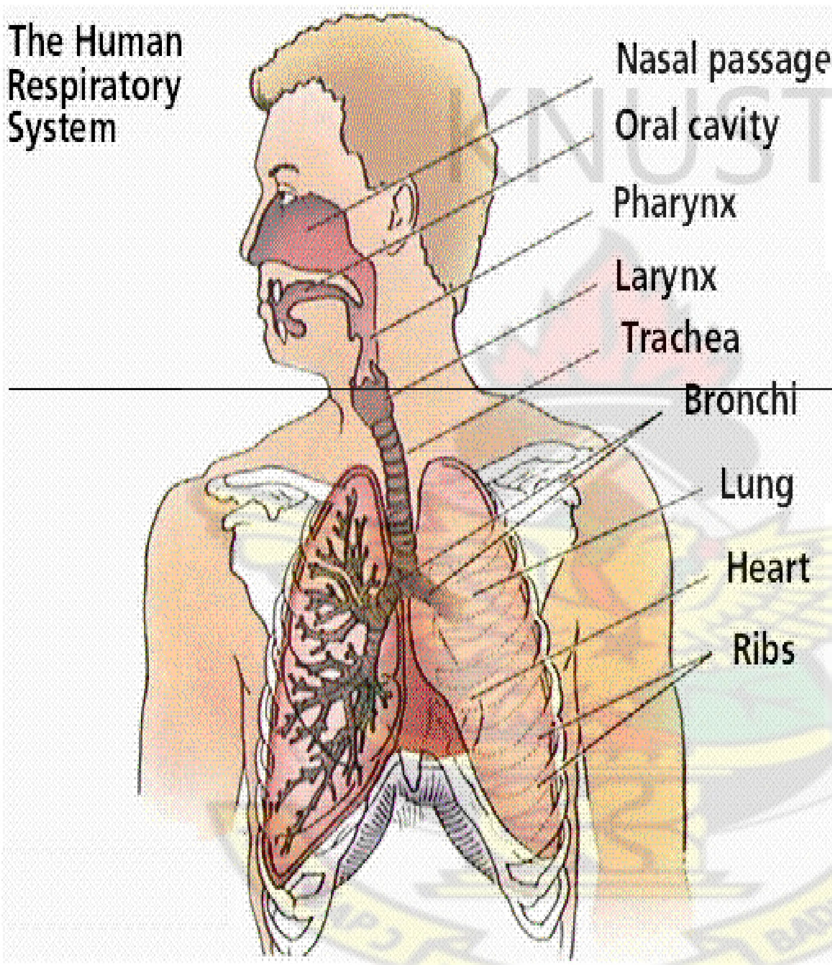
Although by no means representing the entire panoply of chemicals, CO and small particles are considered as reasonable indicators of the relative health risk from combustion smokes that do not contain toxic chemicals such as sulfur, fluorine and lead (as is found in some types of coal, for example) (Smith et al., 2005).This study has therefore chosen to examine the levels of particulate matter ($PM_{2.5}$) and carbon monoxide , that exist in dwellings, based upon emissions released from the combustion of household fuels currently in use in the Bongo district ,Ghana. In order to better understand how these pollutants create adverse health effects, one must first look at the physiological processes underlying the health impacts of exposure.

2.7.2 The Health Impacts of Exposure to Indoor Air Pollution

2.7.2.1 Physiological Impacts of Pollutants

To understand the physiology and movement of pollutants through the body, pollutants must first be divided into two categories: aerosols (PM) and gases (CO, CO_2, and SO_2). Aerosols are small solid or liquid particles that are suspended in air to form a mixture (Yassi et al., 2001). These particles are generated with different size distributions depending on the source, and the size of the particles in turn determines how the particle behaves in the human respiratory tract. While larger particles carry much more substance, they are less likely to have an effect on the body because they do not penetrate into the lower respiratory tract. Smaller particles, those with aerodynamic diameters of less than 10 μm and especially those with diameters less than 2.5 μm, enter the airways with greatest efficiency and may be deposited in the alveoli, which are the deepest structures of the lungs (Yassi *et al*., 2001). Patterns of deposition within the lungs are shown in Figure 2.5.

Figure 2. 11: Human Respiratory Tract



Upper Respiratory tract

Acute Upper respiratory infections (AURI)

Cold

Otis media

Pharyngitis

Lower respiratory tract

Acute lower respiratory infections

Bronchitis

Bronchiolitis

Pneumonia

Source: Adapted from Yassi *et al*. 2001. **Note:** Larger (coarse) particles in air pollution are more likely to deposit in the upper respiratory tract. Smaller (fine) particles penetrate deeply into the lower respiratory tract

Adverse health effects created by gases, on the other hand, are often a result of their solubility in water and their chemical reactivity. Once inhaled, soluble gases dissolve into the water surface of the pulmonary tract and are removed, whereas insoluble gases are not dissolved and removed. Insoluble gases will then penetrate to the alveoli more efficiently. In addition, gases can absorb onto the surface of particulates, which then travel to the alveoli. When this happens the effects may be different and sometimes greater than exposure to either the particle or gas alone. Ultimately once inhaled particles or insoluble gases reach the alveoli, they may release their constituents readily into the blood stream. The degree to which they enter the blood and are delivered to the body's tissues depends on the concentration inhaled, the duration of exposure, their solubility in blood and in tissue, the reactivity of the compound, and the respiratory rate of the individual (Yassi *et al*. 2001).

Whether adverse health effects are displayed in an individual exposed to these pollutants depends largely on the dose (= pollutant concentration x exposure duration) received as well as their biological susceptibility to adverse health effects from exposure. Population groups that tend to be more susceptible to the effects of air pollution include: infants, children, the elderly, people with cardiovascular and respiratory diseases and people with impaired immune systems (EPA 2001 as cited in Matooane et al., 2004). Epidemiologists conducting IAP and health research in developing countries have attempted to incorporate these issues into their studies with varying degrees of success. These efforts are discussed below

2.7.2.2. Evidence of Health Effects of Pollutants (Epidemiological Studies)

Epidemiological studies undertaken in developing countries have aimed to establish a causal link between exposure to IAP and health effects in real life settings. According to reviews of these studies, there is good evidence that exposure increases the risk of acute lower respiratory infections in children, chronic obstructive pulmonary disease in adults, and lung cancer where coal is used exclusively (WHO, 2000; Bruce *et al*. 2002). A comprehensive survey conducted by the World Health Organization (WHO) in 2000 found that each year these diseases cause the death of more than 900,000 children under age five and more than 700,000 adults (WHO 2002).

Globally, acute lower respiratory infection is the most common cause of mortality among children under age five. Table 2.6 shows annual mortality caused by IAP exposure from solid fuels.

Table 2. 6: Annual Mortality caused by IAP Exposure from Solid Fuels

Country Grouping	% of Global Population	Children Under Five Years	Adults
High Mortality Developing Countries	38	808,000	232,000
Low Mortality Developing Countries	40	89,000	468,000
Demographically and Economically Developed Countries	22	13,000	9,000

Source: WHO (2002)

As table 2.6 indicates, 98.5 and 98.7 percent of the respective deaths of children and adults from IAP exposure, caused by solid fuel use, occur in developing countries. For high mortality developing regions, including Ghana, IAP ranks fourth in importance as a health risk factor. Links have also been emerging with a number of conditions such as asthma, low birth weight, prenatal mortality, tuberculosis, eye diseases and cancer of the upper airway (Bruce *et al*. 2000; Ezzati and Kammen 2002; WHO 2000). Research has indicated that a disproportionate risk of exposure to IAP exists in women, infants and young children, as they spent the majority of time indoors and cooking (Sharma et al., 1998, Ezzati *et al*. 2000).

While researchers further investigate the relationship between IAP and the health of women and children, methodological limitations continue to plague studies. Inconsistent results due to these limitations have prevented consensus on the issue and have slowed the implementation of policy and interventions. Limitations include a general paucity of studies for many health conditions, imprecise measurements of pollution and/or exposure, the observational nature of all studies, and failure to deal with confounding variables (Bruce *et al*. 2000; Ezzati and Kammen 2002; WHO 2000). Progress is being made, however. Recent literature has emerged which has examined the exposure-response relation for indoor air pollution and acute respiratory infections (ARI). This relation was developed through simultaneous monitoring of IAP and health status for more than 2 years (Ezzati and Kammen, 2002).

2.7. 2.3 Additional health impacts

Clear health risks are associated with obtaining and storing fuel for the domestic cooking stove. Collection of biomass fuels is associated with a variety of mechanical injuries from felling, carrying and splitting wood, encounters with animals such as snakes and scorpions, violence, and exposure to vectors of a number of infectious diseases. For example, a case control study in

Uganda demonstrated a significant risk of contracting sleeping sickness associated with firewood collection. Similarly, fuel storage can place humans at risk from infectious diseases. For example, in Costa Rica, removal of stored firewood was identified as an important method of controlling Chagas disease by depriving triatomine bugs of refuge in proximity to dwellings (Zeledon and Vargas, 1984). Liquid and gas fuels are associated with fires and burns. Poisoning among children with stored kerosene cooking fuel has been repeatedly reported from several countries including India (Dutta et al., 1998). In almost all developing countries it is women who provide fuel for the family and carry out cooking and many other tasks that require energy use in the home and are thus more affected by the health impacts.

2.8 Energy and Gender

There is a differentiated impact of access to energy services for women and men but gender and energy concerns hardly enter macro-level policies. In most of the developing world, food processing, and water and firewood collection are traditionally female gender roles and take much of women's and girls' time and energy. Labour intensity of fire wood collection depends on many factors. Availability of wood, for example, influences traveling distance and time women spend collecting it. Household size and the amount of load a woman is able to carry at a time are all important determining factors. The season of the year also influences the amount of wood to be collected. Especially in May and June when wood has to be stocked for the winter, women and their children sometimes have to gather firewood twice a day, each trip taking up to two hours. Some rural women are reported to carry up to 20 kilograms of firewood traveling an average distance of five kilometers (Warwick and Doig, 2004). Sometimes this is done with a baby strapped on the woman's back. In Tanzania, the amount of time females use collecting water and firewood is estimated to be 250 hours and 700 hours per person per year respectively.

In rural India, an average of 37 hours is spent per person on wood collection per month (Modi et al., 2005).

The effect of fuelwood use on women’s health, future potential and safety can be quite severe. Transporting heavy loads of firewood on foot makes them vulnerable to back injuries. Sometimes girls have to forgo their education to fetch wood for the family, trapping them in inter-generational poverty. A study in Malawi found that literacy levels were lower in fuelwood stressed southern and central regions compared to the northern region where fuelwood is more easily available. The study further found strong associations between the time children spend on resource collection and a reduced likelihood of school attendance, especially among girls (Nanhuni and Findes, 2003).

The time spent by women doing domestic chores such as pounding, and collecting firewood and water reduces the amount of time they can devote to income generating activities. Productivity of income generating activities is also facilitated by access to improved energy for heating and lighting. Access to modern energy services can therefore improve the lives of women by improving their health condition, reducing their time poverty, and improving the productivity of their income generating activities. Women and girls are also exposed to the risk of sexual assault during the course of firewood collection. Refugee women and girls in particular, are highly vulnerable to sexual violence because of the daily need to leave their camps in search of firewood. In natural resources stressed Darfur, for example, refugee women and girls trek hours in search of fuelwood. To avoid walking long distances under the sun, many leave at dawn, either alone or in small groups, to lessen having to compete for the scarce resource. In August

2006 the International Rescue Committee (IRC) reported 200 assault cases during such searches in a five week period from a single camp. Given the stigma associated with rape, it is highly likely that the number of cases is grossly under-reported.

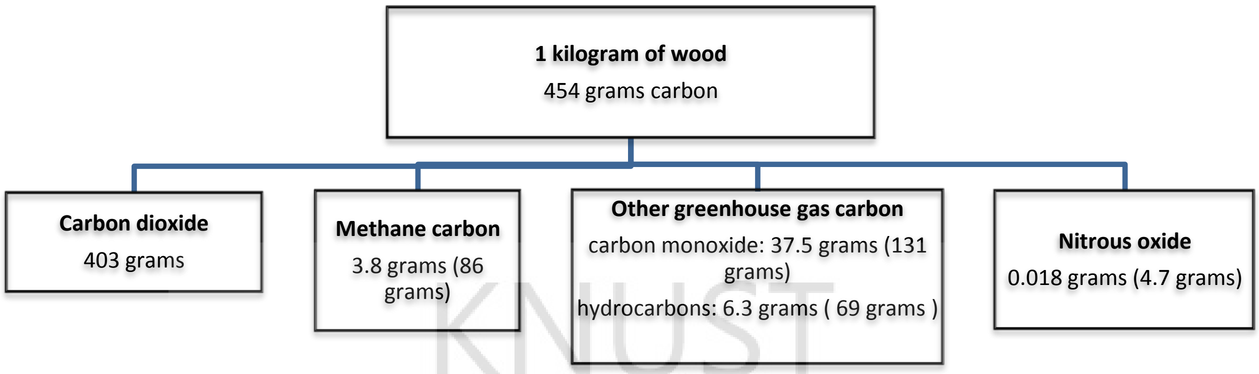
2.9 Environmental effects

2.4 billion People burn biomass fuels on a daily basis to boil water and to cook food. As a result 2 million tonnes of biomass are going up in smoke every day (WHO, 2006). This may not pose a problem where the growth of new trees outpaces human demand. Yet, where wood is scarce and the population is dense, wood collection can put considerable pressure on forests. Particularly in arid and semiarid regions of the world, the need for fuelwood results in significant deforestation, with all its detrimental consequences. In fact, in arid and semiarid parts of West Africa, fuelwood shortages limit the carrying capacity of the land more so than do low crop and livestock yields. In Africa fuelwood collection may be second only to agricultural extension by subsistence farmers as a cause of deforestation. For example, in Cameroon (Africa's leading timber exporter), four times more wood was harvested for fuel than for industrial roundwood in 1998. Biomass fuels (mainly firewood and charcoal) accounted for 80 percent of the entire energy usage for Cameroon in 1999.

This fuelwood shortage does not just affect rural areas. In many developing nations, electricity services in urban areas are irregular and often do not reach poor sectors. Since many households cannot afford kerosene and liquefied petroleum gas (LPG), a substantial portion of the urban poor continue to rely on fuelwood and charcoal. Some have argued that urban fuelwood demand is more destructive of forests than rural needs, because of the intensity of cutting around cities, along roads and later from more distant sources. It is projected that in the Sahel, urban fuelwood use will soon exceed that of rural areas. The biggest problem is when the supply of biomass to meet the demand for firewood declines. In these cases, poor families return to using agricultural residues and dung in place of woodfuel, thus reducing the supply of fodder for animals and for soil protection. In addition, the exorbitant consumption of bio-mass may even result in imbalance in biodiversity and hydrology, especially when there is a preference or planting of certain species of woods for energy use, instead of the natural forests and vegetation of the location (Kammen, 2002). One study has estimated, for example, that in Ethiopia in 1983, if the animal dung used for fuel had been left as soil fertilizer, grain production could have been increased by one to fifteen million tons (Newcombe, 1989).

is estimated that biomass combustion also contributes 20 – 50 percent of global greenhouse gas (GHG) emissions (Zhang et al., 2002, cited in Crutzen and Andreae, 1990).The gases emitted in greatest quantity by the consumption of cooking energy are the following three: Carbon dioxide gas, carbon monoxide and nitrous oxide. The most powerful of these is methane, which over a 20-year period causes more than 20 times the global warming from the same amount of carbon as carbon dioxide (UNDP 2000). Figure 2.6 shows the emissions generated when one kilogram of wood is combusted in a typical open fire stove (Smith et al. 2000 in UNDP 2000). If numbers between parentheses (CO_2 equivalents) are added to the CO_2 grams emitted, the total GHGs emissions are 693.7 CO_2 equivalent grams. Because of significant emissions of non carbon dioxide greenhouse gases, solid biomass fuels, even though renewable, can have a larger greenhouse gas commitment per meal than fossil fuels, kerosene, and liquefied petroleum gas.

Figure 2. 12: Greenhouse gas emissions from a typical biomass cook stove



Note: Numbers between parentheses are CO_2 equivalents of non-CO_2 gases

(Source: Adapted from Smith et al., 2000 in UNDP 2000)

2.10 Finding Solutions

2.10.1 Dissemination of improved biomass stoves and kilns

Many policy analysts stress the need for aggressive dissemination of improved biomass technologies (IBTs) in sub-Saharan Africa, to mitigate the negative effects of traditional biomass energy use – particularly indoor air pollution that is linked to respiratory diseases, one which is the main causes of death for children under the age of five (Karekezi *et al*, 2004). The majority of the efficient stove programs had expectations of reaching 75 percent or greater thermal efficiency, based on the results of laboratory tests. However, the greater part of them failed in technical and social terms, because they did not look at cooking conditions in real situations (WEC, 1999).

Unfortunately, many improved stove projects have not reached their maximum potential because they focused either on fuel efficiency or on reduced smoke, but often not both. Both the cost and efficiency of improved stoves varies considerably. Improved stoves have been promulgated by a variety of non-governmental organizations (NGO) with varying degrees of success. Programmes working in areas with fuel shortages and high fuel prices have often proved most successful.

2.10.2 Forest Management

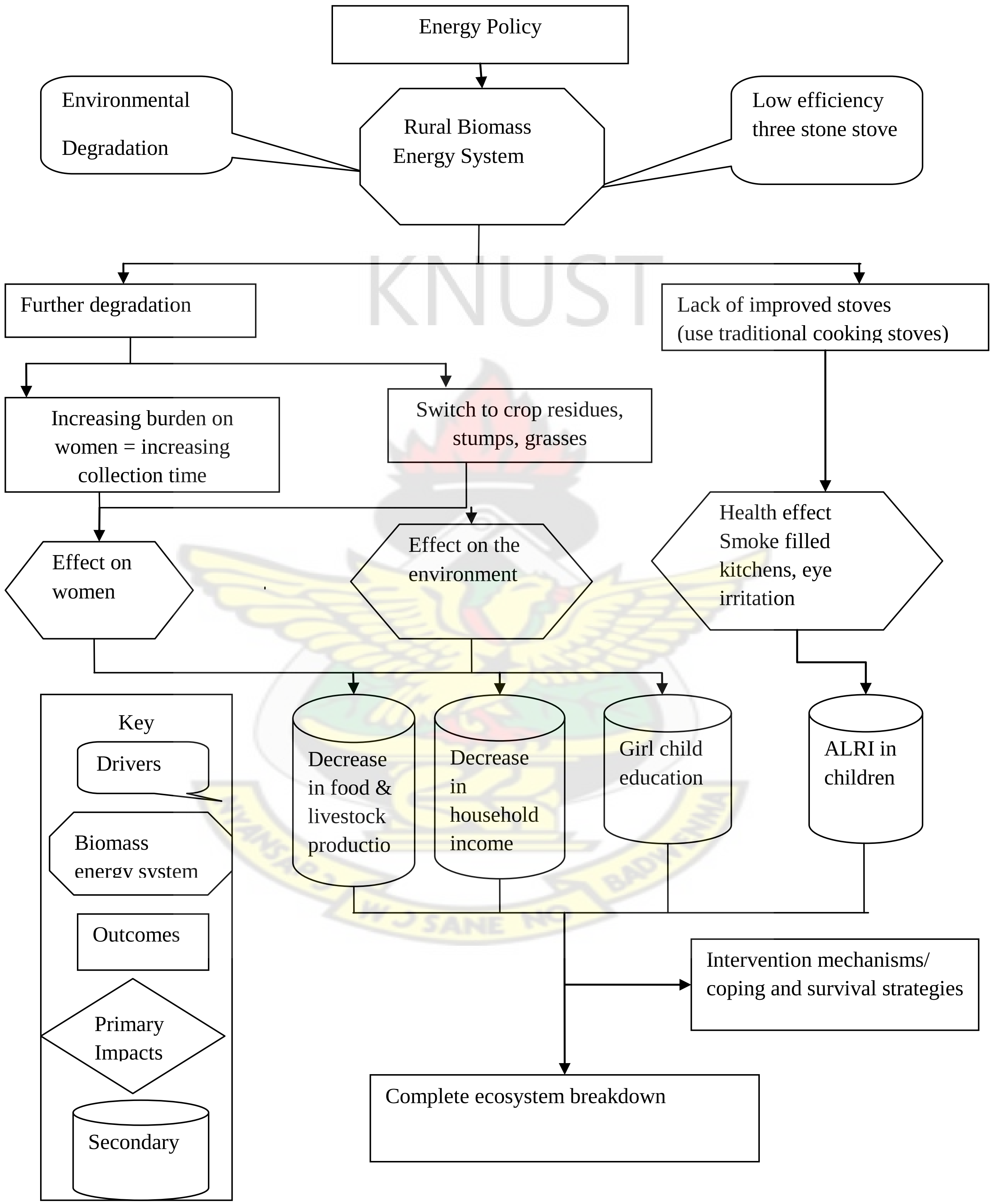
Fuelwood supply shortages have already been partially alleviated in China, India, Indonesia and elsewhere by a combination of forest management and tree farming strategies on national and commercial tree farms. Agroforestry, an approach that encourages farmers to devote a portion of their land to tree planting and community forest projects that encourage community participation in the sustainable management of local communal woodlands have also been helpful in slowing environmental damage. Senegal offers a good case study.

Senegal, as in many other sub-Saharan African countries, forests not only protect soils against erosion and maintain their fertility, but also provide the bulk of the country's needs in energy, and valuable pastoral lands for livestock farming (Republic of Senegal, 1996). The Government opted for a participatory and sustainable style of natural forests management to strike a balance between demand on energy and realistic projections of woodfuel supply. In the early 1980s, the management of natural resources, including forests, was obligatorily participatory and was accompanied by various incentives to make the participation of local communities attractive to them. However, as participation was limited to project execution and the focus of the Forestry Service was actually on reducing woodfuel supply to force substitution with gas, the hoped for results were not attained. National dialogue and consultations at all levels, and a series of national conferences and symposia were conducted to re-evaluate and reshape rural communities' integration and the way to effectively transfer management responsibility to them. It was resolved that a participatory approach to the formulation and implementation of natural resources development is adopted. The National Forestry Action Plan hinged on ensuring effective protection of forest ecosystems, restoring degraded forests, and rationally managing forest resources for a sustainable production of woodfuel and other forest products. The review concluded that in light of the Senegalese macro- and socio-economic environment, the forest resources will remain the main source of energy supply in the foreseeable future. The challenge then will be to devise and implement a sustainable management plan and transfer responsibility to the local communities, to allow a continuous and steady supply of woodfuel while conserving the environment.

2.11 Conceptual Framework

Based on the theoretical insights from the literature, a conceptual framework is developed to guide the study and to answer the research questions. The literature review indicated certain linkages between the demand and supply of traditional energy, the rural women, and the environment and energy policies that guide the industry as shown in figure 2.8 below. The framework illustrates the key drivers of the rural energy crisis and captures the main outcomes and the primary and secondary impacts to which these outcomes give rise. Natural resource degradation and inefficient cooking energy technology are the key drivers of the rural energy crisis. The outcomes are primarily manifest in further degradation, fuel switching and continued dependence on traditional cooking stoves. The primary impacts are in terms of women's health and nutrition and increased labour burden (time). These translate into a variety of more general human health and livelihood issues, such as decrease in food production (lack of time for agricultural activities), lack of education (girl children), deterioration in children's health,

Figure 2.13: Conceptual Framework



Source: Author's construct, 2006

decrease in the household income (women's time not available for income generation activities), and ultimately distress migration (complete biomass and livelihood system breakdown leads to male out-migration in search of employment).

Energy insecure households have their own coping and survival strategies. Thus families try to adapt their demand if fuelwood shortage occurs. Up to a certain degree it is possible to decrease fuelwood consumption by traditional methods, e.g. fire is strictly limited to cooking times; the number of meals are reduced and meals chosen, which need less cooking time; renunciation of warm water for washing and the dishes, etc. However, these measures are not able to prevent the growing of the gap between supply and demand. The government has also its own intervention mechanisms to address the problem. If government intervention is not appropriate, it can aggravate the problem. As households also become more and more vulnerable, some of their strategies become unsustainable and constrain their long term livelihoods.

Both intervention mechanisms and coping strategies are to achieve household energy security. If interventions properly address those causes by considering local differences and are mainly based upon people's strategies, they would likely achieve reduced vulnerability, more household income, increased wealth, and improved food security.

CHAPTER THREE

HOUSEHOLD ENERGY IN RURAL GHANA

3.1 Introduction

The purpose of this chapter is to present the current situation regarding supply and demand for cooking fuels in Ghana, as well as the socio-economic situation, access to and emission of air pollutants and initiatives for improving the supply and consumption of cooking energy. In order to reflect the differences between levels of service and quality of cooking energy, comparisons are made between Ghana and other countries.

3.2 The importance of the rural economy in Ghana.

Like many other developing countries, Ghana has a large rural population mainly engaged in traditional agricultural production. Located on the West African coast, Ghana has an area of about 240,000 km^2. The population is more than 20 million and is growing at a rate of 1.9 per cent per year. The climate is warm and comparatively dry along the south-east coast, hot and humid in the south-west, hot and dry in the north. Ghana was the first country in colonial Africa to become independent. It has an abundance of natural resources, including gold, timber, industrial diamonds, bauxite, manganese, fish, rubber and hydropower.

An estimated 54 per cent of the population lives in rural areas. Most Ghanaians living in rural sectors are farmers, herders, or fishers. Farms are usually subsistent and are often run by families where all members participate in the workload (“Rural Life in Ghana” 2006). However, there are farmers that also work on plantations. Plantations provide many of the export crops, such as cocoa and palm for palm oil. Agriculture accounts for more than 36 per cent of GDP and employs 60 per cent of the total labour force of about 22.5 million people. It contributes to insuring food security , providing raw materials for local industries , generate foreign exchange, and providing employment and incomes for most of the population (especially those living in rural areas) thereby contributing to poverty reduction in the country (NDPC, 2005). Consequently growth in the sector will impact directly on the growth of the economy as well as employment. While the combined output of these rural economic activities constitute more than 30 percent total output in GDP terms, the rural areas are still largely underdeveloped with increasing poverty situation.

Some of the major contributing factors among others include:-

- Poor technologies and inefficient/energy technologies in use are leading to low yields and low labour and land productivity.
- Production of low quality products.
- Heavy post - harvest losses sometimes exceeding 40 percent.
- Provision of low quality social services leading to high-illiteracy of 33.1 percent as compared to urban (14.2 percent), safe and clean water 46 percent while in urban 88 percent.
- High poverty, more than 47 percent of the rural population cannot afford basic needs.

According to the Ministry of Energy (2006), energy services have an impact on all rural economic activities including, agriculture, business, social services, gender equality and poverty. Addressing energy requirements in rural areas is expected to significantly contribute to achieving the Millennium Development Goals (MDGs), the national development vision 2025 and Poverty Reduction Strategy Paper (PRSP).

3.3 Energy Resources and Consumption Patterns in Ghana

3.3.1 Energy Resources in Ghana

Ghana is believed to be potentially well endowed with energy resources. However, much of the potential energy resources are not yet available for use and are yet to be exploited (Ministry of Energy , 2006). The energy sector in Ghana is more explained by the country's low level development of potential non-traditional energy resources, coupled by low demand and its low per capita energy consumption, excessive dependence on biomass energy and very low efficiency in its use. Nearly all of energy resources of the country are from indigenous sources and most of this demand is from biomass.

According to the Energy Commission (2006), out of the national total of 6,645 million tonnes primary indigenous energy production in the country, biomass constitutes 94.5 percent of the total energy resource base. While biomass is the major form of energy, fuel wood accounts for an estimated 56.6 percent of the national total energy resources and the overwhelming majority of traditional biomass energy resource base in the country (84 per cent). As noted in chapter 2, crop residue and dung are considered to be fuels of last resort. In areas where forest resources are depleted they play substantial role in the energy supply and demand balance, especially in the household sector. These two biomass resources constitute about 1.1 million tonnes/year of the national total potential energy resources in the country. However, the biomass resource in the country suffers from highly uneven geographical distribution on various spatial scales. This very unequal spatial distribution is the major problem that confronts the country today. According to the School of Engineering, KNUST (2003) wood fuel resources are under severe pressure in the north-eastern part of the country.

The problem of the energy sector in Ghana is not confined only to the unavailability of the potential resources, but also the capacity to explore the available potential resources the country has and the capacity and ability to consume the readily available and developed energy resources (Ministry of Energy , 2006). It is evidenced that Ghana has vast hydropower resources but only a small fraction has been developed and utilized. Hydropower is the next largest indigenous renewable energy resource after biomass, in the country and it is used almost exclusively to generate electricity. Total installed generation capacity is 1,652MW, comprising 1,072MW of hydro and 550MW of thermal. Out of this potential, most of the hydropower produced is believed to be accounted for by the Volta River. Ghana is endowed with a number of undeveloped sites on the Black Volta, White Volta, Oti River, Tano River and Pra River. In all, the total potential of medium hydro resources is about 1,300 MW with estimated annual generation of 4544 GWh (School of Engineering, KNUST, 2003). However, though Ghana has huge hydropower potential, it has only partly exploited this huge potential mainly owing to the financial constraints for dam construction, and lack of bulk demand to justify grid expansion (Ministry of Energy , 2006).

Ghana's geology indicates the existence of some fossil fuel resources. Whilst potential areas have been identified both on land and offshore, only minor quantities of crude oil have been produced mainly from the Saltpond fields during the late 1970s and early 80s, with a very brief resumption of crude oil production in 1993 (School of Engineering, KNUST, 2003) Ghana recently strake oil in commercial quantities at Cape- Three Points. Exploration is still at the initial phases, until then most petroleum products are imported. Net energy import was about 1.9 million tonnes of oil equivalent in 2000 increasing to about 2.6 million tonnes of oil equivalent by 2004. It comprised 80–83 percent crude oil and about 15-19 percent petroleum products (Energy Commission, 2005).

3.3.2. Energy Consumption Patterns in Ghana

The household sector (primary for cooking and lighting) is the largest energy consumer in Ghana, where traditional biomass fuels predominate. It accounted for almost 50 percent of the country's energy consumption. As per the estimation made by the Energy Commission (2006), the national total final energy consumption in 2000 was 6 million tonnes of oil and about 7.1 million tonnes of oil in 2004. Biomass, principally fuelwood and charcoal, is the major form of energy. This accounts for an estimated 66.9 percent of the total final energy consumption in 2004 in the country. Both the total energy consumption level and share of modern sources of energy consumption in Ghana is one of the lowest in the world. In fact per capita energy consumption is estimated at 360 kilograms of oil equivalent (koe).

The role played by different energy sources varies with the socioeconomic, sub-sectors and places of residences. The modern energy supply is area, sector-and household-specific in the country. It is more accessible to urban areas than to the rural areas and is more consumed by other productive sectors like transport, industry and commerce than the household sector and more by the affluent and well-off people than the poor. Thus, even though the residential sector is frequently cited as the largest energy consumer in most developing countries, it accounts for a relatively very small part of total modern energy consumption. Out of the national total electricity and petroleum product consumption in 2000/03 the share of the household sector was 32 percent and 5 percent respectively in Ghana. The transport sector is the major consumer of modern energy and exclusively depends on petroleum products. As high as 81 percent of petroleum products were consumed by the transport sector alone in the year 2004. The industrial sector is also generally one of the major consumers of modern fuel in developing countries, and next to transport the largest consumer of liquid fuels (Dunkerely, 1981). It is also the case in Ghana. Out of the total final energy consumption in 2000/03, the industrial sector consumed 25, 60 and 7 percent of the modern, electricity and petroleum products respectively.

3.4 Supply and Consumption of the main cooking fuels in Rural Ghana.

This part presents the current situation of the use and market in various sources of cooking energy (fuelwood, charcoal, Kerosene and LPG) in rural Ghana. In Ghana, 94 percent of households rely on wood fuels for cooking (Energy Commission, 2006). Whilst charcoal produced is consumed mainly in the urban areas, firewood is the main fuel consumed in the rural areas. Only 4 percent of the household use LPG for cooking and these are concentrated in the urban. Table 3.1 shows the share of cooking fuels in the household sector for the years 2000-2003.

Table 3. 4: Share of cooking fuels in the residential sector 2000-2003

Fuel	Rural (%)	Urban (%)
Firewood	80	15-16
Charcoal	18	55-61
LP Gas	Less than 1	4 - 6
Electricity	0.3	0.5
Kerosene	0.4	2.2
Other fuels	1.4	1.3

Source: Energy Commission (2005) and GLSS IV (2000)

3.4.1 Woodfuel

Total woodfuels consumed by the household sector was about 11 million tonnes of oil equivalent in 2000. This rose to about 13 million in 2003 (Energy Commission, 2005). The energy sector generates both outflows and inflows to the economy and thus contributes to the GDP indirectly through its use as inputs for production. In terms of sales, it is recorded that woodfuel was the second most purchased fuel in the economy. On the whole, US$400-600 million was spent on woodfuels from 2000 to 2003. Wood fuel share of total national energy cost varied from 29-36 percent between 2000 to 2003, second to petroleum (Energy Commission, 2005). According to Riegelhaupt et al. (2001) nearly 50 percent of firewood is converted to charcoal by the traditional earth mound method with efficiency of about 12.5 percent (6-8kg firewood produces 1.0 kg charcoal). The woodfuel consumed will be reduced if the efficiency of the charcoal making process improves. The annual per capita consumption of woodfuels is estimated around 1,080 kg and it is reliably estimated that about 14 million m^3 of wood are consumed annually for energy production. Available data has indicated that people do not easily substitute fuel and therefore the volume of woodfuel consumption in Ghana could rise to 20 million m^3 by the year 2020 (Forestry Development Master Plan, 1996-2020).

In terms of cooking devices, the most commonly used stoves in both rural and urban areas are the traditional ones with an efficiency of 14 percent and 18 percent for firewood and charcoal stoves respectively, compared to an efficiency of 65 percent and 45 percent for electricity and LPG stoves respectively (Energy Commission, 2006). Although small programs exist in the Forestry Commission (wood lots for the private sector) and in the Energy Commission (improved fuelwood stoves), firewood and charcoal production in Ghana are neither consistently being regulated nor managed. Not a single government institution, neither the Ministry of Energy nor the Ministry for Forestry, or its Forestry Commission, has clearly defined responsibilities and mandates to handle the traditional biomass sector.

The need to actively manage the sustainability of the traditional fuelwood sector is highlighted by the projections of the Energy Commission (2005), which show that fuelwood consumption is expected to double by 2020 under business as usual scenario, and could quadruple by 2020 under the high growth scenario.

3.4.1.1 Projected Demand of Woodfuels

In the Strategic National Energy Plan 2006 -2020 of the Energy Commission of Ghana, the Commission attempts to predict the future energy demand of the country for appropriate plan interventions and preparations to meet the demand. The economy is assessed in three scenarios, that is, high, moderately high and business-as-usual growth scenarios. The economic growth scenarios are based on the Government of Ghana's socio-economic goals as contained in the Ghana Poverty Reduction Strategy-Coordinated Programme for Economic and Social Development (GPRS-CPESD). The GPRS-CPESD objectives include achieving a real GDP per capita of US$1000 by 2012. However the current target is US$1000 by 2015.

High economic growth scenario

Should the Ghana Poverty Reduction Strategy (GPRS) targets to usher the country into a middle income range of US$1,000 per capita in 2015 be realised, demand for woodfuels would grow from about 14 million tonnes in 2000 to 38-46 million tonnes by 2015, and 54 – 66 million tonnes by 2020. Even though, the share of the energy forms will change, woodfuel will still be the dominant fuel. This is expected to put the nation's dwindling forest under undue stress which could culminate into serious deforestation, with serious consequences on climate change, agriculture and water resources, if no significant action is taken. While consumption of woodfuels is running into millions of tonnes, the consumption of other energy forms remains in the thousands.

Moderately economic growth scenario

In the moderately high economic growth scenario, GDP per capita is estimated to be over US$500 by 2015 and the energy demand in terms of woodfuel will still dominate. In 2015, the demand will be 35-42 million tonnes and in 2020 it will be 40-50 million tonnes.

Business-as-usual economic growth scenario

The business-as-usual economic scenario means the current GDP of US$300 (GPRS II) would remain the same till 2020. The energy demand in terms of woodfuels will be 23-28 million tonnes in 2012 and 27-33 million tonnes in 2020. The energy shares as well as the sectoral shares are expected not to change significantly from what prevailed from 2000-2003 under the business- as usual economic growth. In all the scenarios, the expenditure on woodfuels is as important as on petroleum and electricity. Expenditure on woodfuels will equally be as high as those for electricity and petroleum products.

3.4.1.2 Woodfuel Supply and Production

Fuelwood and charcoal production and supply are very decentralized commercial activities that are undertaken all over the country with the highest concentration of commercial charcoal production in the transition zone of Ghana. Private individuals undertake the production and supply of fuelwood and charcoal wholly with very little regulation by Government (Ministry of

Energy , 2003). According to the Energy Commission (2005) about 95 percent of woodfuels are obtained directly from natural forest and the savannah woodlands. The remaining 10 percent is obtained from logging and sawmilling waste. The transitional and savannah zones of Ghana are the major sources of woodfuels preferred by most Ghanaian homes. According to the Royal Danish Ministry of Foreign Affairs, (DANIDA) (2002), the wood in the savannah zone is usually dense, slow-growing and highly lignified which though not suitable for processing into lumber veneer, have high energy content with high calorific values than trees in the forest zone.

3.4. 2 Kerosene and LPG

Kerosene is generally used for lighting of homes that lack electrical power. LPG is primarily used for cooking in Ghana. The total amount of LPG consumed in the year 2004 was about 67,576 tonnes. The household sector accounted for about 76 percent of the LPG consumption in 2000. The rest was accounted for by the industrial (14 percent) and the commercial sectors (10%) respectively (Wang et al. 2006). LPG serves as cooking fuel for about 8.5 percent of the households in Ghana. In the rural areas, LPG provides cooking fuel for only 1.2 percent of the households countrywide as opposed to 29 percent in Greater Accra (Ibid). The cost of LPG and the equipment required (cylinder and burners) makes the use of gas prohibitive to most low-income households. The use of LPG is therefore mainly seen in high and middle-income families in urban areas.

3.5 Comparison of energy cost.

Pricing of woodfuels is purely by demand and supply. There is no price regulation authority for woodfuels and neither is there any known association responsible for pricing of woodfuels.

Wholesale retailing is in maxi jute bags and of average weight between 45 - 50 kilogrammes. Production cost of charcoal is about US $16 equivalent per tonne in the Savannah zone and about US $50 equivalent per tonne in the forest zone. Weighted average cost of production is about US $23 equivalent per tonne. Production costs of charcoal produced from sawmill residue is between US $5 - 6 equivalent per tonne .Charcoal produced in the Savannah zone is usually sold at an average price of about US$ 78 equivalent per tonne on reaching the southern Ghana market. Firewood is retailed at US $23 equivalent per tonne in the south. Comparatively, LPG costs US $313-350 per tonne and kerosene has been US $277-300 per tonne between 2003-2005, making woodfuels the financially least expensive of all the cooking fuels (Energy Commission, 2005).

Traditional charcoal stoves popularly called 'coalpot' sells at about US$1.5-3 equivalent per stove depending upon the quality of metal used in the fabrication. Table 3.2 shows the cost involved in various cooking stoves. Efficient charcoal cook stoves such as Ahibenso which saves 35-40 percent of charcoal usage compared with the traditional 'coal pot' that sells from US $ 5 - 10 equivalent per stove depending upon the size of the stove.

Even though there is no initial capital investment in making a three-stone or mud firewood stove particularly, in rural areas, it is more expensive to use when compared with improved charcoal stove in cases where firewood is purchased. Otherwise, the three-stone or mud firewood stove is the least expensive cooking device and has the lowest life-cycle cost as well. A switch from woodfuel usage to kerosene for cooking is the most expensive option in terms of annual expenses. A switch from woodfuel to electricity for cooking presents the cleanest option in terms of indoor pollution.

Table 3: 5: Cost involved in various cooking devices

Device	Initial Investment cost	Total cost per year[4]($)
Three stone-mud firewood stove	0	44 - 62
Traditional charcoal stove	1.5 - 3	67 - 80
Improved"Ahibenso'charcoal stove	10	37 - 43
LPG (1-2 burner) cooker	30 – 50	83 - 98
Electric (1-2 burner) cooker	20 - 50	81 - 93
Kerosene (1-2 burner) cooker	17 - 25	131 - 161

Source: (Energy Commission, 2005)

However there is an issue of availability since national electricity coverage is still less than 50 percent as of 2004 (Energy Commission, 2005). However, the most advocated option on the mind of the populace is the switch from woodfuels to LPG use, since the latter is 'environmentally' friendly.

3.6 Cooking energy, air pollution and effects on health

As was discussed in Section 2.4 of this work, the use of cooking energy is one of the biggest causes of greenhouse gas emissions. As they constitute simple equipment, small-scale and frequently manufactured without great precision or quality control, domestic stoves produce high quantities of emissions. In a country like Ghana, where 69 percent of the energy is consumed in the residential sector, the consumption of cooking energy has a great impact on the quantity of the country's GG emissions.

[4] This is life cycle cost per year.

3.6.1 Green – house gas emissions and Air pollution in the consumption of cooking energy

The estimates of green house gases and other air pollutant emissions from Ghana's residential sector in comparison with other sectors are presented by Energy Commission (2006) in Table 3.3. The residential sector is by far the highest emitter of most gases, as compared to other sectors of the economy. This is attributed to inefficient use of biomass use in the country.

According to the Energy Commission (2006), energy utilization by the residential sector was responsible for about 68 percent of carbon monoxide (CO), over 50 percent of methane (CH_4) and about 68 percent of nitrous oxide (N_2O) emissions, which are all global warming gases, from 2000 -2004. Over 70 percent of sulphur oxides emissions were also from the residential sector.

Table 3. 6: Average percentage share of gaseous emissions; 2000 - 2004

Gases	Greenhouse Gases				Pollutant Gases			
Sector	$C0_2$	CH_4	N_2O	CO	$*SO_x$	$*NO_x$	*VOC	PM
Residential	24.5	53.0	68.6	68.5	72.2	11.6	19.6	22.4
Comm/Services	0.2	negli	negli	negli	0.1	0.3	negli	negli
Transport	61.6	0.4	19.1	8.0	12.4	51.8	6.4	0.7
Industry	21.5	7.0	9.3	9.0	12.5	5.6	3.0	3.4
Agric & Fisheries	1.4	2.4	2.4	2.5	2.5	2.4	1.0	1.2

Source: Energy Commission 2006 (negli = Negligible * = Total)

Carbon monoxide and particulate matter emissions originate mainly from the residential sector due to the massive use of woodfuels for cooking.

3.6.2 Health Impacts

According to World Health Orgainsation, total deaths attributable to the use of traditional fuels in 2000 in Ghana was 5600 and 2.2 percent of national burden of disease. Acute lower respiratory infections (ALRI) among children under five years of age were 3,960, and chronic obstructive pulmonary disease (COPD) among adults under 30 years old was 1,640. ALRIs are amongst the diseases which most frequently lead patients less than five years of age to the out-patient clinics, in Ghana. In 2004 ALRIs occupy second place in all doctor's appointments at 7.2 percent, losing out only to malaria, which leads with 50 percent (MOH, 2004).

3.7 Efficient stove programmes in Ghana

The Ahibenso stove was the first improved stove to be introduced into the Ghanaian market in 1989. It is cylindrical and comes in various sizes. It is made with a thin metal sheet and has an insulated charcoal holding compartment especially designed to prevent heat losses and conserve energy. The stove has wooden handles. The cooking pots are placed inside the stove to prevent excessive heat loss. It lasts up to 3 years with regular maintenance. The medium sized Ahibenso sells for 3.50 cedis (U.S. $4.30).

This improved stove saves between 35-40% of charcoal over and above the traditional coalpot. Furthermore an expenditure survey conducted among households indicated that it saved between 15-20% of the amount of money normally spent on charcoal. In 1993, alone, a total of 20,000 stoves were produced and distributed .The woodfuel efficiency programme however fizzled out by the mid 1990s after the Ministry's funding ended. In 2002, an NGO, EnterpriseWorks introduced another improved stove called 'Gyapa' by adopting and modifying the ceramic stove from Kenya (KCJ). The Gyapa stove is highly efficient, enabling households to reduce charcoal consumption by around 40 percent. Since its launch in November 2002, over 95,000 stoves have been sold. The Enterprise Works adopted a commercial approach that links ceramists, metalworkers, and retailers to develop a local stove market with aggressive and innovative advertising campaigns. Further dissemination of the Gyapa stoves, however, is constrained by its design not fully meeting consumers' cooking needs.

3.8 Policy framework of the traditional energy sector in Ghana

This section examines the policy framework within which the traditional sector operates.

3.8.1 Biomass Sector Reforms

According to the Ministry of Energy (2006) the production and supply of woodfuels had long been private sector driven and the Government does not intend to intervene in its supply except to initiate and support appropriate regulatory mechanisms that will ensure its sustainability. The strategic focus of the energy policy is to create an environment that will accelerate regeneration of biomass resources. In order to create economic incentives for the better management of woodfuel production and supply, government will

- *Rationalize the regulatory framework for woodfuel exploitation, transportation and distribution by enactment of appropriate legislations that will control the exploitation of biomass resources for the production of woodfuels.*

- *The Forestry Commission and the Energy Commission will ensure the implementation of this policy in collaboration with the District Assemblies.*

In order to ensure sustainable production, marketing and consumption of woodfuels taking into account poverty and gender issues, it is recommended by the Energy Commission (2006), that the government will

- *Establish a comprehensive institutional framework to enhance and co-ordinate woodfuel related activities as an integral part of national energy development strategy*

- *Promote sustainable management of the country's natural forests and woodlands for sustainable production and supply of woodfuels*

- *Regulate the woodfuel transportation, marketing and export system to encourage more sustainable practices*

- *Support development and introduction of improved technologies and higher levels of efficiency in the production and consumption of woodfuels as well as substitution of fuels*

3.8.2 Environmental Protection Agency and Environmental Impact Assessment

According to the Energy Commission (2005), Ghana has a National Environmental Action Plan which defines the environmental framework for various economic sectors including energy. Large scale energy projects require full environmental impact assessment. The Energy Commission requires Environmental Permit from the Environmental Protection Agency (EPA) before it grants construction permits and operational licenses to prospective energy developers.

3.8.3 The Ghana Poverty Reduction Strategy

The vision for the energy sector under the GPRS is to develop an "energy economy" that would ensure reliable supply of high quality energy services for all sectors of the economy while making significant contribution to the export earnings of the country. To support economic growth and consequently alleviate poverty, the energy service is expected to be so structured as to improve on the availability, accessibility, affordability and acceptability of modern forms of energy delivery.

3.8.4 International protocols

Other government policy intentions are evident in a number of environmental related issues and protocols that the Government is signatory to. On an international perspective, the Government is a signatory to several conventions on climate change, biodiversity, land degradation and other environmental issues such the Kyoto Protocol (Energy Commission, 2005). Ghana has also been a key partner in the development of international understanding and guidance in National Strategies for Sustainable Development under Agenda 21 of the United Nations.

3.9 The Study Area: The Bongo District

The Bongo District in the Upper East Region of Ghana is selected for this study. Some of the general specifications taken into account for the selection of this study area can be mentioned. Firstly, districts in Ghana are the basic development units (Constitution of Ghana, 1992) that have planning and implementation powers on all issues related to the development of the district. This enables data collection and analysis to be done in a meaningful way and also ensures that recommendations can be implemented in a meaningful and sustainable way.

Secondly, the Bongo district suffers from severe water shortages and arid soils which have impacted on agricultural productivity and household incomes. Inappropriate farming practices, for instance, have led to increase deterioration in both the vegetation and soils. Intensive farming, overgrazing and constant removal of trees and shrubs without adequate replacement have paved the way for desert-like conditions in many parts of the district. Owing to increased population growth, there is great pressure on land and water resources.

Wildlife has become threatened as vulnerable tree species die off. These, and many other features, are manifestations of land degradation, which is a major environmental problem in the district. Land degradation exhibits itself in three interactive forms: physical, chemical, and biological. Apart from inappropriate farming practices, land degradation can be attributed to the following factors; high population density; overstocking and overgrazing; bush burning; tree felling; land excavation for road and building construction.

Land degradation is also manifested in soil erosion and loss of organic matter; poor animal production due to reduction in available fodder, siltation of water bodies and loss of aquatic life; trekking long distances by women to obtain fuel wood and increasing intensity and duration of drought.

Thirdly, the location of the Bongo district makes it an ideal location for the study of linkages between energy, gender and poverty. The district is characterised by large household sizes, high population density and high fertility rate, high infant mortality rates (resulting from pneumonia and acute respiratory infections, issues strongly related to biomass smoke) as obtained in other parts of the region. Some of these features are associated with the district because of the generally low level of development. The population of the district is predominantly rural and the major economic activity engaged in is farming. Apart from the district capital Bongo, all the rest of the populations live in small farming settlements scattered around the district. Poverty in the district is not only manifested by an inability to afford basic consumption goods, but also by a lack of access to basic needs, such as education, health care, safe drinking water, safe sanitation facilities, and electricity.

Also the overall neglect of the northern regions, their patrilineal family structures reinforced by Islamic practices, and their arid-savannah ecology (Panuccio 1989), are all factors which have acted to maintain women's low status in the three northern regions. Both pre and post-Independence, these regions have been viewed primarily as a labour reserve for the development of the rest of the country and there has been limited investment in development infrastructure in these areas. Out-migration, mainly of younger men to work in the cash economy of the south and beyond, has left women with increased labour burdens and undermined agricultural productivity and food security in these areas, whilst adding little to their incomes. The lack of physical and social infrastructure adds to women's labour burden (e.g. in collecting water, firewood; tending the sick) already more onerous than elsewhere because of agro-climatic conditions. Further, it means that women's income earning opportunities are constrained and that their access to education and thus modern sector employment is limited. On health, educational and poverty indicators, the three northern regions fare worst and gender gaps (e.g. in educational enrolment) tend to be widest. In both private and public spheres, women's decision making role in Ghana is constrained, markedly so in the northern regions.

Further, compared to the southern Ghana, relatively few studies have been carried out in northern Ghana, which contain a significant proportion of the national population. In particular, there are substantial climatic and socio-cultural differences between the northern and southern regions, including different food habits and the use of these biomass fuels for heating, which could have an important bearing on household exposures.

3.9.1 Background to the District

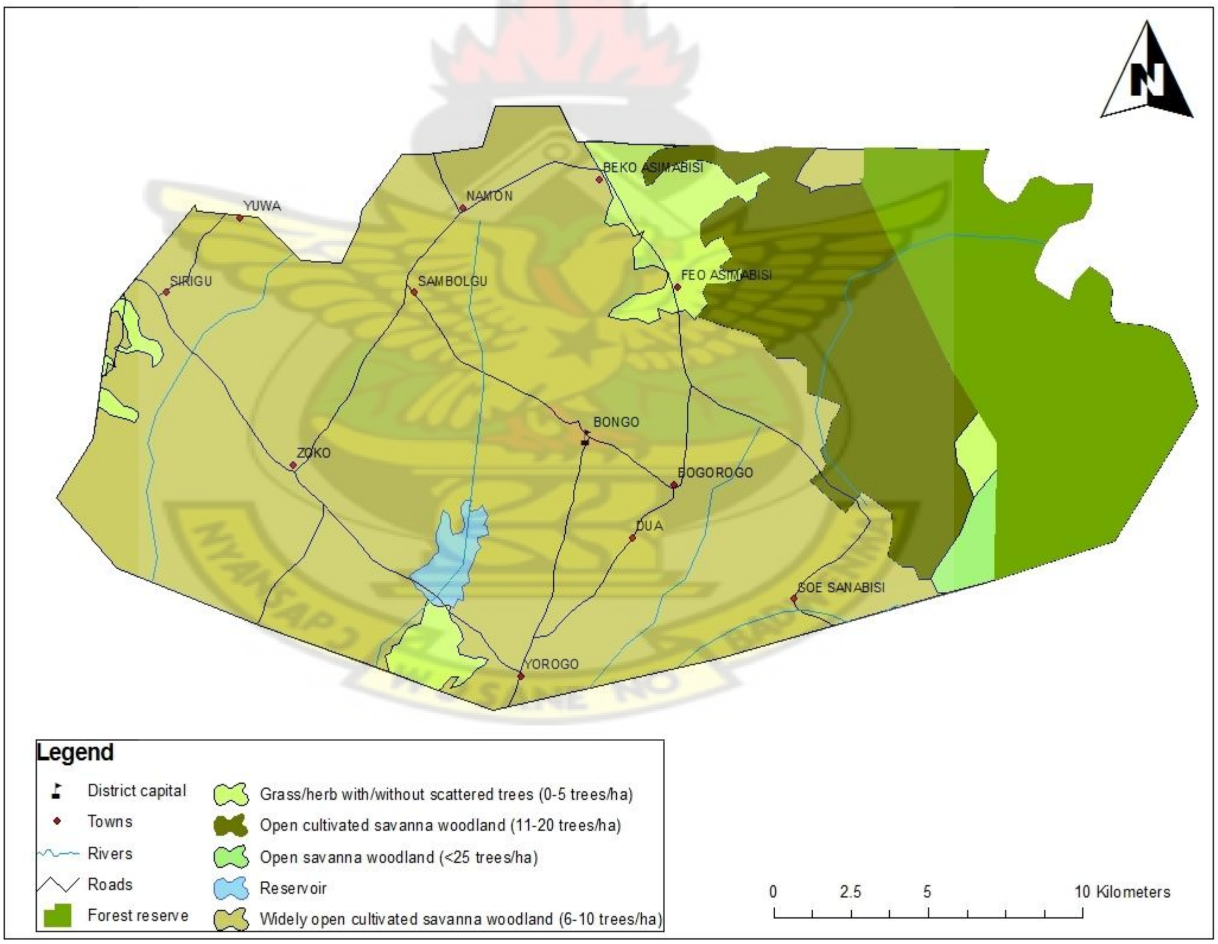
Bongo District is one of the six (6) districts in the Upper East Region of Ghana, with Bongo Township as its district capital. It lies between longitudes 0.45'W and latitudes 10.50'N to 11.09'N and has an area of 459.5 square kilometers. It lies within the onchocerciasis-freed zone of Ghana. The district shares boundaries with Burkina Faso to the North and East, Kassena-Nankana District to the West and Bolgatanga District to the South. Bongo District as a whole had an estimated population of 77,885 in 2000 and a population density of 183 people per sq. km (Ghana Statistical Service, 2005). This relatively high mean figure for the district masks the fact that there is increasing pressure on land for farming and other purposes. This situation is further worsened by the rocky nature of the district thus putting extra pressure on land. Figure 3.1. shows a resource map of the district. The relief of the area is related to the geology. The topography of the area is relatively flat, with occasional rocky outcrops, at an altitude of about 200m above sea level. Viewed at the end of the dry season, the area seems to epitomise the hazards of desertification.

Most trees have been removed and grass cover is sparse. There is serious vulnerability to water and wind erosion. The following statement was made by Blench (1999) concerning the severity of the issue of land degradation in the area.

"Actual soil fertility is determined as much by the exceptional concentrations of population allied with a low-input farming system. Throughout most of Upper East

Region… there are virtually no elements of the system that encourage the return of nutrients to the soil… in the dry season [livestock] are taken away from the area to avoid damage to crops and the manure is effectively lost. Most trees, even leguminous ones, have been removed from the farms in order to increase cropping area. Firewood is so short that the stems of cereals are removed from the farms and used to cook food, thus not returning their organic matter. The elimination of almost all types of ground cover leaves the area prone to wind erosion".

Figure 3. 1: Resource Map Of the Bongo District



Source: Bongo District Planning Unit

According to the School of Engineering, KNUST, (2003) many areas in Ghana are currently facing fuelwood scarcity, particularly, in the north-eastern part of the country. The study area happens to lie within this zone. Plate 3.1 gives a view of the general landscape across the district.

Plate 3.1: General landscape across the district

Source: Author's field Survey, January – April, 2006.

There is a single rainy season from April to September, during which most precipitation falls in brief, intense storms that can flood fields and cause significant erosion. Bongo District has an average of 70 rain days and 600 – 1,400 mm of rainfall per year. Although many of the Bongo soils are inherently fertile and have good water holding capacity, their productivity has been degraded by intensive use. The area's soils are now characterised by low fertility, low water holding capacity and susceptibility to sheet erosion. During the dry season, many rivers and streams dry up, vegetation withers, livestock suffer severe weight losses and as many as 70% of households send at least one member to seek employment in southern Ghana for up to six months.

3.9.2 Socio-economic characteristics

The socio-economic characteristics of the area are based mainly on a very complex network of cultural systems and extractive activities based on land. Crop production and livestock rearing are the major gainful activities with only a relatively few percentage engaged in formal jobs and informal jobs such as trading, vulcanizing, artifacts making and wood cutting. Other activities that sustain the lives of women are *pito* brewing, *sheabutter* processing, *dawadawa* processing and groundnut oil processing.

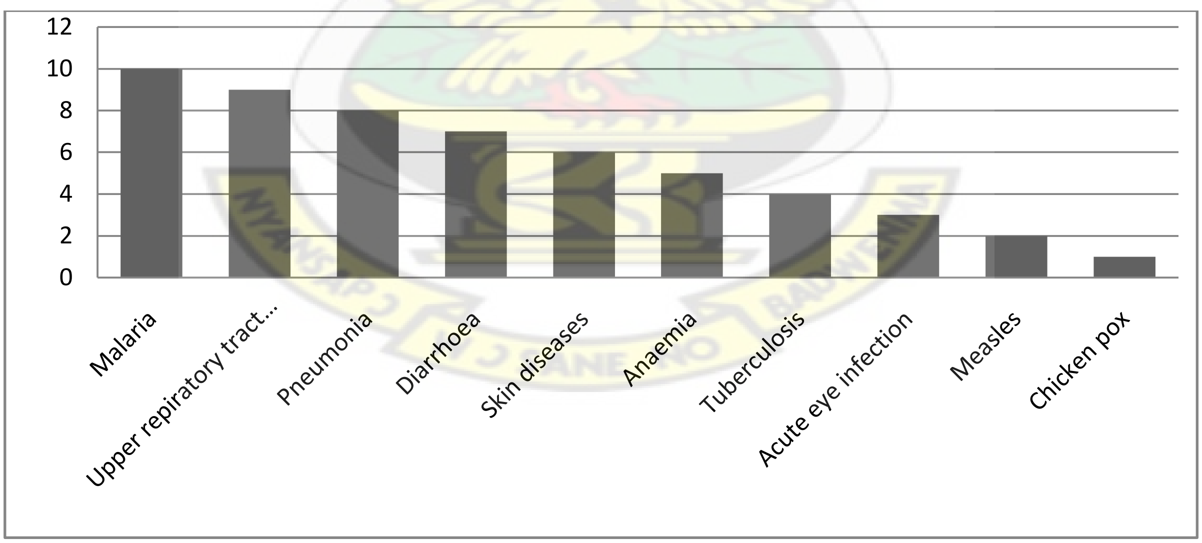
3.9. 3 Employment and Occupational distribution

Agriculture is the dominant occupation of the people, accounting for about 57.9 percent of the employment (Ghana Statistical Service, 2005) . The major outputs of farmers are maize, millet, rice, groundnuts, onions, watermelon and livestock such as cattle, sheep, goats and poultry. The area experiences only one rainy season thus limiting all year round farming to areas such as dam sites and in valleys. The seasonality of the farming activity has resulted in a mass seasonal exodus of the youth to the southern sector of the country during the lean season in search of menial jobs. This has adverse effects since some of them return with the dreaded disease-HIV, whilst the elderly and the aged are left behind to provide labour for the execution of projects at community levels. Other employment avenues include public service, food processing, leather works and trading. Generally men grow cereals while women, whose plots are normally smaller than those of the men, grow crops such as groundnuts, tomatoes, spices and vegetables. It is believed traditionally that it is the responsibility of women to provide for family upkeep i.e. women is expected to contribute the “soup ingredients”. In addition, women provide or gather firewood, clothe themselves, their babies and female children and sometimes bear the costs for health care and education. Apart from farming, women in the district undertake income-generating activities to meet their personal cash requirements. As providers of labour to the household, women work on their own plots after labour requirements for the household have been met. Factors that determine the success of women in agriculture are money for purchase of inputs, land, labour and traditional responsibilities. Women aim at growing enough for family consumption, processing and for sale.

3.9.4 Health

Good health is crucial as households livelihoods rely on the health of family members. To estimate the incidence of diseases in the Bongo district, data were collected from both the Bongo district hospital and at the communal level. Figure 5.2 shows the ten top diseases from the District by Rank.

Figure 3.2: Top Ten Diseases By Ranking.



Source: Bongo District Hospital, 2006.

3.9.5 Energy resources and development- Natural Capital Livelihood Assets.

Given its geography, the Bongo district has a huge potential for the development of renewable and micro- hydro electric power.

Renewable energy

Bongo one of the most drought-prone districts in Ghana suffers severe water shortages, both for consumption and irrigation. Over a long period, the reliance on fuelwood for heating and cooking has accelerated large scale deforestation, reduced water retention and intensified soil erosion. This has impacted on agricultural productivity and contributed to the relatively high levels of poverty in the district. The national government now regards rural energy policy as central to its attempts to reverse the loss of vegetation and sustain the livelihoods of populations in remote rural areas. The Ghana Poverty Reduction Strategy 2003 – 2005 (GPRS) emphasizes the importance of both renewable energy sources and energy conservation.

Biomass

The Red Volta Forest Reserve supports a number of wildlife and serves as a source of fuelwood production for settlements nearer to it. Also, quite a number of tropical crops are cultivated in the district; generate a lot of post harvest residue for the production of biomass energy. Examples of agricultural residues include maize cobs, sorghum and millet stalks. Another form of energy that can be derived from agricultural waste is in the form of animal waste. Livestock rearing is one the major occupations of people living in the study area. A lot of dung is therefore produced each day and this can be used as a major feed stock of biogas plants.

Solar energy

Ghana is well endowed with solar energy resources as it receives daily solar irradiation of between 4 and 6 kWh/m and a corresponding annual sunshine duration of 1800-3000hours (KITE, 2003). It has been established that the southern parts of Ghana exhibit very high diffuse radiation levels (over 45%) whilst the north has moderate levels of diffuse radiation between 32 and 45 percent (DANIDA, 2002). According to the report, increases in solar radiation is much higher in the Sudan Savannah zone but decreases in the High Rainforest zone. This phenomena is reflected in the changes in the rainfall pattern where the highest decrease in rainfall is in the Sudan savannah zone, (the project area) because the increases in temperature and solar radiation are highest.

Small hydro power

The Akunkidbota River found in the study area has been cited to be a potential site for the generation of hydro electric power (JICA, 2006).

CHAPTER FOUR

RESEARCH DESIGN AND METHODOLOGY

4.1 Introduction

This chapter provides the background on the study and elaborates on the processes and methods employed in formulating the problem, selecting instruments for analyzing the problem, and how conclusions were arrived at.

4.2 The Research Strategy and Design

This research adopts the case study approach, focusing on household cooking energy use dynamics in the Bongo District. As a research strategy, case studies aim to bring depth to particular phenomena by studying the relationships and processes that define the case (Denscombe, 2003). It is therefore the aim to provide an in depth and holistic account of the cultural and social factors determining household cooking energy choice, and their implication on the introduction of modern energy alternatives. In order to provide an in depth account, the research relies on multi-method data collection, often referred to as triangulations. Besides allowing for an understanding of the relationship in a more rounded and complete way, it also allows for the validity of data to be tested, as findings from one method are checked against another (Denscombe, 2003).

4.3 The household as a unit of research and analysis

The unit of analysis determines *what* or *whom* being studied. Determining the unit(s) of analysis in a case study research, helps in measuring or analyzing the problem identified (Yin, 2003). The survey was designed to capture data at the household level, in turn making the household the logical primary unit of measurement and analysis. The household was defined as those individuals - resident and non-resident - that were listed by the respondent (who in most cases was the real or acting household head) as belonging to that household. Ardington and Lund (1996) have argued that, despite critical literature on the household as the unit of measurement the *de jure* household, i.e. including resident migrant members, is the most appropriate unit of measurement in rural livelihood studies. This is because of the high level of economic cooperation that takes place between local and non-local household members.

4.4 Survey methods and Data collection

The data used for the study was collected during the fieldwork that was carried out between January – April 2006. The primary data were obtained through the administration of structured questionnaire at the household level and supporting data through focused group discussions, Participatory Rural Appraisal (PRAs) and Key Informants Interviews. The secondary data were taken from the different authorities as well as relevant publications.

4.4.1 Selection of the Settlements

A total of fifteen settlements were selected for the purpose of collecting information. The multi-stage sampling design was used in the selection of the respondent to be interviewed. The sample frame consisted of the six sub-districts found in the Bongo district based on the classification of the Bongo District Assembly. Using the simple random sampling procedure, settlements within each sub-district were sampled. Households within the selected settlements were listed and using probability proportion to size the number of households to be interviewed in each selected community was estimated using simple statistical analysis. The settlements and the total number of households sampled are shown in table 4.1.

Table 4.1: List of Settlements and Number of Questionnaire Administered

Settlement	Households	Percent
Beo saporo	48	7.7
Soe sanabisi	42	6.7
Gowrie -tingre	108	17.3
Vea asoranabisi	36	5.8
Goo awaa	24	3.8
Zoko-gamborogo azaabisi	66	10.6
Anafobisi kasenenga	13	2.1
Zoko tarango	26	4.2
Feo asimabisi	41	6.6
Beko asimabisi	36	5.8
Market soe soboko	41	6.6
Adaboya	37	5.9
Samblugu abokobisi	35	5.6
Nayarogo galarom	32	5.1
Bongo social center	40	6.4
Total	625	100.0

Source: Author's field Survey, January – April, 2006

In relation to the monitoring of Indoor Air Pollution (IAP), the study, collected detailed primary data on several household-level exposure indicators (for fuel type, housing type, kitchen type, ventilation, stove type, etc.) through the administration of a structured questionnaire to 45 selected households. These households were selected from the 625 sampled of households. The relatively small sample size in this study reflects the time-intensive and expensive nature of real-time IAP monitoring.

Unlike other studies that use air samplers which measures pollutant concentrations over 24 hours, two real-time instruments were used in this study. As a result, each dwelling required 24 hours to sample and then an additional 24 hours to charge batteries. Similar studies, which have employed real-time monitoring techniques, have used sample sizes of 20-30 dwellings as well (Saksena et al., 2007; Park and Lee, 2003; Lawrence and Taneja, 2005; Adonis and Gil, 2001; Muller et al., 2003; Brauer et al., 1996)). In addition, a small sample size provides a more detailed case study, and as such, more information concerning physical, technical and family parameters affecting IAP and exposure could be collected. While larger studies are more representative of whole populations, the aforementioned issues are not always adequately addressed (Ahmed et al., 2005).

4.5 Data Collection Approaches

Several methods were employed in collecting both quantitative and qualitative data for the study. A skillful use of a combination of qualitative and quantitative techniques will give a more comprehensive understanding of the topic (Bryman, 2004). Quantitative research collects numerical data in order to explain, predict and or control phenomena of interest and data analysis is mainly statistical. Qualitative research involves the studied use and collection of a variety of empirical materials, case study, personal experience, introspective, life story interview, observational, historical, interactional, and visual texts-that describe routine and problematic moments and meaning in individuals' lives and phenomenon.

4.6 Quantitative Data

4.6.1 Participant Recruitment

A knock-on-the-door approach was used to initiate contact with future participants. If the head of the household was unwilling to participate or no one over the age of 18 was home, the next household was approached. At each dwelling, either the female or male head of the household was first approached to be the principal respondent. If they were not present, households were then asked to self-appoint a respondent, provided that they were at least 18years old. Once consent was obtained, instruments were set up and survey begun.

4.6.2 The study questionnaires

Two different questionnaires were deployed during the study. First of all, a general questionnaire (Appendix 2) was administered to the entire sample (625). The questionnaire covered the following themes and issues.

1. Background and demographic profile of household respondents and /or members
2. The household economic portfolio for sustainable livelihoods
3. Household energy consumption and usage patterns.
4. Local government services used (access to services)
5. Household assets and financial resources (level of resources)
6. Health of household members in relation to their energy usage.

In order to collect information related to IAP exposure and other contributing factors, a second questionnaire adapted from the University of California–Berkeley and EnterpriseWorks, Ghana (Appendix 3) was used. The Indoor Air Pollution monitoring questionnaire endeavor to:

1. provide information about the household members and their houses especially the kitchen design.
2. determine the amount of cooking that took place on the day in which the house was monitored.
3. record systematic information on the implementation of pollution measurement in each household
4. give the households and enumerators an opportunity to make other comments about the process and any changes that that process may have created

Fine particulate matter (PM) and carbon monoxide (CO), the two most important and most studied pollutants associated with biomass combustion smoke, were measured in the sampled households. The particulate and CO measurement devices were placed on the wall of the kitchen for 24 hours according to the following criteria:

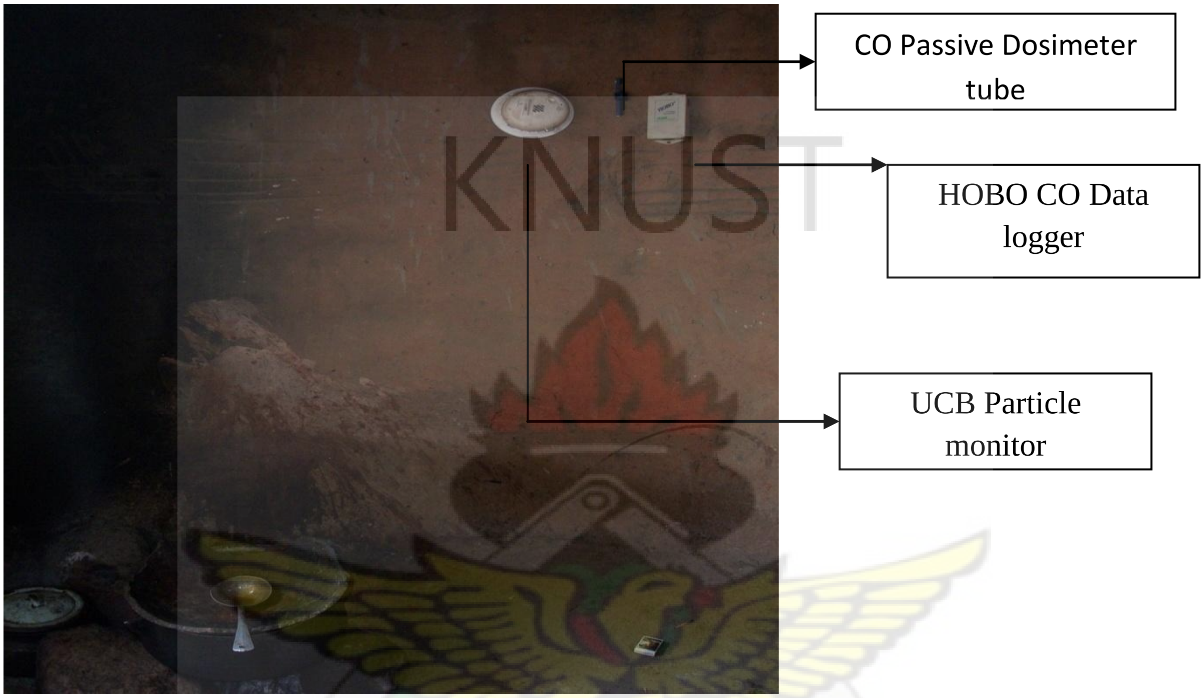
1. Approximately 100 cm from the edge of the combustion zone (this distance away from the stove approximates the edge of the active cooking area)

2. At a height of 125 cm above the floor (this height relates to the approximate breathing height of a standing woman)

3. At least 150 cm away (horizontally) from doors and windows, where possible

All three devices were co-located (placed next to each other) and placed in a relatively safe location to minimize the risk of interrupting normal household activities or being disturbed or damaged. Detailed kitchen sketches were made during the initial visit of the before monitoring, so that the sampling location could be duplicated in the after monitoring phase. Plate 4.1 shows, the placement of the equipment in a kitchen.

Plate 4.1. Placement of monitoring equipment in a sampled Kitchen.



Source: Author’s field Survey, January – April, 2006

Fine particulate matter was measured in each of the households using the University of California-Berkeley Particle Monitor (UCB PM) with a photoelectric detector. The UCB PM measured and logged the fine PM concentration every minute (in units of milligrams PM per cubic meter of air, mg/m3). The monitor measures particles of aerodynamic diameter less than approximately 2.5 microns (called $PM_{2.5}$) (Litton et al., 2004; Edwards et al., 2006)). The monitors were produced and calibrated in the Indoor Air Pollution Laboratory at the University of California-Berkeley (UC-Berkeley) prior to their use on the ground in the study area. The photoelectric chamber was cleaned with isopropyl alcohol after every five 24-hour uses. Carbon monoxide was measured in each of the households with the HOBO CO logger (model #H11-001, Onset Computer Company, Bourne, MA, USA: http://onsetcomp.com/), which recorded the CO concentration every minute (in units of parts CO per million parts of air, ppm). The seven loggers used in this study were calibrated at the Indoor Air Pollution Lab at UC-Berkeley using CO standard gas cylinders of 5 and 60 ppm. Also, in the middle of the sampling campaign, before the start of the After monitoring, a co-location calibration check was run, where the six routinely used loggers were compared to the seventh ("gold standard") logger which was only used for such co-location calibration checks. In addition, as a backup, CO was also measured by a CO diffusion tube (model #810-1DL, Gastec Corporation, Japan; http://www.gastec.co.jp/) in each of the 45 households. By design, these tubes yielded one average (or integrated) concentration of CO for the 24 hour monitoring period, also recorded in ppm. The protocols for the three measurement methods used in this study, along with the HOBO CO Calibration Check Protocol can be found at CEIHD's website: http://ceihd.berkeley.edu/heh.IAPprotocols.htm). The Sampling Data Forms are included in Appendix 4.

The questionnaires, originally in English, were translated back into the local language for checking purposes and a small-scale pre-test was conducted. A revised draft of the questionnaire with instructions for interviewers was prepared and using the interviewers who were part of the survey, a pilot survey was conducted under field conditions. A manual analysis of the pilot survey was carried out and after extensive debriefing by the interviewers, the questionnaire was finalized. The questionnaire was designed using a highly structured protocol, where detailed instructions were provided to the interviewers covering the response options provided and appropriate skips in questions to be asked during face-to-face interviews.

4.7 Qualitative Data

For the study, qualitative data was collected through

1. In- depth interviews,
2. Participatory Rural Appraisal (PRA) tools
3. Focused group discussions.
4. Participant Observation

4.7.1 In-depth interview with Key- Informants

Interviews are about exchange of views between two persons who have a conversation about a topic of common interest (Kvale, 1996). This method allows the researcher to study subjective meanings and motives, alongside the more object viable attributes and aspirations that can be tapped by structured questionnaires. Questionnaires are a means of explaining and understanding the kinds of relationships, which can only be described by more extensive quantitative approaches (Johnston et al., 2000).

In-depth interviews were conducted with the following people

1. Bongo District Chief Executive.
2. The Chief Executive of Northern Electricity Department
3. Members of village committees
4. Representative of women’s groups
5. Representatives of men’s groups
6. District Health Officer of the Bongo Hospital.

These interviews were focused on issues relating to poverty, gender and energy and the impact on rural livelihoods. It also concentrated on issues of consumption, production, utilization of energy services, access to information and communications.

Interviews are not only preferred because of their ability to give an understanding of how people perceive and think about what they do, but they generate a lot of information very quickly, enable the researcher to cover a wide variety of topics, clarify issues as they arise and following up unanticipated themes. However the method is largely determined by interpersonal and listening skills of the interviewer and the interviewees may not be willing to share experiences especially what they consider to be sensitive information and therefore may give information that does not reflect what they actually do.

4.7.2 Focus Group Discussions (FGDs)

A focus group is a collection of a small number of people, typically between four and twelve that meet to discuss a topic of mutual interest, with assistance from a facilitator (Gatrell, 2002). Usually, the group members represent particular positions or interests. Focus group discussions were used however, separating the females from the males to ensure that the females are fully integrated in the discussions. Indeed, due to the extent of privacy and intimacy of the questions, women were more likely to be over-shadowed, since men generally appear to be more vocal and discuss issues more freely than women.

Another challenge was how to group or blend the different ages and the socio-economic backgrounds of the respondents. It is noted that focus group discussions are best conducted with participants who are similar to one another (Krueger , 1994). Time was an asset and very limited for the research, otherwise, it was most appropriate grouping respondents according to ages and socio-economic class to enable comparism of the information to assess variations in data. In all, four discussion groups were formed. One group comprised of a chief and his elders which focused on poverty, gender, energy and livelihood issues in their community and the district as a whole. Two focus group discussions were also organized for both male and female groups focusing on energy, poverty and livelihoods issues in the study communities and the fourth group discussion was done for only females that focused on gender issues in the study communities. Averagely ten to thirteen individuals formed a group and the discussions lasted for about 1-2 hours.

4.7.3 Participant Observation

Despite linguistic and cultural differences, researchers recognize grief, joy sadness, anger and other emotions from the gestures and talks to respondents (Gubrium and Sankar, 1994). Observation enables the researcher to gain a broader perspective on views of the community members and relationships with in it. During this study, observations were made all the time; during interactions with members and during transect walks to and from the communities in some homes that were visited. Observed phenomena were recorded in a note book and were further used during analysis.

Observation is very important because it produces rich detail and description (especially non-verbal) information about people in the context of their everyday lives. Observation was particularly very necessary in revealing information about observable features such as the type of household, structure of houses, environmental conditions prevalent, the appearances of the people and types of observable behaviours and practices.

4.8 Data

The study relied to a large extent on primary data since there was not much data published at the district level. Besides, the use of primary data provided a better understanding of the factors at play in the district and allowed a deeper analysis to be done. Data collected from various sources concentrated on current consumption patterns of household energy at the local level, livelihood strategies adopted by local people, poverty situation of studied communities, energy policies and their direct and indirect effects on the district.

4.8.1 Sources of data

Primary sources of data included, households, male and female groups and key informants. Secondary sources of data included published and unpublished materials, District development plans, published and unpublished papers on a wide of energy and livelihood issues.

4.8.2 Collection of primary data

A total of three interviewers with work experience in the district were employed to administer the questionnaire over a period of one month. The principal researcher daily reviewed completed questionnaires and directly supervised the collection of data.

The skills of the interviewers were improved and consolidated by a training section that was organised. The topics treated included the non-judgmental approach, trustworthiness, listening skill, and the ability to relax the respondent and how to respond to the unexpected. Criteria for selection of interviewers included ability to understand, speak, read and write the local dialect of the study area fluently, are born in, or have spent a fair amount of time in the study area and be conversant with the local traditional practices and geographical conditions.

During the training sections, the interviewers were briefed on the objective and purpose of the study as to help them know the following:

1. The type of data to be collected,
2. The nature of work the study entails, and
3. The kind of people to be contacted for the required information.

After this, a pilot survey was done to check whether the questions asked were clear to the respondents as well as to the interviewers. This helped to know how well the questions suited the local setting, if the questions were easy to understand and how long the interview will take. The pre-testing of the questionnaire was part of the training of interviewers. After the pre-testing, some questions were modified, others were removed and some were added. For example, the classification of socio –economic status was constructed using information on household ownership of a number of consumer items ranging from a television to bicycle or car, as well as dwelling characteristics such as source of drinking water, availability of sanitation facilities and the type of material used for housing.

On issues of vulnerability, respondents found it difficult to develop a ‘time-line’ identifying difficult financial times for the household over the previous five years. Therefore situations were cited and respondents were asked to state how they coped with the situation. Situations cited included marriage, deaths, sickness, crop failures, scarcity of fuelwood and floods. The 24-hour time format required for activities in which household members engaged in was problematic. Respondents were not able to give accurate times for household activities engaged in by others household members except themselves. Thus the questionnaire was redesigned so that it was applicable to only the respondent. Table 4.2, shows a check list for the pilot study.

Table 4.2: Check-list for Pilot study

	Acceptance	Not acceptable	modifications
Validity and reliability	Generally good		None
Time needed for administering each questionnaire		Time was too long	Some variables were removed because STATA cloud generate them during analysis
Presentation (paper, format, etc)	Generally good		none
Pre- coding of questionnaire		A few boxes were missing	The missing boxes were inserted.
Accuracy of translation (adapted to the local language).		There were a few ambiguities.	The questionnaire was translated back and retraining of interviewers conducted to ensure accuracy.
Organisation of content	Generally good		none
Handling and administering the questionnaire	Generally good		None.

A total of 625 questionnaires were administered in the main study. The use of local personnel and the frequent call-backs ensured a response rate of 95 percent. Daily review of completed questionnaire during the period of the survey also enabled data gaps to be filled before the end of the exercise. At the national level, data was collected almost exclusively by the author by use of interview guides which centered on a set of points prepared prior to the meetings. A combination of methods were used to collect data based on a design incorporating all the actors who had been predetermined during the research design, confirmed and revised during the pilot survey.

4.9 Data analysis

Data analysis is the process of bringing order, structure and meaning to the mass of data collected. Tools of descriptive and inferential statistics were used in analyzing the acquired data in this study. Two levels of analysis are conducted. These are: Descriptive analysis- Describing the data using descriptive statistics by examining relationships and trends using statistics, and testing for significant relationships.

The exploratory data analysis (EDA) approach was used for analyzing the data (Saunders et al 1997) using mainly tables and graphical presentations. The EDA approach is precisely that--an approach--not a set of techniques, but an attitude/philosophy about how a data analysis should be carried out. Descriptive statistics are used to describe and compare variables numerically with a focus on (i) measures of central tendency (median, mode and mean values) and (ii) dispersion (range, interquartile/quintile range, deciles and percentages and standard deviations). Asset holding pattern variables are cross tabulated with human development indicators such as educational variables and employment of the respondents as well as household characteristics including sex and marital status of households to observe relationships among the data.

The issue of how one variable or set of variables relate to another or other variables is analysed statistically by testing the likelihood of the relationship occurring by chance , that is, its significance. Testing for statistical significance means calculating the likelihood that the relationship observed between variables in a sample can be attributed to sampling error only. Mostly chi square tests of grouped data were used to test the significance of two or more variables.

4.9.1 Wealth index estimation

The strength of the relationship between the variables, specifically asset holding on one hand, and human development on the other hand is analysed using the asset index. This index is based on the wealth index in the Ghana Demographic and Health Survey 2003 (GSS, 2003), which is fully discussed by Rutstein and Johnson (2004). The asset of each household group is generated by means of principal components analyses based on households' possession of livelihood assets. These are specifically , Farmland, Tractor , Plough/Trailer, Large Farm Animals (cattle), Medium Farm Animals (Goats, Sheep and Pigs), Poultry (Chicken and Guinea fowls, Agricultural Products (Millet, groundnuts etc),Vehicles (Bicycles, Motorcycles and cars), Sewing machine, Television, Radio, and a Stereo system. According to Filmer and Prichett (2001), the principal components analysis (PCA) is used to assign the indicator weights. This is the same procedure that is used for the DHS wealth index. The procedure first standardizes the indicator variables (calculating z- scores); then the factor coefficient scores (factor loadings or weights) are calculated; and finally, for each household, the indicator values are multiplied by the loadings and summed to produce the household's index value.

Accordingly, each asset was assigned a weight or factor score which was generated through principal component analysis (see Appendix 5) and the resulting asset scores were standardized in relation to a normal distribution with a mean of zero and standard deviation of one.

Households were then assigned a score for each asset, and the scores were summed for each household (See Appendix 6). The total household asset index was therefore derived as the sum of all individual household components scores as shown in the formula:

$$Total\ Asset\ Index = \sum_{t=1}^{n} \left(\left\{ \frac{value\ of\ asset\ variable - unweighted\ mean\ of\ asset\ variable}{un-weighted\ standard\ deviation\ of\ asset\ variable} \right\} "raw"\ assets\ factor\ score \right)$$

4.10 Data management

Meticulous attention was employed on the part of the researcher to ensure that, all forms are completed according to the pre-designated specifications, errors are corrected and no forms are lost. The forms were sent to a central location where they will be counted and processed for tabulation. All data were checked and double entered into Microsoft Access relational databases and Microsoft Excel spreadsheet to ensure accuracy.

4.11 Research scope and limitation

Given the constraints of time and resources of a particular research agenda, the concepts, theories, actors and spatial coverage of the research have to be clearly defined. The research work is designed to provide insight into how the available energy forms at the rural level can be harnessed and appropriately utilized to improve the livelihood strategies of rural women, to the present energy forms and consumption patterns at the rural level, the demand and the sources of supply of the energy forms and how they affect the environment now and in the future, the use of energy forms at the rural level affect the health of the community members, especially women and their children and identify the linkages between access to energy forms and livelihood strategies and gender equity in general.

Data was collected from the Bongo districts with households being the main unit of analysis. Women who are the main cooks in the households as well as men who are the main breadwinners will be the target groups to be interviewed.

The main problems anticipated relate to the extent to which respondents tell the truth in answering questions about socio-economic status. Social desirability effects might work in two directions, some exaggeration or under-reporting.

4.12 Ethical considerations

In order not to infringe on the emotions and cultural and social rights of respondents, the study endeavored to obtain the respondent's consent before, the start of the interview, respected the informant's privacy, ensured that information is protected against third parties accessing it, and observed or respected certain cultural values, traditions or taboos.

CHAPTER FIVE

SURVEY FINDINGS- HOUSEHOLD ENERGY USE IN BONGO

5.1 Household Characteristics

Energy use patterns are closely linked to agro-climatic and socio-economic condition.

5.1.1. Age-Sex Distribution of Sampled Household Population

The age distribution of the members of the sampled households shows that 23.2 per cent of the people were of below age 30 and 71.4 percent ranged between the age group of 30 to 65, while the remaining 5.4 per cent were above 65 years old (Table 5.1). This reflects the situation in most developing countries, where a combination of high fertility and declining mortality results in high population growth rates and a high percentage of young people. Males in the study area constitute 152 (24.3 percent) and females 473 (75.7 percent).

Table 5:3: Age-Sex Distribution of Study Population

Age Category	Male	Female	Total	
			Number	Percentage
Less than 30	24	121	145	23.2
30-65	112	334	446	71.4
Above 65	16	18	34	5.4

Source: Author's field Survey, January – April, 2006

5.1.2 Household Composition

Households in Ghana are predominately male-headed. Accordingly, out of the surveyed 625 sampled households 63 per cent of the households in the area were male-headed and 37 percent female-headed. The size of the household in most fuelwood literature (Chen et al., 2006, Heltberg et al., 2000) is expected to influence the amount of fuelwood used, because of the increased energy demand (for cooking) and the increased labour for it collection. All households surveyed had between 1 and 12 household members, with an average of 5.5 persons per household. This is comparable to the district figure that stands at 5.8 (GSS, 2002). The total number of household members in the surveyed households was 3,435.

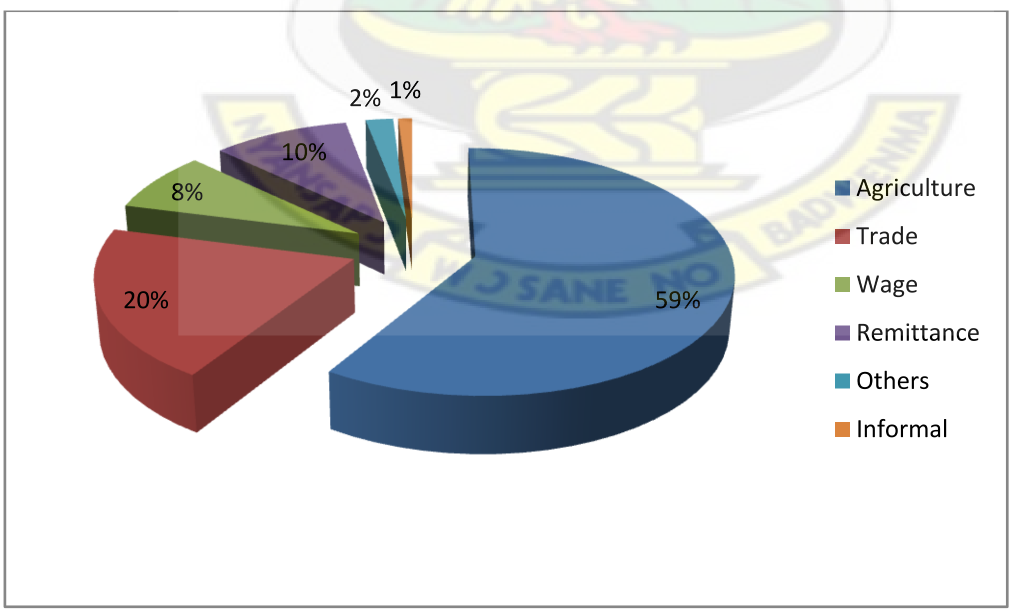
5.1.3 Educational Status of the Households

Educational attainment is widely believed to be an important component of human capital and an effective means of improving income-earning capacity. Higher education, especially for women, is usually associated with greater knowledge and of use of good cooking practices as well as providing alternatives to drudge work. Analysis of the household data shows that the level of educational levels in the Bongo district is low. Approximately 83.4 per cent of the respondents had not even completed one year of schooling, while 4.6 per cent and 11 per cent have had secondary and primary education respectively. Only 0.3 per cent reported having had tertiary education.

5.1.4 Household Income Sources and Asset Ownership

The availability of cash or equivalent enables people to adopt different livelihoods strategies. Financial assets are not only important sources of livelihoods but have a particular importance for the intra-household bargaining strength of women and men (Sen, 1990). Both primary and secondary data collected from the field showed that cash incomes available to households came from sources such as the sale of agricultural product (e.g. sale of crops, livestock), self employment (e.g. informal trading, hairdressing, tailoring etc), remittances, local occasional works (e.g. casual work, weeding etc) and local employment (clerical services, teaching etc). Figure 5.1 below shows household sources of income. On the average, 59 percent of all the households interviewed derived their incomes from the sale of crops and livestock, 8 per cent from local occasional works, 20 percent from self employment, 1 percent from both government welfare grants such as pensions and local employment. Cash incomes from remittances constituted about 10 per cent of cash incomes available to households. Other sources of income (sales of seasonal fruits and occasional firewood) constituted about 2 percent.

Figure 5. 4: Sources of household income



Source: Author's field Survey, January – April, 2006

Very few people and households are involved in enterprise, business and services related opportunities which are more income and opportunity generating to capitalize and utilize local human resources. However in these households cash incomes sources are not mutually exclusive and many households' show a combination of two or three income sources to make a living, since most of the income sources identified except for local employment are irregular. As at the time of the survey, 11 per cent of households reported having borrowed monies within the past six months. Loans were predominantly obtained from friends and relatives (for 15.9 percent of households reporting debt), from non-governmental orgnisations (for 44 percent of households reporting debt) such as Catholic Relive Services (CRS), World Vision International, Social Investment Fund (SIF) and ADRA and from "Susu group" (for 20.3 per cent of households reporting debt). Banks also serve as sources of loans for 20.3 percent of households.

Household wealth has a number of advantages as an indicator of economic well-being and as a means of examining wealth inequalities, particularly within this population. First, it is a more permanent indicator of well-being than income or consumption (Rutstein and Johnson, 2004)). This is particularly the case with the rural population, who are often subsistence farmers and thus do not earn cash income. Second, household wealth is fairly easily measured in surveys through questions about assets. To capture the economic status of households, the study employed a measure based on Filmer and Pritchett (1999, 2001) and used a wealth composite index computed as a linear combination of household assets indicators through principal component analysis[5]. Table 5.2 below presents the wealth categories of households.

[5] Please refer to chapter four for a description of the construction of the wealth index.

Table 5. 2: Distribution of Household Wealth by Categories across households

Wealth Index	Frequency	Percent
Poorest	148	24
Poor	224	36
Middle	184	29
Wealthiest	69	11
Total	**625**	**100**

Source: Author's field Survey, January – April, 2006

Differences between household's wealth categories and households reporting debt was not scientifically significant. Poor households are often less borrowers of money compared to moderately well off households. Qualitative data shows most loans were collected without any interest and were mostly used for paying school fees (1 percent), invest into business activities (80 percent) and paying bills (19 percent) such as hospital bills. Ownership of durables and livestock was also recorded as proxies for income. Table 5.3 shows the rate of ownership of physical assets across households.

Statistical analysis of household data collected from individual households indicates that ownership of hoes (97.4 percent of households) was very common among households. However the rate of ownership of other farm implements and producer goods were relatively low (less than 50 per cent ownership frequency in all categories) except for ownership of radios (53.3 percent).

Table 5. 3: Ownership of Durables Across households

Asset type	Number of households	Percentage of households (%)
Productive assets		
Hoe	609	97.4
Cutlasses	599	95.8
Bullock plough	115	18.4
Donkey ploughs	38	6.1
Donkey carts	95	48.3
Sewing machines	23	3.7
Household (electric) appliances (including battery-operated /transistor sets also)		
Radio	331	53
Tape cassettes recorder	45	7.2
TV	44	7.1
Fan	14	2.2
Transportation assets		
Bicycles	302	48.3
Motor cycles	37	5.9

Source: Author's field Survey, January – April, 2006

5.1.5 Housing Characteristics

Parikh et al. (2001) showed the influence of kitchen location on exposure to and concentration of pollutants. Table 5.4 shows the household characteristics of most households. The majority of these houses were constructed with mud (61.4percent). Most housing units had thatched roofs (52.5 per cent).

Table 5. 4: Housing Characteristics of households

Housing characteristics	Frequency of Households	Percentage (%)
Roof material		
Thatched	328	52.5
Mud and poles	20	3.2
Iron sheets	115	18.4
Asbestos sheets	1	0.2
Thatched & Iron sheets	161	25.8
Wall material		
Mud	384	61.4
Mud bricks	234	37.4
Cement blocks	6	1.0
Mud bricks & cement blocks	1	0.2
Floor material		
Earth (cow dung)	226	36.2
Cement	308	49.3
Earth & Cement	91	14.6

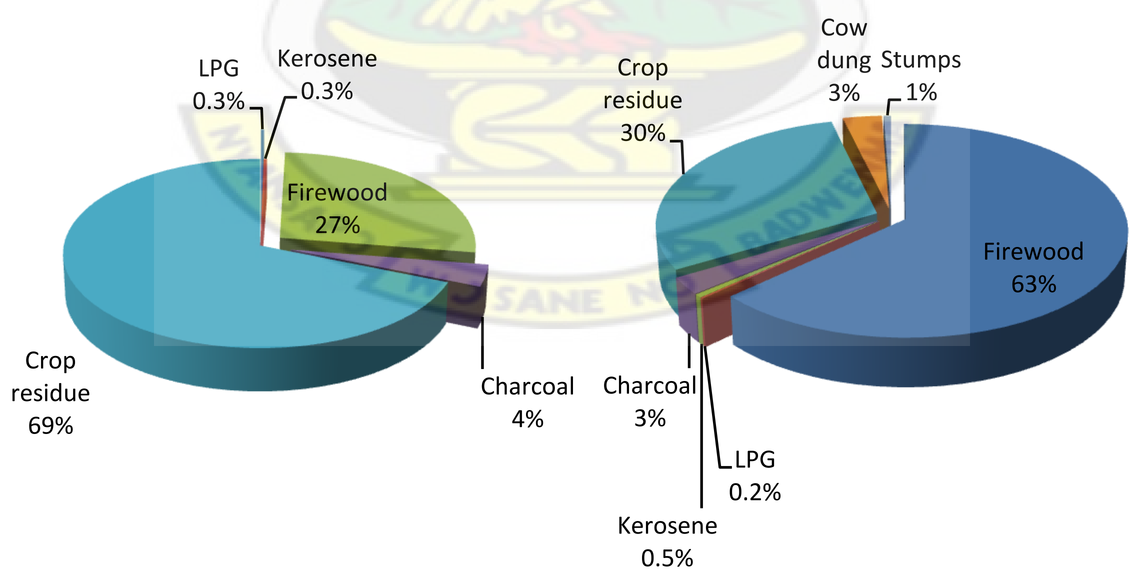
Source: Author's field Survey, January – April, 2006.

Cement floor materials (49.3 percent), dominated most households found in the study area. Most households derived their drinking water from sources outside their homes, only 0.3 percent, reported the presence of tap water in their house. The mean number of people per housing unit was 5.50 ± 0.7.

5.2. Characteristics of household energy consumption

Although abundant in energy resources, its distribution across the country is uneven resulting in seasonal and spatial variations in energy supply. Augmenting supply with investments into energy systems at the community level requires huge financial outlays and it takes time. In the absence of such investments, rural households use available energy sources for various consumption needs. For the purpose of analysis, the cooking energy system is selected because it reflected the highest demand for energy. The survey found that energy from biomass are the predominate types of energy found in the study area. These range from trees to crop residues to the use of cow dung. Crop residues are the commonly used traditional energy source by 69 percent of households. The specific reasons for this choice vary from location to location but are generally symptomatic of the fact that alternatives are either too expensive to consider or simply inexistent. Figure 5.2 present an overview of the main and secondary cooking fuels across households.

Figure 5 5: Main and Secondary Cooking fuels across households



Main cooking Fuels Secondary Cooking Fuels

Source: Author's field Survey, January – April, 2006.

The combination of extensive land clearing activities in the past has made crop residues the only remaining alternative. However even, the collection of crop residues can sometimes constitute a major source of frustration for households. As stated by, a resident of the village of Gowrie:

"...It is obvious that wood is better than crop residue for cooking purposes. However, wood availability has declined a lot over the past two decades, making access to it very difficult. Crop residues generates lots of fumes but remains the only option at our disposal. As a result, our livestock's are left with nothing to feed on.

...Furthermore, during the early rainy season, both wood branches and crop residues become very scarce and women have to resort to using cow dung, rubbish and other crop parts such as maize cob, crop roots and stumps. Consequently, women often complain of eye injuries and other respiratory problems stemming from the use of these materials".

27 percent of the sampled households rely on energy from firewood and 4 percent depend on charcoal. The use of petroleum products like kerosene and LPG as a main cooking fuel in the study area was quite negligible. However as a secondary fuel, only 2 per cent and 1 percent used liquefied petroleum gas and kerosene respectively. The use of electricity for cooking is almost negligible.

However most households show a multiple use of fuels for cooking. The most common household fuel mixes in the district are; crop- residue and firewood (50 percent), kerosene, charcoal and firewood (38.8 percent). Fuelwood in the form of split wood, branches and twigs are mostly used for food preparation. Women strongly preferred the first two types of wood and in particular those from the indigenous nazire tree.

Wood from the following trees was also used regularly: kane, tanga, sheanut, dawadawa, and kpalga and berry tree. Crop residues from sorghum stalks and millet stalks were the main types used as fuels, although there were evidence of the use of groundnut plants stems. Plate 5.1 and 5.2 shows stock of crop residues and firewood collected by households.

Plate 5.1: Stock of crop residues collected by a household

Source: Author's field Survey, January – April, 2006.

Plate 5.2: Stock of firewood collected by households

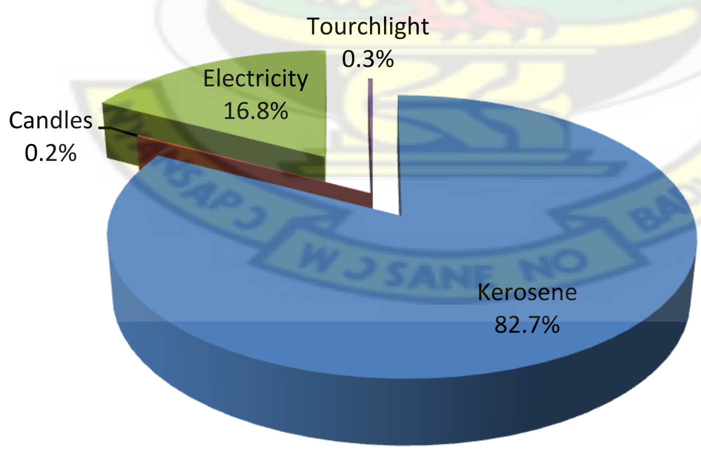
Source: Author's field Survey, January – April, 2006.

Compounding the lack of clean energy sources for cooking purposes is the lack of energy for lighting. Grid access to electricity is virtually inexistent in most of the villages, making kerosene and candles the main sources of energy for lighting. Figure 5.3 present an overview of energy sources for lighting across households. As a respondents from the village of Soe explains:

"The best light source we have in the house is a kerosene lamp (which hangs from the ceiling in the master bedroom). Lately however, kerosene has been in short supply and its price has increased beyond our reach. As a result, we have increasingly switched to using candles, and when these run out, we simply live in the dark".

Concerning lighting, the main fuel used for lighting was kerosene (82.7 percent), followed by electricity (16.8 percent).

Figure 5.6: Main Lighting fuels across households



Source: Author's field Survey, January – April, 2006.

On average, the surveyed households used 1,249,806 mega-joules of energy per month on for domestic cooking.

5.2.1: Crop Residues

Crop residue as domestic cooking energy source contributed about 34,758 kg (46.3 per cent) of the total 75,066 kg biomass fuel consumed by the surveyed households per month. Crop residues contribute less in energy terms than its gross weight, which factor signifies the inferior quality of crop residues in the energy content as compared to that of fuel wood and charcoal. Crop residues constitute 521370 mega-joules (4.1 per cent) out of the total traditional biomass energy consumed per month in households (Table 5.5).

5.2.2: Fuel Wood

Fuelwood forms the next most common household cooking energy after crop residues. Fuelwood constitutes 51.0 percent of the total 38304 kg of biomass fuel used by households each month on average. However in terms of energy content, fuel wood is by far the dominant fuel, contributing 53.63 percent of the total biomass fuel consumed by households on average per month (Table 5.5).

Table 5. 5: Sample Household Monthly Biomass Fuel Consumption in Kg and Mega Joules

Biomass Fuel Consumption				
	In Kg		In Mega Joules	
Fuel Type	Total	Percentage	Total	Percentage
All Biomass	75066.00	100.0	1249,809.00	100
Crop residue	34758.00	46.3	521370.00	41.7
Fuelwood	38304.00	51.0	670320.00	53.63
Charcoal	2004.00	2.7	58116.00	4.6

Source: Author's field Survey, January – April, 2006.

The comparison between the position of fuel wood in terms of its weight and energy content reveals that fuel wood contribute more in its weight than its energy content. This is mainly due to the fact that the calorific value of wood is less than that of charcoal, which is a more concentrated energy fuel. The calorific value of wood is estimated to be about 17.5 mega joules per kg of wood (Appendix 7).

5.2.3: Charcoal

Charcoal is the preferred energy source for most households if they had the choice. According to the survey, it constitutes 2004 kg (2.7 Per cent) of the total 75,066 kg of biomass fuel utilized by the sampled households per month (Table 5.5). Charcoal constitutes 58,116 mega-joules (4.6 per cent) of energy out of the total 1249,806 mega-joules of biomass fuel consumed by the surveyed households (Table 5.5). In energy terms, charcoal provides much higher heat than that produced by wood. The calorific value of charcoal is estimated to be 29 mega-joules per kg (Appendix 7).

5.3 Cooking practices

As this survey was intended to understand the vulnerability and risks of bio-fuels, it was necessary to know the cooking practices followed -- such as number of meals cooked, (degree of) involvement in cooking, and type of stove used -- that influence exposure to indoor air pollutants from burning of bio-fuels. These behaviours are interdependent and are influenced by variables such as income and landholdings that have been discussed earlier.

The traditional mud stove, is most commonly used for cooking. This stove has no chimney and consists of stones plastered with mud to form a rough cube that is one square foot on each side, leaving one side open to feed fuel. Smoke from the stove emits directly into the room. While primarily designed for fuelwood, the stove has been adapted in some areas to burn dung, and crop residue. Households often build more than one mud stove, and even those that cook with charcoal and kerosene invariably use one. Sometimes a stove is improvised by using three hard stones or rocks. Stove types vary across households: 64.5 percent use three-stone stones and 32.2 percent mud stoves prepared by women; further, 3.4 percent do use coal pots. All the households at least use two types of cooking stoves. Table 5.6 shows the distribution of primary cooking stoves across households and Plates 5.3-5.4 shows the tree –stone and mud stoves used in the sampled households.

Table 5.6: Stove Types Used by Households

Type of Stove	Frequency	Percent
Three stone stove	403	64.5
Mud stove	201	32.2
Coalpot	21	3.4
Total	**625**	**100.0**

Source: Author's field Survey, January – April, 2006.

Plate 5.3: Three Stone Stove

Plate 5.4 : Mud Stove.

The type of stove used to burn the biofuels not only affects the time spent cooking or collecting fuel, but more significantly it determines whether the fuel burned has a harmful effect on the cooks and others in the room. As discussed earlier, the smoke carries many pollutants ranging from carbon monoxide to suspended particulate matter that can be extremely damaging to one's lungs over the long run. Traditional stoves have been found to be extremely polluting in this respect and much effort over the past two decades has been directed toward designing and disseminating alternative models of stoves, often referred to as improved stoves. The thermal efficiency for the traditional stove has been quoted to range between 10 percent to 15 percent due to the high radiation losses (Warwick and Doig, 2004). This implies that, the majority of households in the district lose the lion share of the energy inputs. On the one hand while this creates a burden on the expenditure of households, it also exerts much more pressure than required for use on the already depleted biomass resource base of the area, on the other hand.

Households in the study area usually kept firewood fires burning for 90 minutes a day on the average. Crop residue fires were kept burning for only 30 minutes, because they need constant tending of the fire to keep it burning. Besides using the fires for cooking, there are various other uses to which they are put either before or after the major use. Uses include heating of water and food processing. The daily choice of cooking stove depended upon cooking needs – the amount to be cooked, the type of food and the preferred preparations of meals. Ninety -nine percent of the households had a kitchen attached to the main house, while a negligible 1 percent had kitchens detached from the main house. Ventilation conditions in household kitchens were very poor.

Only 31.4 percent of the households reported having windows in their kitchens. Smoke extraction devices such as eaves spaces and chimneys were almost non-existent in most of the households surveyed. When households were asked about the use of improved stoves (Ggypa, Ahienbenso) 1.3 percent affirmed in the positive and 98.7 percent answered in the negative. Eighty –two per cent of families cook three meals a day, 12 percent two meals and 6 per cent one male a day. Charcoal (50.7 percent) and LPG (42.2 percent) were cited as the fuel of choice of most households if they had the chance to choose their cooking fuels. Reasons given for these choices are shown in Table 5.7

Table 5 7: Reasons for choices of household fuels

Reason Given	Frequency	Percent
Cooks faster	220	35.2
Hygienic	21	3.4
Smoke less	334	53.4
Cooks faster & smokeless	50	8.0
Total	**625**	**100.0**

Source: Author's field Survey, January – April, 2006.

5.4 Opportunity costs for women: Tradeoff between biomass fuel collection and cooking

Since biofuel management is primarily a woman's responsibility in the study area, the increasing problems of fuelwood supply lead to conflicts for these women, who must combine their role in productive activities such as farming and trading with domestic activities. In order to investigate how their coping strategies are affected, the household economy in which women participate is considered. Each respondent was asked to provide an estimate in minutes, of time spent on various precategorized activities, based on their experience for a typical day.

Thus, each respondent had to account for 24 hours or 1,440 minutes. For the purposes of this study, the activities pursued in a 24-hour day have been categorized as collecting fuel, fetching water, cooking, other housework, earning income, other leisure, and other miscellaneous activities. Fuel collection often implies walking long distances to the nearest forest or brush growth for firewood or in search of cow dung and/or crop residues. The survey results showed that the majority of households acquire their biomass through gathering (71 percent) and the remaining 29 percent purchase it. Further 58 percent of households using biomass gather their fuels from their farms and from trees on household lands, while the rest (13 percent) comes from various sources including, forests and trees on non-household lands.

Typically, gatherers had to cover an average of 3 kilometers (km) from their homes to find firewood for the home. The least distance covered is 1 Km and the coverage can be as far as 6 Km. Fuelwood gatherers on an average make about 16 trips per month and spend approximately three hours per trip, thus spending about 42 hours a month in fuelwood collection. Fuelwood is collected for about ten months in a year and the stock of fuelwood is maintained for the rest of the time. With respect to combustible agricultural residues, collection is mostly done at the end of the cropping season, where stalks of sorghum and millet are tied into bundles and carried to the house at the end of farm work. Table 5.8 shows the time and effort involved in biomass collection.

According to leach and Mearns (1989) the distance and time spent to collect woodfuel is commonly used as the measure of scarcity. There is strong evidence that the time spent in collecting firewood can vary greatly from one week or season to the next, depending on other household labour demands (Tinker, 1987).

Table 5.8: Time and Effort involved in biomass collection

Type of effort to collect fuelwood	Number of Households	Percentage of households
Distance		
Up to 1km	85	13.6
1-2 km	50	8.0
2-3 km	204	32.6
3-4 km	212	33.9
More than 4 km	74	11.8
Average no. of trips per household per month	16	
Average time spent per month per household	42.2	

Source: Author's field Survey, January – April, 2006.

Women's roles and responsibilities were observed in terms of total time allocation per day/ per activity (Table 5.9). Fetching water in the study area also involves in most cases walking relatively long distances to the water source and carrying several pots of water on the head. Cooking time includes actual time cooking and serving, but it excludes time spent processing food. This is done specifically to analyze the relationship between fuel use and IAP exposure during cooking. Housework is defined as time spent on processing food, cleaning dishes, house and clothes, childcare and shopping. Income-producing activities can range from working for hours in the fields for wages or contributing to the family farm as well as tending animals. Time spent on leisure includes socializing, sleeping, and personal care activities such as bathing and eating and other activities that women may pursue apart from all those listed above and to account for what remains of the 24 hours in a day.

Unlike fuel gathering which does not occur on a daily basis, fetching water seems to be a more universal daily chore, with the entire sample reporting that they spent some time on it. On average, across all household sampled , women spend about 3 hours fetching firewood and almost 2 hours cooking , and close to 4 hours on other housework. They spend almost 5 hours pursuing income-earning activities; 10.2 hours sleeping, pursuing other leisure, and personal care and other miscellaneous activities.

Table 5.9 Average time spent daily by women (N =473)

Activity Type	Description	Minimum	Maximum	Average hours/day
Collecting fuel		.00	7.00	2.53
Fetch water		1.00	4.00	2.60
Cook a meal		1.00	5.00	1.99
Household work	child caring, washing utensils and clothes, house cleaning	2.00	5.00	3.60
Income generation	Farming , livestock rearing, trading	2.00	8.00	5.21
Leisure activity	Taking meals, Bathing, Leisure Sleep	7.00	13.00	10.21

Source: Author’s field Survey, January – April, 2006.

The household data shows that women’s lives mainly revolved around non-monetized work such as collecting fuel, fetching water, cooking, and housework. Outside of other leisure activities, which include sleeping, the highest amount of time is spent doing other housework, which includes processing food, cleaning dishes and house, taking care of children, and other domestic activities. On the average, 11 hours are spent on these activities a day, with 5 hours spent pursuing paid work.

5.4.1 Opportunity costs of using fuelwood.

Time is also an important resource for rural households as evidenced by the proportion of household income earned through agricultural activities especially food crop production (see Table 5.10). It may be therefore untenable not to assume that time allocated to bio-fuel collection could generate some level of income. The question then arises as to whether employment generating opportunities exist in rural communities. First, availability of such opportunities will vary from one community to the other and the severity of this situation may sometimes warrant migration to other communities. Churchill (1987) indicated that rural women do have income-generating opportunities such as food processing and petty trading. Ocloo (1997) makes a similar argument, for example, by indicating that about 30 percent of Ghanaian women engage in petty trading and food processing. Moreover, time could also be used productively to generate human capital (e.g. especially through female child education).

Nevertheless, the argument advanced in this study is that rural folks may have something doing, either on their own farms, as casual labourers, trading or taking care of children at home, or even leisure. This suggests that time spent on bio-fuel collection could be and should be valued in monetary terms. It is upon this basis that the opportunity cost, based on the national minimum wage approach of women's time devoted to bio-fuel collection is estimated to derive the price of bio-fuel.

5.4.1.1 The Minimum wage approach.

From sub-section two, agriculture (59 percent) and trading (20 percent) constituted the two major income sources of the sampled households. Since the survey communities are basically rural, it seems practical to use rural agriculture and trading wages to put a value on the opportunity cost of time spent collecting bio-fuels. Therefore, in computing an appropriate wage to value women's time, this approach draws on the employment data of the Ghana Living Standards Survey fourth round (GLSS4) conducted in 1998/99. Specifically, this approach relies on the average basic hourly wage of women in 1999 to value their time allocated to bio-fuel collection. In 1999, the average basic hourly wage was 0.0381pesewas for women and ¢0.0598 for men engaged in the agriculture sector and 0.1123 for women and 0.2554 pesewas for men engaged in the trading sector. For the same period, the national daily minimum wage was set at 0.2900 pesewas. This increased to ¢1.9200 in 2006, representing an annual growth rate of 31.0 per cent. In order to have a corresponding figure for the hourly wage of women for our household survey period 2006 who are engaged in agriculture, the annual growth rate was used for extrapolation purposes[6], resulting in a value of 0.252246 pesewas per hour. This implies an average hourly and daily opportunity cost of 0.252246 and 0.665929 pesewas respectively. For a monthly opportunity cost the value is ¢28.076884.

For women in the trading sector, using the same procedure, the average hourly and daily opportunity cost was 0.743496 pesewas and ¢1.,62829 respectively. The monthly opportunity cost is ¢82.831402.

[6] The applied formula, $Wt = Wo(1 + g)^t$, was used in calculating for the annual growth rate, where Wt denotes women's wage in the current period t, Wo denotes their wage in the previous year and g is the growth rate between the two periods.

The daily opportunity costs gives an idea as to what a firewood carrier would earn through employment if government, donor agencies or private firms are to intervene with energy projects that will considerably enhance energy accessibility within a reasonable period of time. It must also be pointed out that such interventions in the rural energy sector are not entirely free, especially when renewable energy is being provided by the private sector, generally seen as the engine for growth and efficiency in the provision of goods and services in Ghana. The contracting of private firms, Non Governmental Organisations (NGOs), Community Based Organisations (CBOs) and individuals to deliver services ranging from the construction of energy facilities, to capacity building suggests at least the need to recover costs, if not having profit motives. In effect, although these interventions may lead to time and possible costs savings, they also impose some degree of financial burden on households. In the final analysis, whether such interventions improves or worsens the welfare of households or communities would call for further research to determine the effect of the intervention.

5.5: Seasonality and trends of household energy

Due to the use into which fuelwood are put, local people are the first to recognize any changes in the nature and stock of resources. When exploring particularly which types of changes the households perceived to have occurred in the area, they were first asked whether they thought that the availability of fuelwood resources had changed during their life time and if there were times in the year where households encountered fuelwood shortages. All of the respondents indicated that the resource is decreasing with time. Over 80 percent of households were of the opinion that the availability of fuelwood has become very scare in the last 5- 10 years. Table 5.10 shows the perception of households according to the availability of fuelwood in the study communities. A t-test showed a significant difference between the mean number of households that said fuelwood was on the decrease, and on the increase ($P < 0.05$).

Table 5. 10: Proportion of households' perception about the availability of fuelwood in the last 5-10 years

Fuelwood Availability	Frequency	Percent
Scare	531	85.0
not scare	92	14.7
No idea	2	.3
Total	**625**	**100.0**

Source: Author's field Survey, January – April, 2006.

Additionally, the households were asked to describe the types of changes they had observed in the area. A great majority of them (90 percent) stated that changes had taken place and they commonly immediately described the changes. The most commonly described change was that of a *reduced number of trees,* which was described by 72 per cent of the respondents and the *burning of bush fallows,* was *described* by 86 per cent of the respondents. The majority described a drastic change:

"This was a forest in the past, now it is a desert..." Woman, 65 years old.

"There was a forest here in the past. Now many, many trees have disappeared…" Man, 75 years old.

"The time of trees is finished." Man, 40 years old.

All of the respondents commented about woodfuel shortage during the rainy season in May and September to December. Table 5.11 shows the distribution of answers.

Table 5.11: Proportion of households reporting shortage of woodfuel during the year

Months	Frequency	Percent
August-September	256	41.0
July-October	173	27.7
March-August	154	24.6
May-June	42	6.7
Total	**625**	**100.0**

Source: Author's field Survey, January – April, 2006.

It could not be fully possible to explain clearly, why they do feel and experience shortage at different times of the year, but some elderly residents and biomass fuel sellers responded that different sets of people required different types of biomass fuel, which are all not available in all seasons. However, there seems to have been some explainable facts through fieldwork and observation. This is concerning the fluctuating supplies occurring in the market, availability of biomass fuel at the sources, and amount of labour available for the purpose in relation to the seasons of the year. When the surrounding biomass fuel supplier peasant community members are busy in their agricultural work in the fields, they restrained their labour from the fuel business. Some of them indicate that dry seasons are better for them to supply fuels to the town than that of the wet season, as they can engage in this business as off-season activity or non-agricultural work. Collection of fuel wood in the dry season is also felt to be easier in the woods than in the environs. Moreover, journey to cover the distance up to fifteen to twenty kilometers back and forth, and collecting from various scattered points in the area becomes quite an arduous, tiresome and time-taking task in wet season.

5.5.1 Conceptions of reasons behind wood fuel shortages.

The reasons explaining the environmental changes in the area were discussed with most of the households and through the FGDs. Above all, the respondents stressed that reduced precipitation was behind the environmental changes in the area, stating this in all of the interviews where the topic was discussed. Some farmers stressed that particularly the drought in the 1980s had had long lasting effects:

"The drought in the 1980s destroyed everything. All these trees have grown after it. Also the animals died, because of the drought. As a result of the drought many people left the village to look for food and water."Man, 45 years old.

In addition to the reduced precipitation, approximately one third of the farmers stated that local people had also caused environmental changes. In some of these interviews the cutting of trees was mentioned as a reason for changes in the environment. A few farmers stated briefly that "people cut the trees" without specifying why the trees were cut or by whom. Some others specified, however, that trees were cut to sell firewood or build houses:

"...now the people cut most of the trees to get cash, because of the poor harvests." Woman, 55 years old.

Furthermore, a woman farmer also said straightforwardly that she had to sell firewood and grass to earn extra income, since her husband had taken another wife and lived elsewhere without supporting her financially. Particularly intensive cutting of trees was also practiced among the farmers connected to the fuelwood trade. Farmers who traded wood were the poorest people who had to do it in order to maintain their livelihood. Similarly to the pastoralists, the farmers did not suggest that collection of firewood for their own use had caused environmental changes.

When some farmers were asked separately whether they thought that cutting trees for domestic firewood consumption had damaged the trees, most of them agreed. At the same time, a man and two women emphasised that firewood collection had not contributed to the environmental changes, for only such dry parts or dead trees that were not useful anymore were cut. Two men also stated that felling trees in order to clear land for agriculture had affected the environment and emphasized that there were more farmers in the area than before. Some villagers also suggested that farmers had contributed to the environmental changes by environmentally harmful farming methods. Two male farmers stated that cultivating the land without adequately long fallow periods had affected the environment negatively. Also a few farmers described the uncontrolled use of fire as one factor destroying the environment:

"Because of fire, some people lose a lot of trees. The trees become very dry and will not grow again. People burn their lands before cultivation. This sometimes spreads and burns grasses and trees."Man, 50 years

"It used to be better. Now there is less of everything. The land does not give the same crop. The people usually cultivate the same area for many years and this will reduce its productivity. The rain has also diminished. The rainy season is now short and the crops do not get ready."Man, 58 years old.

A man also mentioned that animals had affected the environment by eating grass and two women believed that the wind was particularly harmful to the environment. One of them, a teacher in the village school, described that environmental changes had occurred as a result of a process in which human activities, the wind and the spreading sand had interacted:

"After people cut the trees, the wind destroys the growing trees. Woman (teacher), 32 years old.

5.6 Effect of energy scarcity on women in bongo

When there is a hazard such as energy scarcity, societies are affected in different ways, but rural women have proven to bear the greatest burden as they are usually ill equipped for such a disaster. Bongo is no exception. In Bongo, the women's challenges, as in other rural areas, are associated with economic failure, health problems and time spent searching for wood fuel.

5.6.1 Wasted time and extra burden

The time spent by women in the collection of biomass fuel was cited as one of the main problems that have resulted due to energy scarcity. They claim to waste a great deal of time in their search for energy. They wake up before dawn, walk long distances and also spend considerable time in cutting dead branches from trees. One of the respondents had this to say

"Once I had to climb the tree, before I had access to the dead branches".

Dead branches have to be cut into smaller pieces to be able to carry to households. This is a waste of time and an extra burden on these women as searching for woodfuel reduces time for other everyday chores.

One woman had this to say: "*When you have walked far and still spend time gathering firewood for hours, you get back home and you find all the housework still waiting for you"*.

This is a big problem, also experienced by other rural women throughout the world.

5.6.2 Health Problems[7]

Together with the above-mentioned impacts, women have to deal with health problems related to the usage of inferior fuels. Health problems mentioned ranged from back pains, snake bite to the smoke and smell effect from the use of biomass fuels. From the field observation, watching women during the interview talk about their cooking – fuel health issues showed that the issue was of a great concern to them. One woman had this to say,

"I always feel so tired after cooking with crop residues, I can hardly eat, and I always bring out sputum which is black in colour".

Out of the all the health problems mentioned as having a negative impact on them, it seem the smoke from cooking fuels was of great concern to the women in Bongo. According to the women in Bongo more problematic is the fact that some of them still access their consumable energy from unhygienic sources such as agricultural residues and cow dung. The respondents also agreed that the situation is made worse by the fact that they have to share the agricultural residues with animals. The women have also noted that their children catch smoke related diseases very easily when there are near the cooking areas.

5.6.3 Loss of Livestock and crops

Unexpectedly, one greatest worry for women in the study area is the loss of livestock and crops when there is not enough crop residues to feed their livestocks .This is due to two reasons. The first one is that some women can buy or cook foods that require less energy , or use other sources

[7] Health problems related to household energy use is discussed in details in the next chapter.

of energy crops (crops roots) for household consumption but do not have access to forage for livestock. When there is energy scarcity especially in the late dry seasons, the problem is usually intensified because energy sources for cooking usually become scare. According to the women, when there is energy scarcity humans find it difficult to survive and it is even worse for animals. "At least as humans we can find alternatives, but for the livestock when there is no forage, there is nothing they can do'

Secondly, as a result of high unemployment rates in this area, the Bongo community depends on their livestock and crops for survival. The women depend especially on crop residues as sources of fuels. When there is lack of cooking fuel, women in Bongo do not only find it difficult to give forage to their livestock but are also unable to use them as manure for fertilizing their farms. Having experienced all these problems, women in Bongo are conscious of their roles in rebuilding their area. As a result they have developed some coping mechanisms in order to try and recover from the impact of energy scarcity.

5. 7 Bongo women's strategies for mitigating energy scarcity

Women are not passive victims of the problem of vulnerabilities related to household energy consumption. Based on their capacity or available capital and opportunities they try to implement different strategies to handle the stress situation. There are different classifications of these strategies that households adopt to minimize the impact of the crisis. Blaikie (1994) divided these households' strategies as preventive, impact minimizing, and recovery strategies. For other authors the three household strategies are classified as insurance strategies, crisis strategies, and distress strategies.

In this study, these strategies are either coping or survival. Strategies used by households in response to declining availability of woodfuel in abnormal seasons of the year are coping strategies. These households' strategies are used to minimize the impact of livelihood shocks. On the other hand when households are becoming more and more vulnerable, their strategies are limited to survival or to combat destitution and death. Those strategies that are used to combat destitution and death are survival strategies.

5.7.1 Coping Strategies.

In relation to the health effect of household energy, most of the respondents did not have any coping strategy as to how to reduce the impacts. A woman from one of the communities had this to say:

"We have no alternative than to use woodfuel for cooking. Now due to firewood shortage we are even using crop residues and there is nothing we can do about the smoke even though it makes us cough and makes our eyes red."

Most of the respondents were of the view, the only coping strategy was to use charcoal but they commented it was too expensive for them. However in relation to the seasonality and shortage of woodfuels the main coping strategies adopted by rural communities in the Bongo district include buying of firewood, use of other sources of energy (cow dung, crop stumps and garbage), felling wet tress and sun drying them into firewood and improving fuel management e.g. quenching the fire immediately after preparing the meals.

Normally, most households collect woodfuel from common resources or from farms. But in situations of firewood scarcity, households have to rely on the household capital to purchase firewood. For instance, one of the focus group participants in the women group stated how they depend on their agriculture products and livestock:

"We are subsistence farmers and our produce sustains as throughout the year till the next growing season. They are our means of food security. When we face woodfuel shortage or if we have any financial constraint in general we mainly depend on our livestock and farm products. Once I had to sell a bowl of beans so I could buy firewood for cooking".

Other participants also supported the view and they added that first small animals such as goats and sheep including poultry will be sold. However, livestock production and productivity is constrained by disease, shortage of animal feed and poor veterinary services. Although livestock and farm produce sale is an important coping mechanism during woodfuel shortage, it is not only challenged by declining numbers and quality but also by declining market price during the crisis.

Selling of available assets including livestock repeatedly as a coping strategy weaken households' resource base and exposes them to permanent food insecurity. Once households faced the problem and have sold assets of what so ever, it will take some years to recover these assets. This indicates that if seasonal household fuel insecurity occurs repeatedly, it depletes the available resource base and reduces their ability to accumulate the financial resources they need to invest in strategies for improving their livelihoods.

Households in the studied communities also tend to use other energy sources such as crop roots, weeds, shrubs and cow dung. Women and young children are the first to be involved in this activity. However, the use of crop roots and dung as fuel seriously affects soil fertility, reducing soil and mineral retention leading to land degradation. However, in a district where, agricultural production depends mostly on soil productivity, and in the absence of technological improvements, land degradation has negative economic implications that are potentially significant. First, depletion of soil nutrients and loss of organic matter reduce soil productivity, which in turn will reduce crop yield. This has a direct negative impact on both income generation /cash saving opportunities and food security particularly in the presence of a rapidly growing population.

Felling of wet trees and letting it to sundry is the other important means of coping with woodfuel shortage crisis in the study area. However only a few households cited this option of coping strategy since generally the available bush land has become devoid of any trees for fuel wood collection. Based on their local knowledge about the management of woodfuel resources, coping strategies such as quenching the fire immediately after preparing the meals were also practiced by some households.

5.7.2 Survival Strategies

Some of the main survival strategies that are experienced by households are social networks and support from relatives or friends, decreasing daily food intake and changing food stuff. Decreasing the amount of daily food intake is one of the major responses that the energy insecured households use to mitigate the impact of energy crisis. They try to decrease both the amount and quality of food consumed during the period woodfuel shortage. One of the respondents explained it as follows:

"When our woodfuel shortage problem gets worse, we decrease our daily food intake. We cook once a day and try to conserve the available small amount by consuming it bit by bit. It is a way of keeping ourselves alive. Once we have a piece of breakfast that may be for one day. It is just to save our lives".

People's response is not only by decreasing the amount and frequency of food intake but also by changing and decreasing the quality of available food. This is what one of the respondents had to say;

"*When fuelwood is available, most of the time we prepare tuo zaafi and soup in the evenings, but in situation of woodfuel scarcity we turn to consume "rasta kooko. This is a dish where one adds water to millet flour and consumes it without cooking. We are poor and there is nothing we can do about our situation".*

Another had this to say;

"I hardly boil any water in times of woodfuel shortage and consume leftover foods without heating them".

Households also turn to relay on their social networks and relatives in times of woodfuel shortage. The support could be loan, borrowing woodfuel from others and agricultural tools. One respondent explained this as follows:

"We have a good culture of helping and supporting each other. Those who have sufficient woodfuel or all the necessary household and agricultural equipment will help and support those

who have not enough woodfuel or all the necessary agricultural and household tools. When the support is food and money it is given on loan basis. Poor people are not also self sufficient in all household tools and agricultural equipment they need. Thus, they borrow those tools and equipment from their relatives, friends, and from the members of their social networks if they have one".

Other respondents also said that they help each other in times of crises. However, over time poor people or those who need support are increasing in number. When natural causes like drought occur, all people are affected.

The other important means of earning small income or a means of getting daily meal for the destitute is engaging in daily labor. Most often people move to the regional capital, Bolgatanga to work in chop bars or work in the markets by carrying foodstuffs in order to earn a little money, so they can buy woodfuel and cook. Most respondents indicated that for many poor people in the area, especially if they are landless, daily wage labor is a common means of earning survival meals. For instance, one respondent said:

"Daily labor is most poor people's way of life. It is their livelihood. However our men do nothing to help us in times of woodfuel crisis, since it is we who bear the responsibility of looking after our children and securing the household with woodfuel. They sit under the trees and talk all day".

Seasonally household energy insecured people engage in daily labor only when they face the problem. Chronically energy insecured people usually do not have land or any other reliable asset to depend on or engage in. Therefore, daily labor is their important occupation and every household member including teenage children are involved. The last alternative for some household is to sleep without eating the whole day.

5.8 Determinants of cooking fuel choice in households

From the previous sections, it can be concluded that the dependence on wood-fuel as source of household energy has a detrimental impact on the welfare and environment of users. Thus it is important to discover what factors determine the demands for these fuels so that suitable policy instruments may be devised to ensure that these households switch over to less polluting fuels. Given the pervasive income ladder hypothesis for fuel use that holds that in low income countries poorer households use cheaper and dirtier fuels and gradually switch to more expensive and cleaner fuels as income rises (Masera et al., 2000) the distribution of fuel choices by household wealth categories (which is being used here as a proxy for household income) is presented in Table 5.12. It should be noted that in order to classify any given household as the user of a particular fuel, only the main fuel is being used here. This is the fuel the family uses to cook their main meals. This relationship between the choice of primary cooking fuel and wealth level can be seen from table 5.12.   It shows that biomass fuels are used by most households, even in the top income brackets. Crop residues   are used by all income categories and their users are by no means just the poor. In fact, it peak in the middle of the income distribution and remain widely used in the top income categories. The implication is that in rural areas economic development and income growth will not in itself lead to displacement of dirty fuels such as dung. This situation resembles the firewood puzzle, and the potential explanations are similar:

the rural elites often own more land and therefore have easier access to crop residues; certain traditional foods or methods of preparation sometimes require use of crop residues; and more generally, users of crop residues may not perceive these fuels to be undesirable. Firewood and charcoal usage persists well up across all levels of the income distribution. The continued substantial reliance on wood fuels well up the income distribution is something of a puzzle. It challenges the energy ladder model suggesting that household income and the affordability of alternatives cannot be the only reason for using firewood.

For kerosene, there is no universal pattern of growing or declining usage across the income distribution Kerosene for cooking is mostly found in urban areas for cooking. The most common pattern is for kerosene usage for cooking to first increase with expenditures and later decline. This is consistent with the notion that kerosene might play the role of a transition fuel at an intermediate level of the energy ladder between solid fuels and LPG.

Table 5.12: Wealth levels and Households Cooking Fuels

	Percentage of households using				
Wealth categories	Crop residue	Firewood	Charcoal	Kerosene	LPG gas
Poorest	66.2	32.4	0.7	0.7	0.0
Poor	73.2	23.2	3.1	0.4	0.0
Middle	72.3	25.0	2.7	0.0	0.0
Wealthiest	50.7	31.9	14.5	0.0	2.9
Total	68.8	26.9	3.7	0.3	0.3

Source: Author’s field Survey, January – April, 2006.

Besides income level, resource conditions and other household characteristics are also relevant in determining the type of cooking fuels consumed by households as described by the energy ladder concept in chapter 2. In the light of these facts, further investigation was made to access the different cooking fuel choices available to the sampled households in the district, and the different factors that affect a household's probability of choosing one cooking fuel over another. A household's cooking fuel choice consumption decision can be understood by analysing its decision in a constrained utility maximization framework (Browning and Zupan, 2003; Amacher et al., 1999), subject to a set of economic and non-economic constraints (equation 1). Economic factors include market price of fuel, and household income. Non-economic factors include a set of household demographic and infrastructure factors as mentioned above.

Consider Uij to be the maximum utility ith household derives if it chooses to use one of the energy sources in jth energy sources alternative, i.e. 1, 2, or 3 where 1= a household chooses to use crop residue as its principal energy source, 2 = a household chooses to use firewood as it principal energy source; and 3 = a household chooses to use charcoal as it main energy source.

The indirect utility function of a household can be written as follows.

$$Uij = Vij + \varepsilon ij \qquad (1)$$

Where, εij is the stochastic disturbances term accounting for the influence of omitted variables. Vij is the function of observable variables specified (refer to specification of variables) in the model. The probability that ith household chooses a jth alternative can be expressed as follows.

$$Pij = Pr\,(Uij > UiJ)\,, j = 1, 2, 3\; where\; j \neq J \qquad (2)$$

It is assumed that the difference between εij and εiJ are iid and normally distributed. Now consider Yi is the i^{th} household's migration decision with possible mutually exclusive and exhaustive choices either '1' = at least a household chooses to use crop residue as its principal energy source , '2" = at least a household chooses to use firewood as its principal energy source ; and '3" = at least a household chooses to use charcoal as its main energy source.

This decision depends on the

$Yi*$

$Yi = j \; if \; Yi* > 0$

$J \; if \; Yi* = 0$ (3)

Here J= the last category treated as reference category. $Yi*$ is latent variable, which is assumed to be determined mainly by the explanatory variables specified in the models. $Yi*$ which is continuous and is defined as follows.

$Yi* = Xi\beta + \varepsilon$ (4)

Where X_i represents vector of other explanatory variables in the model including the change in time the opportunity cost the household incurred in using the energy source. β is the vector unknown parameter to be estimated and $\varepsilon i \sim N(0, \sigma 2)$. The probability that at least one household chooses to use one of the energy sources can be obtained as follows.

$\Pr(yi = j) = \Pr(Yi* > 0)$

$= Pr(Xi\beta + \varepsilon i > 0)$

$= Pr\ (\varepsilon i\ >\ -Xi\beta)$

$= F\ (Xi\beta)\ =\ \varphi\ (Xi\beta)$ (5)

F is the cumulative distribution function of disturbances term, which is replaced by the logistic cumulative density function, φ. Then the probability that at least none of the households chooses not to use any of the fuel chooses is expresses as

$Pr\ (yi\ = J)\ =\ 1 - \varphi\ (Xi\beta)$ (6)

Then, response probabilities of multinomial logit model are given

The probability that $\Pr[\ Yi = j] = \frac{\exp(\beta_j' X_j)}{\sum_{j=0}^{j} \exp(\beta_j' X_j)}$ (7)

Where:

Pr[Yi = j] is the probability of choosing either firewood or charcoal with crop residue as the reference cooking fuel category,

J is the number of fuels in the choice set,

j = 0 is crop residue,

Xi is a vector of the predictor (exogenous) social factors (variables)

B_j is a vector of the estimated parameters

When the logit equation above is rearranged using algebra, the regression equations is as follows

$P_i = \frac{e^{(b_0 + b_1 x_1 \ldots\ldots\ldots + b_v x_v)}}{1 + e^{(b_0 + b_1 x_1 \ldots\ldots\ldots + b_v x_v)}}$ (8)

The equations used to estimate the coefficients is

$$\ln\left[\frac{P_i}{1-P_i}\right] = b_0 + b_1x_1 + \ldots\ldots b_v x_v \quad (9)$$

From equation 9, the quantity Pi/(1 – Pi) is the odds ratio. In fact, equation 9 has expressed the logit (log odds) as a linear function of the independent factors (Xs). Equation 9 allows for the interpretation of the logit weights for variables in the same way as in linear regressions. For example, the variable weights refer to the degree to which the probability of choosing one crop residue alternative would change with a one-year change in age of household head.

For example, $\boldsymbol{e^{bv}}$ (in equation 8) is the multiplicative factor by which the odds ratio would change if X changes by one unit. The Wald chi-square test is used for testing individual coefficients. With regard to joint test or goodness of fit of the models, the pseudo R^2, and model Chi-square test are used. The model Chi-square test is used to test whether all the beta coefficients except intercept are equal to zero at K-1 degree of freedom. Where k = number of parameters including intercept term. As suggested by McFadden the pseudo R^2 is computed as 1-Lur/ L0 (Wooldridge 2002), where Lur = log-likelihood function for an estimated model and L0 = log-likelihood function in model without intercept.

5.8.1 Specification of variables

The variables specified in the models are described below.

5.8.1 .1 Dependent variable

The dependent variable is the cooking fuel choice (crop residue, firewood, or charcoal) with crop residue as the reference choice. Estimated coefficients measure the estimated change in the logit for a one-unit change in the predictor variable while the other predictor variables are held constant. A positive estimated coefficient implies an increase in the likelihood that a household will choose the alternative fuel. A negative estimated coefficient indicates that there is less likelihood that a household will change to alternative fuel. P-value indicates whether or not a change in the predictor significantly changes the logit at the acceptance level. That is, does a change in the predictor variable significantly affect the choice of response category compared to the reference category? If p-value is greater than the accepted confidence level, then there is insufficient evidence that a change in the predictor affects the choice of response category from reference category.

5.8.1.2 Independent Variables.

AGE **:** Field observation and interviews with respondents, confirmed that the use of crop residues comes with experience of how to use to it prepare local delegacies. The age of wife is therefore expected to influence fuel choice through developed loyalty for crop residue. The older the wife (other things being equal), the more likely the household will continue using crop residue. Older people are also less likely to travel far to collect firewood due to health problems related to ageing.

EDUCATION: The level of education of the wife is expected to have a positive effect on the choice of crop residue alternatives. This is because level of education improves knowledge of fuel attributes, taste and preference for better fuels, and income, which then can be used to purchase the fuels which are comparatively expensive.

OCCUPATION: Occupation is expected to have a positive effect on crop residues alternatives. Households who are employed in non-farm work are more likely to use crop residue alternatives than their counterpart farm-workers. It is believed that this behaviour is caused by improvements in income, which elevate households in non-farm work to higher social class.

*HOUSEHOLD SIZE***:** The size of the sample household, that is the total number of persons normally residing together (i.e. under the same roof) and taking food from the same kitchen (including temporary stay away and excluding temporary visitors) has been used as t6an explanatory variable. It is expected to have either positive or negative sign depending on the fuel choice in consideration.

FEMALE: It is hypothesised that female-headed households are more likely to use crop residues than in using firewood or charcoal.

TIME: Longer cooking periods, would result in crop residue alternative being used. Since crop residue burns very fast and thus will require large amounts of it to cook.

Land: The cultivated area has a positive impact on agricultural production (at a given labour input level), and hence on (cash) income. This induces a higher consumption of leisure as well as goods that require energy inputs. The sign of the resulting effect on fuelwood collection and labour input in fuelwood collection is unclear. LIGHT: access to electricity (grid connection) to capture derived effects from electricity to other Fuels. The effect on other fuels is indeterminant.

ASSET: Household wealth status is an important parameter that influences the fuel choice. Other than income, the composition of the gender, age and education of its members are likely to affect the household's principal activity related to energy .The following are the variables used in the model. Variable descriptions, units of measurements and the hypothesised effects of the determinants of choice and quantities consumed are presented in Table 5.13

Table 5 .13: Description of variables, measurement units and expected effects for the discrete- continuous choice model

Variables Description	Measurement units	Expected effect on dependent variable		
		Crop residue	Firewood	Charcoal
OCCUPW Occupation of wife of household (1= agricultural , 0 = non agricultural)	Dummy	+	-	-
ASSET Assets index of household	Number	-	+	+
AGE Age of woman	Years	+	-	-
FEMALE Sex of household (1= female , 0 = male	Dummy	+	-	-
HHSIZE Household size	Number	+	+/-	+/-
EDC (literate = 1 , 0 = illiterate)	Dummy	-	+	+
TIME Time for cooking a meal	Number	-	+	+
LAND Cultivated land area of household	Hectares	-/+	-	-
OPPCOST Opportunity cost in the collection of firewood .	Dummy	-	+	+
LIGHT Lighting fuel used in the household (electricity =1 , 0 = other)	Dummy	-/+	-/+	-/+
Main cooking fuel Crop residue Firewood Charcoal	Dummy	NA	NA	NA

Source : Author's field Survey, January – April, 2006.

Note: (+) denotes a positive effect on the dependent variable , (-) Denotes a negative effect on the dependent variable and NA denotes " not applicable"

From field observations, to a large extent, only women and girls collect firewood and prepare food. For this reason, the analysis targeted women rather than men and about 90 percent of the sampled respondents were women. Table 5.14 present the estimates of the β coefficients of the multinomial logit results of firewood and charcoal as compared to firewood, controlling for the impact of gender. Based on the statistical significance of the McFadden R2 (measure of the goodness of fit) at 1 percent, explanatory variables explain 14 percent of the variation in the model. Since social norms discourage men from participating in fuel procurement and cooking, the influence of gender has been removed from the analysis in table 5.14 by excluding the responses of male respondents in the analysis. Most of the parameter estimates on the explanatory variables included in the model are significant.

Table 5 14: Multinomial regression for fuel choices

	Firewood			Charcoal		
Exogenous variable	Coefficient	Standard error	Odds ratio	Coefficient	Standard error	Odds ratio
Constant	-3.940***	0.873		5.238**	1.868	
HHSIZE	0.231***	0.063	1.260	0.059	0.173	1.061
AGE	-0.022**	0.009	0.979	-0.055*	0.029	0.946
OCCUPW	0.004	0.217	1.004	-0.399	0.622	0.671
LAND	0.124	0.101	1.133	-0.533 **	0.265	0.587
FEMALE	-0.169	0.318	0.844	-0.158	0.708	0.854
ASSET	0.040*	0.022	1.041	0.119 **	0.036	1.127
EDU	0.651**	0.304	1.918	0.611	0.644	1.843
TIME	0.125*	0.067	1.133	-0.017	0.154	0.983
LIGHT	0.862**	0.333	2.368	-3.702***	0.698	0.025
OPPCOST	-0.194*	0.108	0.824	-0.097	0.318	0.908
Log Likelihood	-391.18619					
PseudoR-squared	0.1367					

Source: Author’s field Survey, January – April, 2006. Note: * is significant at 10% level, and ** at 5%, and *** at 1%.

Theoretical expectation was that an increase in the level of education of wife has a positive effect on the choice of firewood and charcoal. The results are in agreement with the hypothesised influence and show that an increase in the level of education of the wife positively affects a household's choice of firewood.

One possible explanation is that if firewood less polluting than crop residue[8] and wives who are educated may know of the health effect of biomass fuels, and thus will prefer to go for firewood which is less polluting than crop residues. Although the substitution of crop residue for charcoal is not significant, the desired hypothesized effect was. This may be due to the smaller number of households that use charcoal as the main cooking fuel. Household size has positive and significant impacts on the consumption of firewood. Larger families consume more firewood and have more labor available for firewood collection and thus are more favorably to use firewood. Other things being equal, to feed many people requires a large amount of fuel in aggregate. Hence, the expectation is that larger households will prefer to use firewood since it is comparatively cheaper to use firewood to cook for many people as it has a lower consumption rate per unit of time compared to charcoal or crop residue. Age was expected to be a significant factor in determining household fuel choice. In fact, an increase in age of wife was expected to be less likely to make a household switch from crop residue. The results show that the age of wife had negative coefficients for firewood and charcoal. Their p-values are both significant at 5 percent confidence level. The effect of age may become clearer only at older ages. Since the mean ages of women in the sample was 42.1 the sample was made of generally younger households whose desire for better things may be growing. Older people are also less likely to

[8] This relationship was confirmed in chapter five.

walk long distances to forest and market places to obtained firewood and charcoal, due to physiological changes that occur in human beings as one ages. Thus they are likely to use crop residues that can be found within their immediate vicinities.

The nature of occupation of wife was expected to have a positive influence on fuel choice away from crop residue. Specifically, women who are employed in non-farm activities were thought to be more likely to use firewood or charcoal. This was because they are more likely to make more money than their counterparts in farm – based work, which most of the time was on subsistence basis. A possible explanation of the negative relationship between non- farm and charcoal use is that women are generally underpaid regardless of their occupation. Secondly, cultural beliefs may keep working women to a common culture and societal lifestyle of using firewood. If a household cooks mainly the foods that require long preparation, the household is expected to be likely to use firewood and less likely to use charcoal compared to the use of crop residues. Regression results in Table 5.17 confirm this.

However, the results are statistically significant for firewood only. The fact that the type of food is not statistically significant for charcoal may be explained by the fact that crop residues and firewood are closer substitutes than crop residues and charcoal. Since charcoal is more comparatively expensive, it is less preferred in cooking foods that take more time. Firewood on the other hand compared to crop residue is more suitable to use when cooking foods that require longer cooking periods, because they have a less burning rate compared to crop residues. This finding turns to confirm the food switching and-fuel switching relationship cited in chapter four.

As expected, the opportunity cost of time in the collection of firewood had a negative and significant effect on households using firewood for cooking. It had a negative but not significant, impact on charcoal consumption. This means that as forest resources become increasingly scarce, as measured by the opportunity cost of collection time households react by reducing their consumption of forest fuelwood. This implies that households respond to scarcity or by substituting between fuels. However this substitution is not in favour of superior fuels such as charcoal, but in favour of less polluting fuels such as crop residues. This confirms the assumption, that households in the study area are substituting fuelwood with crop residue, when faced with fuel scarcity.

Households with women as household's heads are more likely to use crop residues than in using firewood or charcoal. Female household's heads turn, to assume a double responsibility of taking care of the households. Thus they will prefer to use crop residues that do not require much time and effort to gather, since they have to use the time in other economic activities. Female households also turn to be poor, and thus cannot afford such crop residue alternatives. The household wealth index which has been used as a proxy to the income increases the probability of using both firewood and charcoal over crop residue. This relationship turns to confirm the energy–poverty concept that was discussed in previous chapters. The poorer the household the more likely the household will use fuels that are lower on the energy ladder.

An increase in the household cultivated area is associated with a negative and significant preference for charcoal against crop residues. Cultivated land, serve as a source of energy for crop residues. It is therefore likely that household's larger cultivated lands will use the crop residues for cooking, than buying charcoal, which will draw on the household budget. The source of lighting energy is a significant determinant of the preference of a given energy source. A change from kerosene as lighting energy to electricity involves in a drop of the crop residues utilization and increases the usage of firewood. However when the choice is between crop residues versus charcoal, households are more likely to go for crop residues than charcoal. These findings strongly relate to the gender –energy nexus. Field observations suggest that when households have electricity as a source of lighting in the households, the light is mostly sited in the man's room than in the kitchen. However, women who usually take care of the kitchen and cooking fuels are usually very poor to afford other alternatives of crop- residue compared to men.

5.9 Conclusion

Results from the study have proven that the Bongo district is prone to energy scarcity as a result of the arid climate, land degradation and lack of infrastructure. Furthermore, the study shows that women were vulnerable to energy scarcity as a result of their social, economic and political conditions. Respondents further pointed out that, as a result of their vulnerability, they were prone to the impact of water scarcity. These women were particularly prone to loss of livestock, health problems and wasted time and energy. The chapter has, in addition, demonstrated that over the years women had developed coping strategies in order to deal with energy scarcity. These strategies include reduction in the number of meals cooked, borrowing and sleeping without eating. The analyses in this chapter have shown the abundant knowledge the women have collected as a result of their daily use of energy resources and the effects of the lack thereof.

The study also reveals a set of important factors that determine household cooking fuel choice. It shows that the level of education of wife, wealth status, time spent in cooking and the lighting used in households are all significant factors in determining the probability of switching from crop residue to firewood or to Charcoal. The consumption evidence tells a consistent story: all three fuels tend to be inferior goods[9]. As people wealth status tends to grow they prefer to go for firewood instead of residues and substituent charcoal for firewood. These consumption observations should have favorable implications for Ghana's environment as household wealth status increases. If lower wealth resourced households grow to behave like higher wealth resourced households as the economy grows, then as wealth increases , more households will convert from residues to fuelwood and then to charcoal. The additional residues remaining on the ground will help sustain soil productivity.

However evidence suggest that wealth status of a household is not the only determining factor influencing the choice of cooking fuels, but other socio-cultural(time for cooking a meal, education, household size etc) factors also play a role. The results of this study have important policy implications because they suggest the need to also focus on such factors in policy design. At least for households in poor developing countries, such as those in Ghana, perhaps more attention should be paid to these factors. In particular, government policies towards the use of a cleaner energy in Ghana require not only increasing supply of modern energy sources but also accelerating economic growth of poor rural household.

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[9] A type of good for which demand declines as the level of income or real GDP in the economy increases.

CHAPTER SIX

HOUSEHOLD ENERGY, GENDER AND HEALTH ISSUES IN THE BONGO DISTRICT

6.1 Introduction

Household use of traditional biomass fuels - fuel wood, dung, and crop residues - is widespread in rural Ghana. According to the 4th round of the Ghana Living Standards Survey Report (GLSS 4) conducted in 1998–1999 covering 5,998 households, 84.4 percent of rural households and 24.9 percent of urban households relied on biomass as their primary cooking fuel. However in rural Ghana the household sector has been able to optimize its biomass use, without intervention by the state, through the involvement of women. The role of women has been taken for granted in relation to their traditional gender role, by which socially accepted and culturally sensitive imbalances have been established. Health issues pervade the biomass cycle from the stage of biomass-gathering to its end-use. Women, who link the outdoor biomass resource environment with domestic consumption, initiate the cycle and traverse it repeatedly. Burning biomass in traditional stoves (open- fire three-stone “stoves” or other stoves of low efficiency, often with little ventilation) emits smoke containing large quantities of harmful pollutants—with serious health consequences for the exposed population.

The primary intent of this chapter is to investigate the health impacts on household’s members in the provision and use of their household energy. This chapter first focuses on the physical exhaustion, psychological deterioration, and ill-health generated by the cycle, as reported by participants in the study in section 6.2. Section 6.3 examined the health impacts associated with the use of cooking fuels and try to compare results across other studies. Section 6.4, looks at the smoke effect reported by households and try establishing the effects with other cofounders.

6.2 Detrimental effects in the acquisition of household energy

During the field survey, the detrimental effects of procuring and carrying biomass were noted. Morbidity issues related to biomass-gathering are inseparable from the process of carrying, in which ‘‘head-loading’’ takes place. Thus, the health problems reported by the households, including injuries, physical discomfort and psychological discomfort were recorded by gender of respondents in relation to the work they perform in procuring and carrying. The household based gender-disaggregated data were tabulated to reflect the nature of health problems. Table 6.1 shows the major health problems reported by all 625 households.

The self-perceived morbidity records furnished by the households include 11 categories of problems. Five of these problems, including injuries (cuts and sprains), backache, headache, chest pain and pest attacks, are widespread and occur frequently. Carrying involves head-loading of fuelwood from outdoor sources for domestic use. Carrying seems to have quite strong and consistent effects. Analysis of the field data reveals that the whole phenomenon clearly manifests gender differentiation.

The total number of problems reported by men was insignificant. This was due primarily to their extremely low engagement in procuring and head-loading fuelwood. Many problems reflect the double burdens of women because often gathering is followed by carrying, which is the second segment of the cycle, and performed by the same persons. The fuelwood gathered from outside sources is not left behind and therefore, it is immediately carried to the final destination, the household.

Table 6. 7: Self - reported morbidity in relation to biomass collection and Use

Self-reported morbidity	Number of household reporting	Women	Men
Injuries	575	434	140
Snake bites	172	138	35
Insect & Pest bites	445	336	109
Headaches	350	271	79
Chest pains	376	299	77
Fatigue	495	484	11
Stiff neck	434	434	0
Backache	424	412	12
Skin irritation	487	480	7
Fungus infection	384	384	0
Sinus problems	127	127	0
Waist pains	523	523	0

Source: Author's field Survey, January – April, 2006.

Here are a number of narrations made by respondents, in relation to the collection of fuelwood in the district.

"I collected wood before, and it was heavy on my back and it made my neck go stiff. She adds, 'I collected wood 4 times each week for 5 hours each time. My 3 daughters also collected wood I fell down one time carrying wood, and I have a scar on my head".

" I was once bitten by a scorpion when I went in search of wood. Sometimes we have to carry our babies along in search of firewood. This makes the whole process so tiring since we have to carry them, along with carrying the bundles of firewood".

In gathering and carrying, women are exposed to the sun, to rain and to humid conditions. The activities that are performed tend to cause injuries, cuts, bruises, sprains and in some cases fractures where there are incidents of falling while pulling wood and climbing. Gatherers were also subjected to snake bites, fungal infections and pests while collecting dead wood from the fields. Skin irritation and allergic reactions are reported as consequences of this exposure, contact and subjection of the gatherers to hostile conditions.

Nearly 90 percent of the respondents mentioned head-loading as one of the most exhausting tasks in the system. Immediate health consequences are fatigue, headaches, and pains in the joints and chest. The elderly believe head-loading to be the most crucial single factor causing repetitive strain injuries, and say it causes serious physical suffering. However field observations show that there seem to be differences between men and women in the transporting of firewood. When men are involved, donkey carts are mostly used in transporting firewood, whiles women turn to transport by head- loading. Plate 6.1 and 6.2 shows the different transport mechanism employed by household.

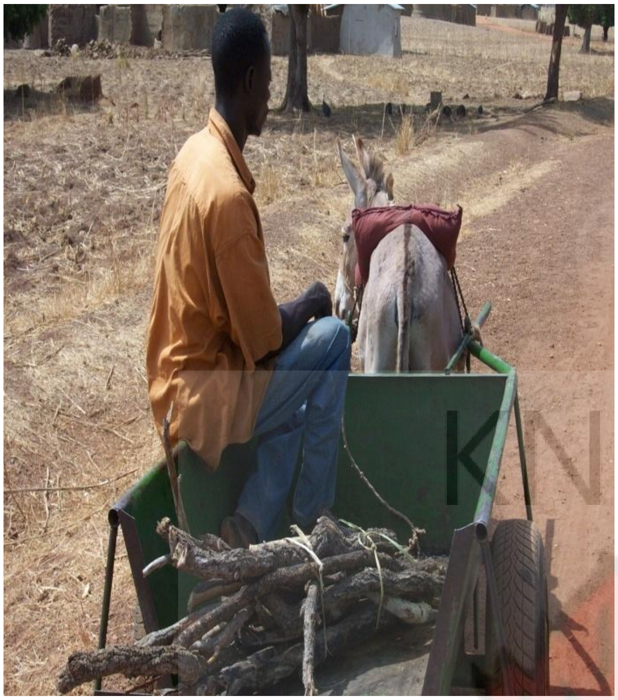


Plate 6.1: Man transporting firewood by donkey cart

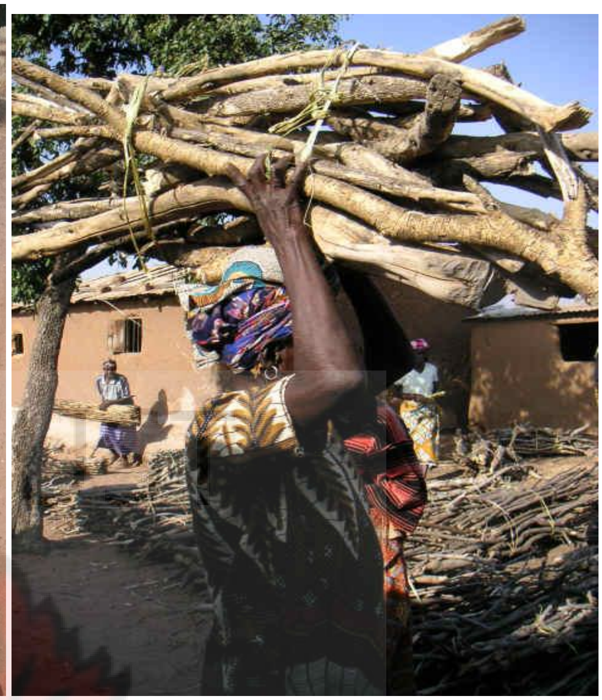


Plate 6.2. Woman transporting firewood by head-loading

6.2.1 Gender differentiation

Gender differentiation in the running of the household energy cycle has been promoted by society. It is marked by the division of work or activities, engagement patterns, and use of available sources. At the very outset it is quite apparent that women dominate the biomass energy cycle and it is emphatically considered to be primarily women's domain and part of their domesticity. They are the gatherers and deliverers of raw materials and also the generators of energy and the end-users. This means that around 82 percent of the biomass consumed in the domestic sector in Ghana, is handled by women as one of their domestic chores. From the stage of procuring to the combustion and waste disposal it is women's responsibility. No matter what detrimental effects they have to bear, they have to adjust to resource depletion, scarcity and poor quality biomass. For women who rely on multiple sources for free gathering, the drudgery is excessive. These being the realities, it is clear that morbidity relating to the biomass cycle has a strong correlation with gender. Table 6.2 lists the various activities involved in household fuel preparation and delineation on the basis of gender are reflected.

Table 6. 8: Activity matrix in household fuel management

Fuel	Fuelwood	Gender	Crop Residue	Gender	Animal Dung	Gender
Source	Natural resources		By-product of agricultural activities.		By –product of livestock activities	
Procurement						
	Harvesting	♀	Harvesting	♀	Harvesting	♀
	Bundling	♀	Bundling	♀	Bundling	♀
	Carrying	♀	Carrying	♀	Carrying	♀
	Splitting	♀				
Use	Cooking Food	♀	Cooking Food	♀	Cooking Food	♀
	Meat/Fish smoking	♀	Meat/Fish smoking	♀	Plastering of wall	♀
	Shea butter making	♀	Jute rope making	♂♀	Floor material	
	Local beer brewing	♀			Fertilizer	♂
	Sales	♀♂				

Source: Author’s field Survey, January – April, 2006.

Key ♀ - Activity typically carried out by female, ♂ Activity typically carried out by males, ♂♀ Males and Females Play distinct role.

Fuelwood cutting, collection, head loading, processing, storage and sales are primarily the task of females in the study area. They are also exclusively responsible for cooking food. These patterns in the performance of various tasks are socially grounded and related to gender. Men's engagement in this cycle is occasional. Previous studies conducted by Ardayfio-Schandorf (1986) reiterated the same features. The splitting of wood is one of the major activities in which men are involved as helpers. Gathering deadwood and head-loading are not in the men's domain of work; as a result their engagement in the cycle is occasional and appears in the form of a helping hand in the tasks considered ‘‘heavy’’ and ‘‘masculine’’

With respect to other fuel sources apart from biomass fuel, table 6.3, below shows that, the responsibility for household energy is shared out between men and women. Women are primarily responsible for supplying the household with cooking fuels (bio- fuels) and to a lesser extent electricity and kerosene. Men are primarily responsible for grid electricity when it is available in the community and also for kerosene. Cooking energy is generated through the direct combustion of crop residues plus a significant portion of fire wood. This is to meet a recurring need for cooking two/three meals a day.

Table 6 9: Household Energy Responsibilities of Men and Women

Energy type	Women (%)	Men(%)
Biomass	96	6
Kerosene	23	77
Electricity	0	100

Source: Author's field Survey, January – April, 2006.

In almost (99 percent) the entire households surveyed, women take up the responsibility of supplying the household with the cooking fuel and men take up the responsibility of supplying the lighting fuel.

6.3 Health Effects of Indoor air pollution (IAP).

Biomass combustion within a confined space in the household interior also has serious health implications. Exposure to hazardous outputs, including particulates, causes serious health problems. Respondents are often exposed six to eight hours a day, and even longer during peak seasons in the agriculture cycle, rainy seasons, and in seasons where grains are stored above kitchen hearths for smoke-drying.

6.3.1 Result of the IAP monitoring exercise.

The study monitored indoor air pollution levels, using Particulate matter ($PM_{2.5}$) and Carbon monoxide (CO) as the indicated pollutants. In all, a subset of 45 households from the 625 households, were monitored. Biomass fuels (firewood and crop residues) and the traditional stoves (mud stove and three stone stoves) were the dominant type of fuel and stoves used. Other Independent and environmental factors studied included kitchen volume, construction materials of kitchen(wall, roof) , number of windows present , number of people cooked for and other sources of smoke (cigarettes, burnt garbage , lamps and mosquito coils) during the monitoring period. However there were no reported cigarettes smoked and no incense or mosquito coils burned in any of the kitchens; nor was any relevant garbage burning or any other nearby air pollution source reported during both phases of monitoring

Tables 6.4 shows the results of the overall means and standard deviations of $PM_{2.5}$ and CO in the kitchens of the 45 households monitored. Averaging during a 24-hour period, household members, especially the primary cooks, were exposed to 0.07mg/m3 of particulate matter and 12.63 ppm of Carbon monoxide.

Table 6.10: Average Kitchen Concentrations of PM and CO

IAP Measurement	Minimum	Maximum	Mean	Std. Deviation
PM: Average (mg/m^3)	.05	6.39	.7056	.98840
PM: Minimum (mg/m^3)	.02	5.36	.1825	.80554
PM: Maximum (mg/m^3)	.80	76.04	37.7013	22.33790
PM: Highest 15-min ave.	.32	50.60	12.2196	11.62236
PM: 2nd highest 15-min ave	.14	33.05	7.7820	7.86929
PM: 3rd highest 15-min ave	.13	24.71	5.6578	6.03955
CO: Mean, HOBO (ppm)	2.90	45.60	12.6311	9.96110
CO: Maximum, HOBO (ppm)	26.60	432.60	128.8200	92.87469
CO: Mean Tubes (ppm)	1.90	43.00	8.8133	9.05367

Source: Author's field Survey, January – April, 2006.

In a study by the Center for Entrepreneurship in International Health and Development(CHIED 2006), which took place in rural southern Ghana , similar levels of CO were found (i.e 12.3 ± 9.9 ppm), as well values for $PM_{2.5}$ levels (0.65 ± 0.49mg/m^3), even though the current study figures are slightly higher than that of CHIED.

6.3.2 Comparison of the kitchen concentrations to international standards.

The World Health Organization(WHO) sets air pollution guidelines to offer guidance in reducing health impacts of air pollution (both indoor and outdoor) based on current scientific evidence. The WHO recently set new Air Quality Guidelines (AQG) for $PM_{2.5}$, ozone, nitrogen dioxide, and sulfur dioxide, along with interim targets which are intended as incremental steps in a progressive reduction of air pollution in more polluted areas (WHO, 2005). The guideline for carbon monoxide was set in 2000 (WHO, 2000). National Standards for indoor air pollution in the country have not yet been established by the Environmental Protection Agency (EPA) the organization responsible for air quality standards in the country. The results of the IAP monitoring in the 45 households are compared to the World Health Organization's AQG and interim target-1 (WHO, 2005) in Table 6.5 below.

Table 6 11: Comparism of IAP with international Standards

Pollutant.	24-hr Mean Concentration (in this study).	WHO interim target -1[10]	WHO Air Quality Guideline.[11]
PM2.5	706ug/m^3	75 ug/m3 (24-hr mean)	25 ug/m3 (24-hr ave)
CO[12]	14.49mg/m^3	NA	10 mg/m3 (8-hr ave)

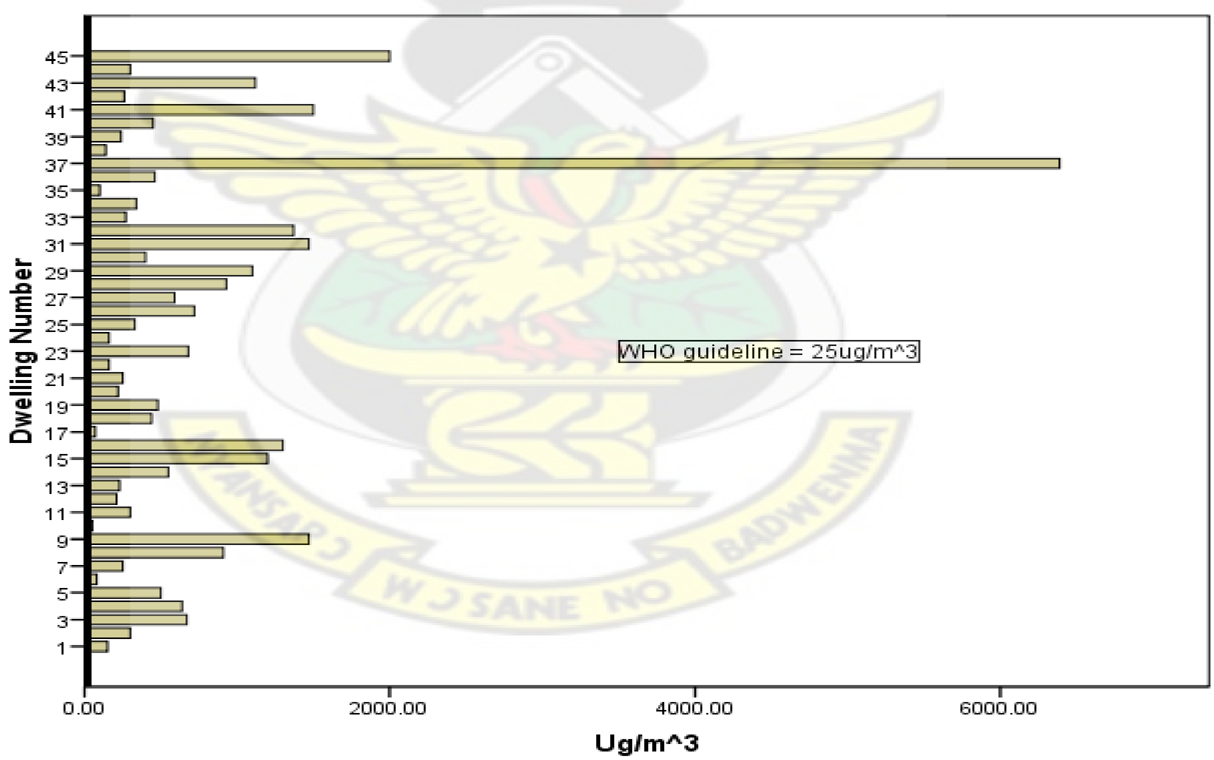
Source: Author's field Survey, January – April, 2006. and WHO, (2005).

As can be seen from table 6.5 above both $PM_{2.5}$ and CO concentrations were well above the permissible levels recommended by the WHO. The level of exceedances is very worrisome, as

[10] WHO 2005
[11] WHO 2006.
[12] Note that the CO concentrations reported above in parts per million (ppm) were converted to mg/m3 to match the units used by WHO (by multiplying by the gram molecular weight of CO, 28, and dividing by the conversion factor of 24.45).

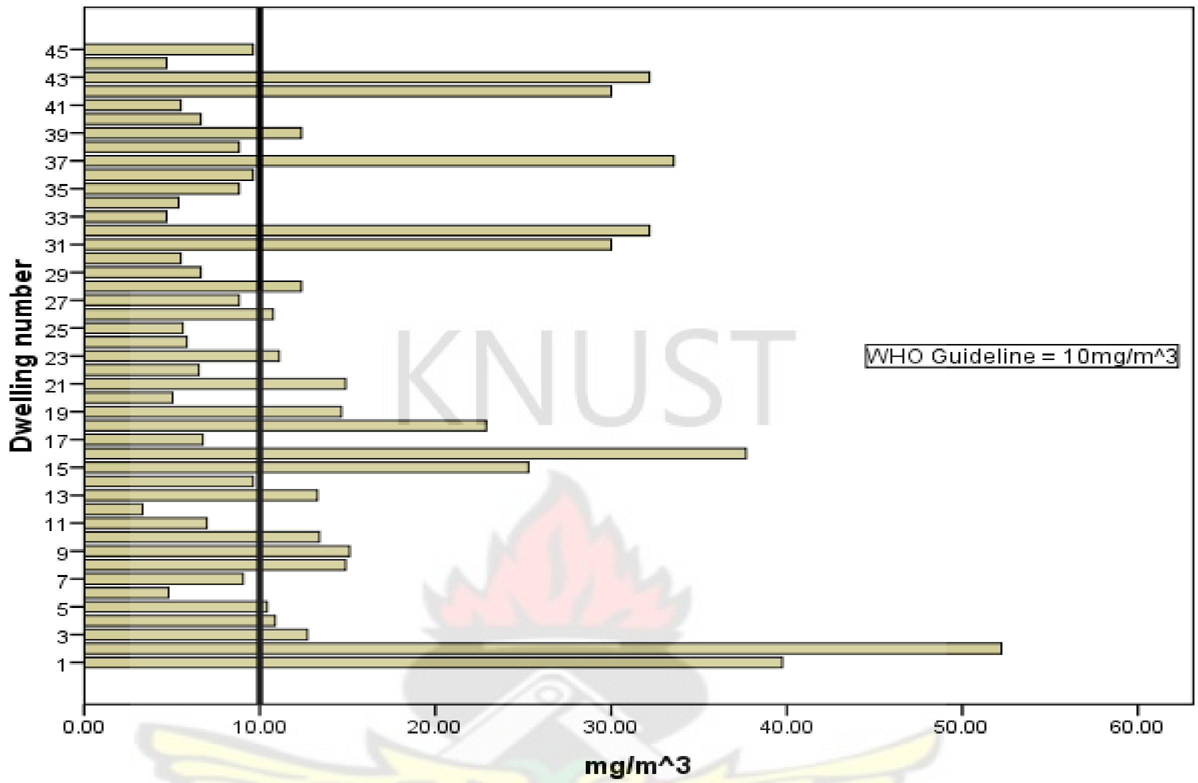
values established by WHO are designed to protect the health of an “average” individual (WHO, 2005). Figures 6.1 and 6.2 gives a more detailed analysis of PM $_{2.5}$ and CO averages across the individual households surveyed compared with WHO guidelines. The dark vertical lines in both graphs represents the WHO established guideline value not to be exceeded for that time frame (24-hr for $PM_{2.5}$ and CO). $PM_{2.5}$ concentration in all households exceeded WHO recommendation by 28.2 times. The main reason for this observation is the high dependency on agricultural residues, which releases high amounts of toxic pollutants as illustrated by the energy ladder concept.

Figure 6. 6: 24-hour PM $_{2.5}$ mean concentrations across sampled households.



Source: Author’s field Survey, January – April, 2006. (The dark vertical line represents the WHO established guideline value not to be exceeded for that time frame)

Figure 6 7: 24-hour CO mean concentrations across sampled households

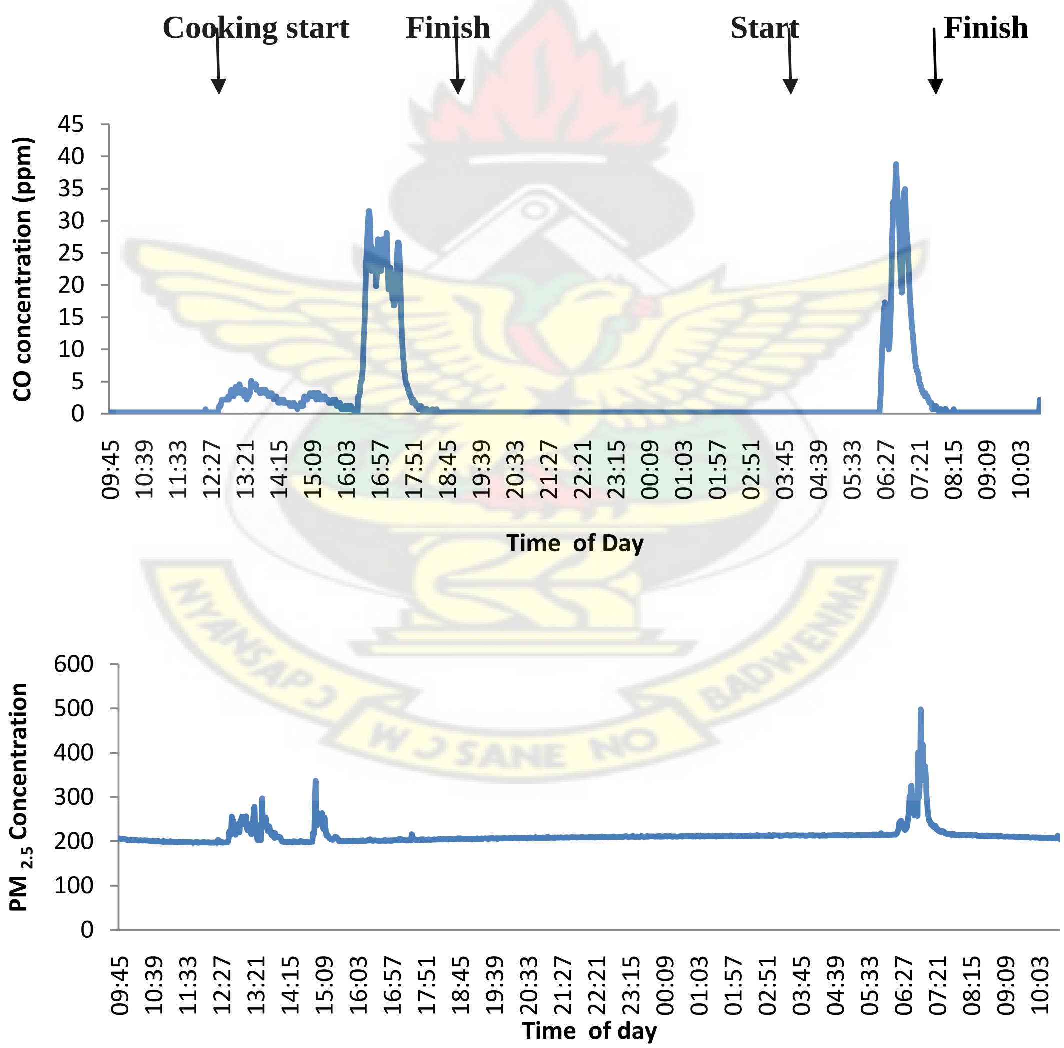


Source: Author's field Survey, January – April, 2006. (The dark line represents the WHO established guideline value not to be exceeded for that time frame)

6.3.3 24-hr Household Variation and Cross-household Variation

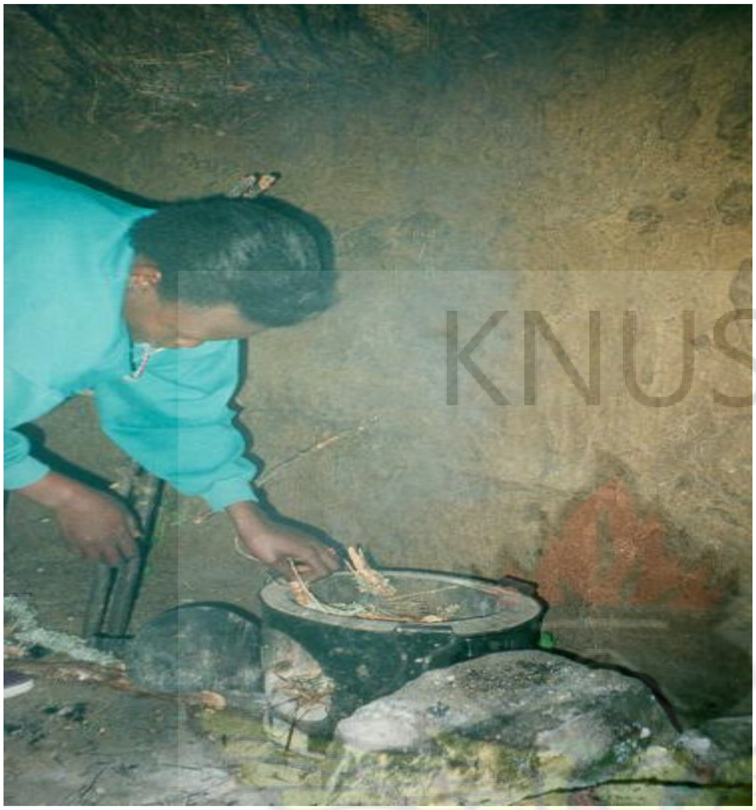
Smoke emissions from a biomass stove exhibit very large variability throughout the day, including large peaks of short duration. This can be seen for example in the pollution profile of Figure 6.3 below. At the time of sampling, participants were asked to write down the time period in which fuel was used in their dwelling for cooking. Once this information was cross-referenced to indoor air measurements, it became evident that often peaks in emissions corresponded with approximate times when fuel use was recorded (Figure 6.3). This pattern indicates that some household members are consistently closest to the fire when pollution level is the highest. These episodes typically occur when fuel is added or moved, the stove is lit, the cooking pot is placed on or removed from the fire, or food is stirred (in particular when cooking the common dish of "*saatroka"*) as in plate 6.3. CO and $PM_{2.5}$ peaks generally occur together, as would be expected since both pollutants are produced during combustion. Due to the continuous nature of the data collected, both the time of actual cooking events and the peak exposure concentrations are recorded in the data.

Figure 6. 8: Peaks of emissions for CO(above) and $PM_{2.5}$ (below) displayed during the times of fuel use



Source: Author's field Survey, January – April, 2006.

Plate 6.3: Woman cooking in smoked filled kitchen



Household members involved in cooking are exposed to episodes of high pollution when they work directly above the fire.

Other studies have highlighted this trend as well. Continuous measurement of CO levels in a study by Röllin et al.,(2004) showed that measurable levels of CO coincided with the time of cooking activities in dwellings that used wood. Similarly, Park and Lee (2003) found that particulate concentrations changed drastically during overall monitoring time and peaks were strongly associated with frequency of wood burning stove use. Ezzati et al.,(2000a) found that peaks in emission concentrations commonly occurred when fuel was added or moved, the stove was lit, the cooking pot was placed on or removed from the fire, or the food was stirred.

Variation inside a dwelling does not only exist within a 24-hr period; it can also exist day to day. According to Ezzati *et* al. (2000a), emissions in a single dwelling can vary each day because of: fuel characteristics such as moisture content or density, air flow, type of food cooked, or whether the household uses multiple stoves or fuels. Due to time constraints we were unable to revisit dwellings to determine how large day-to-day variation was. Other studies have examined this, however. Jin et al., (2005) conducted multiple measurements in the same dwelling and found that standard deviations of the mean varied between 10 percent and 100 percent. Despite this large range in variation, they stated that more variation in pollution existed across different households than within households. Ezzati *et al*. (2000b) visited 20 percent of the dwellings within their sample in between 6-15 times to monitor intra-household variation. Again, they found that while variation within a household exists, the variation is not as high as inter household variation.

Similarly in this study, variability was demonstrated across houses within the sample. This pattern can be illustrated through the wide ranges that pollutants exhibited across kitchen types ($PM_{2.5}$:02 – 76.04 mg/m^3, CO range: 26.60 – 432.60ppm,). There are many possible explanations behind this variation. Inter-household variation was suggested to be strongly affected by structural arrangements: cooking locations, construction materials and ventilation practices in a study carried out in Bangladesh (Dasgupta et al., 2004).

The duration of stove use, quantity and grade of fuel used, and stove use behaviour are other commonly cited reasons behind inter-household variation (Jin *et al*. 2005). Similarly, each household visited displayed unique structural and behavioural differences in the amount and duration of fuel use.

Dasgupta *et al*. (2004) stated that inter-household differences in pollution and accompanying exposure are largely attributable to two factors: the level of peak concentrations during cooking and the rate at which concentrations decline after cooking. All of these factors make it difficult to accurately assess IAP levels and corresponding exposures across households.

6.4 Extrapolation of the kitchen concentrations: health implications

The science of quantifying the human health effects of exposure to air pollution is extremely complex, but has advanced much over the past several decades. The best data for doing so come from large epidemiological studies of outdoor air pollution and health conducted over the past two decades spanning five continents. Such studies typically measure the effects of air pollution in terms of PM and have provided evidence of associations between PM and the following adverse health outcomes: mortality, hospital admissions for cardiovascular and respiratory disease, urgent care visits, asthma attacks, acute bronchitis, respiratory symptoms, and restrictions in activity (Ostro, 2004).

The persistency of PM is mainly due to the fact that such fine particles can be inhaled deeply into the lungs where the clearance time of the deposited particles is much longer, thereby increasing the risk of adverse health effects. Bala (1997) developed a set of mathematical potential exposure equations, used to calculate the exposure of individuals. The equation to predict the health risk for particulate matter (PM), on an annual basis is as below in Box (1)

Box 1- Health impact prediction

Change in lower Respiratory illness (per child) = 0.0169 × change in PM Change in Asthma attacks (per person) = 0.0326 × change in PM Change in respiratory Symptoms (per person) = 0.183 × change in PM Change in Chronic Bronchitis (per person) = 6.12×10^{-5}change in PM The change in PM is calculated by the following equation: Change in PM = C_{avg}-C_{WHO}

Where

C_{avg} = Annual average of PM (24-hour), mg/m3

= E/24 (E= Exposure)

C_{WHO} = WHO standard, 0.04mg/m3

Source: Bala (1998)

Given only kitchen concentrations measured in this study, to develop personal exposure concentrations, data was pulled from studies that measured both kitchen and exposure concentrations for household members. A recent IAP monitoring study in Mexico that included kitchen concentration measurement methods similar to those used here (i.e. the same instrument and same placement criteria were used), but also measured the 24-hour personal PM exposure concentration, found that the ratio of the personal $PM_{2.5}$ exposure concentration of the main cook of the household to kitchen $PM_{2.5}$ concentration (the cook/kitchen ratio) to be 0.21 to 0.26 (Johnson et al., 2005). Bruce et al. 2004 showed child/kitchen concentration ratios ranging from 0.42 to 0.79 in rural Guatemala, which seemed to increase with increasing level (quality) of the kitchens. That same trend was seen in a CEIHD study in Nicaragua (CEIHD, 2003) which found cook/kitchen concentration ratios of 0.56 and 0.73 for two groups using open fires and 0.79 and 0.92 for the same two groups when they upgraded to an improved stove with a chimney (the EcoStove).

These three studies show the obvious, that the range in the ratio of personal exposure to kitchen concentrations is very large and dependent on the individual situation. Hence, attempting to assign such a ratio to a new situation, such as that in the Bongo district, is not particularly accurate and introduces much uncertainty. Nonetheless, a personal/kitchen concentration ratio of 0.50 was used here as the "best" estimate. A "high" personal exposure case of 0.8 and a "low" exposure case of 0.25 were also considered.

Multiplying the kitchen $PM_{2.5}$ concentration average of 706 ug/m3 by the best estimate of 0.50 for the personal/kitchen concentration ratio yielded a personal exposure concentration estimate of 353 ug/m3 or 0.353 mg/m3. The same was done for the low personal exposure case (personal/kitchen= 0.25) and the high personal exposure case (=0.80) giving 176.5 ug/m3 or 0.1765 mg/m3 and 564.8 ug/m3 or 0.5648 respectively. Table 6.6 below gives the average relative change of being affected by the different personal exposure thresholds across households.

Table 6. 12: Average relative chance of being affected by IAP related diseases.

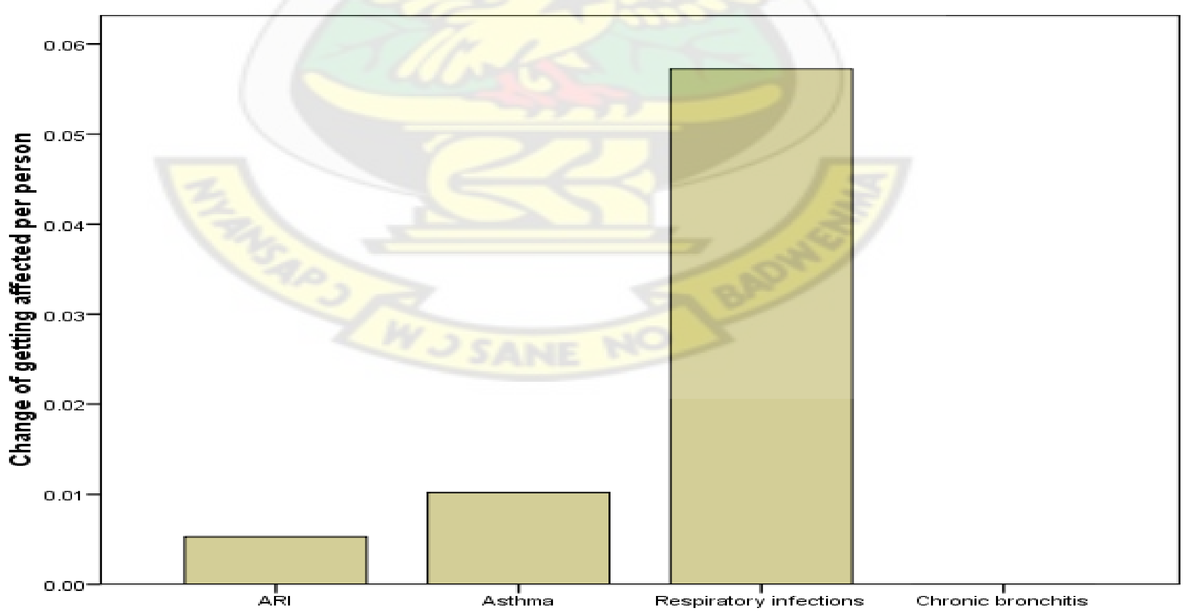
	Personal exposure thresholds		
Disease	Low	Best	High
Acute respiratory lower infections	0.023	0.053	0.088
Asthma	0.044	0.102	0.171
Respiratory Infections	0.250	0.572	0.960
Chronic bronchitis	0.000	0.000	0.000

Source: Author's field Survey, January – April, 2006.

From the table 6.6 , a unit change in PM levels will increase the relative chance of households members being infected with acute respiratory lower infections(ARLI) by 0.053, 0.102 for being infected with asthma and 0.572 of being infected with respiratory infections for the best personal level estimates. Figure 6.4 below gives a graphical illustration of the relative chance of households members being infected with IAP – related diseases across the sampled households.

Respiratory infections (wheezing, coughing) dominate, followed by asthma and then acute respiratory lower infections in children. In chapter 3, a health profile in the district showed that respiratory diseases were the second commonest disease after malaria. This results justify the evidence that exposure to biomass cook stove smoke may contribute to number of patients suffering from respiratory infection in the study area.

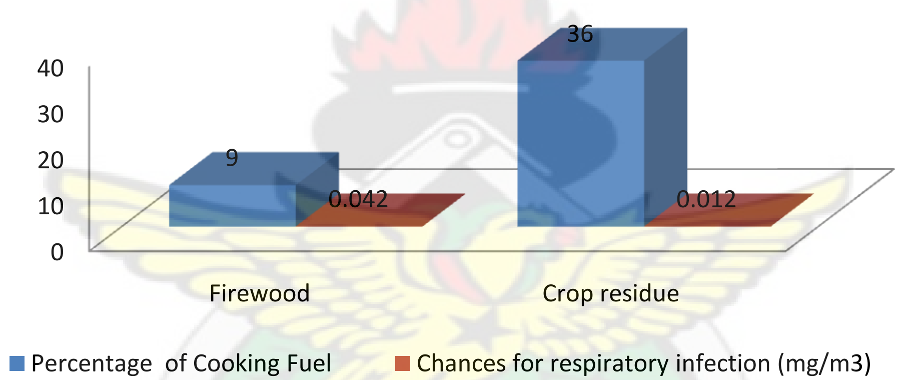
Figure 6. 9: Graphical illustration of the Relative chance of being affected by IAP – related diseases



Source: Author's field Survey, January – April, 2006.

According to Smith (2006), different fuels have different emission factors and ill-effect. Figure 6.5, shows the chances of getting affected by different types of respiratory diseases varies with use of different biomass fuels as energy sources. Households using crop residue has a 0.012 relative chance of being infected with respiratory infections, whiles firewood has 0.042 relative chance of being infected with respiratory infections.

Figure 6.10: Fuel Consumption pattern and chances for respiratory infection



Source: Author's field Survey, January – April, 2006.

6.5 Local Health Problems associated with IAP[13].

The effects of smoke inhalation on the respondent, especially women and children were noticeable in observations of village life. Coughing by women begins at dawn when fires are made to cook breakfast and heat water. Very young children who spend most of the time with

[13] This part onwards deals with the entire sample (625 households).

their mothers strapped to their backs during such cooking times, are also exposed to large amount of cooking smoke. Normally such children had bouts of coughing accompanied with running noses.

6.5.1 Local Knowledge and Behaviour

Across all households and socio-demographic groups, the majority of respondents were aware that smoke from cooking and heating was a health hazard. Regarding knowledge of the causes of IAP, only 5 percent of those interviewed knew that smoke from fuel combustion contained harmful components, including dust, CO, SO_2, fluoride, and "other chemicals." Even where knowledge of health risks exists, it must be coupled with knowledge about effective interventions (or solutions) from which individuals and households may choose. Analysis of the results indicated that the awareness about interventions for reducing indoor smoke was relatively low, except for a few respondents who cited the opening of windows and doors whilst cooking and using very dried biomass fuels. In all, majority of the respondents thought that there was nothing they could do to reduce IAP in their kitchens. Most respondents could not identify alternative fuels.

6.5.2 IAP- Health Related Symptoms

A high percentage of sampled individuals reported experiencing respiratory symptoms that may be related to exposure to indoor air pollution. Eye irritation, mostly in the form of the tearing whiles cooking was cited as the most prevalent smoke related symptom by a majority of the women interviewed. Table 6.7 below shows the prevalence of smoke-related diseases among males, females and children across the sampled households.

Table 6. 13: Prevalence of smoke-related disease symptoms among males, females and children (aged < 6) by 625 households

Disease symptoms	Women	Men		Children
		Smokers	Non-smokers	(aged<6)
Cough	457	6	51	494
Chest / breathing problems	369	2	2	41
Tired /Stress	420	0	1	11
Eye irritations /tearing	464	5	58	508
Loss of appetite	135	0	0	0
Rise in body temperature	193	0	1	38
Phlegm	224	0	0	1
Headache	442	1	11	54

Source: Author's field Survey, January – April, 2006.

This is what respondents had to say about the use of crop residue for cooking:

"I always loss appetite after cooking with the crop residues and my sputum is always black after cooking. The use of biomass for cooking has made me blind in one eye".

Plate 6.4 shows a women who claimed she got blind in one eye due to smoke from cooking fuels (her consent was sought, before showing her picture in the thesis). Pokhrel et al. (2005) in their study provides confirmatory evidence that the use of solid fuel in unflued indoor stoves is associated with increased risk of cataract in women who do the cooking. Other studies (Mohan et al. 1989, Zodpey and Ughade, 1999 and Mishra et al.1999) have also provided some evidence of an association between cataract or blindness and exposure to indoor smoke from household use of solid biomass fuels, such as animal dung, wood, and crop residues.

Infected left eye

Plate 6.4 showing woman's left eye, infected by cooking smoke.

A further analysis of the smoke related disease that occur on a daily basis , indicated that eye irritation, headache and coughing are the top three ailment that occur.

6.5.3 Regression Analysis of Health Symptoms.

The occurrence of disease is often linked to confounders such as income, sex, occupation, age, and population of villages. On the basis of direct response data of females, logistic regression analysis were made about the patterns of the relationship between the top two smoke related health symptoms and other variables. Only linkages for females are looked into, as they are the most affected by the use of bio-fuels for cooking. The odds ratio from the logistic regression estimated for women respondent reporting coughing and eye irritation are presented in table 6.8.

Column Two and Three shows the odds of coughing and experiencing eye irritation in relation with some socio-economic and housing characteristics. Both, negative log likelihood and model Chi-square coefficient show that models best fit the data. About 15 percent of the variation in the coughing variable is explained by the model, whiles 14 percent of the variation in the eye irritation variable is explained by the model. Results show that an increase in the age of the wife of the household showed a negative effect on the respondent experiencing eye irritation. Thus for every additional year in the wife's' age, there is a 4 per cent decrease of her not experiencing eye irritation. These finding support field observations, where the younger age groups were the ones found mostly involved in household cooking. Although the effect on coughing was not significant, the expected sign was achieved. Prevalence rates of coughing and eye –irritations was also found to be related to the education of female adults. From table 6.8 for every increase in the probability of being illiterate there is 3.6 chance of coughing and 5.7 chance of experiencing an eye irritation. Among the females adults interviewed, the risk of coughing was 0.21 times lower for households using firewood when compared to those using crop residues as their main fuels. Thus crop residues were more likely to increase coughing than firewood fuel. This observation support the energy ladder concept discussed in chapter 2, that fuels at the lower rungs of the ladder produces more pollutants and are thus more harmful to users. The risk of experiencing an eye irritation was not significant, although the anticipated signs were achieved.

Table 6. 14: Logistic Regression on the relationship between Household characteristics and self-reported respiratory disease symptoms[14]

	Coughing		Eye irritation	
Variable	Odds ratio	Z-value	Odds ratio	Z-value
Age	0.986	-0.81	0.965*	-1.65
Education (1= illiterate)	3.625**	2.28	5.739**	2.64
Occupation (1= farming)	5.172**	2.34	0.576	-0.93
Cooked 2 meals per day (1 =yes)	0.370**	-2.04	0.688	-0.50
Window (1= yes)	0.381**	-2.23	0.935	-0.12
Lighting (1= electricity)	0.096	-0.06	0.756	-0.37
Cooking fuel^t				
Firewood	0.214**	-3.31	4.166	1.35
Others	0.284	-1.29	0.654	-0.40
Wealth Index	0.979	-0.56	0.954	-1.08
McFadden Pseudo R –Square	0.1460		0.1396	

t= crop residue was the base category variable. Note: * is significant at 10% level, and ** at 5%, and *** at 1%.

Source: Field survey, January – April 2006

Work by Benneh et al. (1993) in the Greater Accra Metropolitan Area (GAMA) point to the fact that exposure to suspended particulates and other oxides of carbon account for the higher risk observed among the bio-fuel users. Their study in 1992 revealed that wood (587.1 $\mu g/m^3$) and charcoal (341.2 $\mu g/m^3$) users had higher mean concentration of Total Suspended Particulates (TSP) within their immediate cooking vicinity than Liquefied Petroleum Gas users (195.2$\mu g/m^3$).

[14] Only the two top most respiratory symptoms are reported.

Though the Environmental Protection Agency (EPA) has no standard for indoor air quality, the mean Total Suspended Particulates observed for Liquefied Petroleum Gas is within the standard established by the World Health Organisation for outdoor air quality (150-230 µg/m^3). Users of charcoal and firewood however recorded higher concentrations than the World Health Organisation (WHO) standard and are therefore likely to suffer from symptoms of respiratory infections. There is a strong correlation between the type of fuel used and the reported incidence of coughing ($\chi 2$= 29.186 p=0.005) or eye irritation ($\chi 2$= 19.188 p=0.038) among female respondent. These data provide the empirical basis for associating type of cooking fuel with the incidence of respiratory infections in these communities.

Table 6.8 also reveals that poorly ventilated kitchens resulting from poor housing designs could trigger off allergies, which mostly manifest as sinuses and other acute respiratory problem symptoms. Data from Table 6.8 points to the fact that among the households surveyed women who cook in ventilated kitchens are 62 per cent less susceptible to coughing than for women cooking in poorly ventilated kitchens. The relationship between cross ventilation and problems of eye irritation was however not statistically significant. Other factors that are significant correlates of respiratory infections among the households studied are the occupation of the female respondent. This broadly relates to the dusty nature of farming activities as against non-farming activities.

CHAPTER SEVEN

FINDINGS, IMPLICATIONS, RECOMMENDATIONS AND CONCLUSION

7.1 Introduction

The analysis of data from the field with reference to the conceptual framework reveals certain findings on the impact of traditional fuel consumption in the Bongo District. This chapter discusses the main findings and their implications, suggests policy recommendations that aim at ameliorating the effect on the traditional fuel consumption on users (especially women) and the environment, and draws conclusion from the study.

7.2 Findings

The major findings of the study are:

7.2.1 Households in the study are energy poor

As in many parts of the country, in the Bongo district, biomass demand is by far in excess of the sustainable supply, as clearly demonstrated by the number of households relying on crop residues for cooking purposes. These fuels are considered to be at the lowest rung of the energy ladder, and thus makes it possible to conclude that for the households in the Bongo district are living in energy poverty which means they lack access to sufficient choice in accessing adequate, affordable, reliable, clean, high-quality, safe and benign energy services to support economic and human development. In the past, energy policies have focused on the commercial energy carriers: electricity, coal, gas and petroleum products. There is a growing interest in renewable energies, primarily for electricity generation, but the overwhelming tendency in the energy sector has been to focus on investment in electricity and fossil fuels. Urban users are the primary beneficiaries, and although the urban poor may also to some extent benefit, the rural poor – the majority of the poor in the country – generally do not benefit at all. As a result, there is a particularly heavy reliance by rural households and industries on locally supplied biomass fuels.

To overcome these challenges the Energy Commission made an attempt to integrate the woodfuel sector into the country's energy sector reforms. Certain policy objectives and actions were outlined (Section 3.5 of the Chapter 3). However till date, the authority that should accompany the implementation of these policies has not been delegated. To some extent it can also be explained by the fact that biomass does not fall squarely under the authority of energy ministries, since it is made up of tree and agricultural products that are normally the concern of ministries of Lands and Forestry and Food and Agriculture. The Ministry of Lands and Forestry is in charge of fuelwood supply while consumption and demand rest with the Ministry of Energy. There is frequently a lack of cross ministry co-operation. The National Environmental Action Plan (Section 3.5 of the Chapter 3) is also non-functional in terms of woodfuel production. The resultant effect is uncoordinated woodfuel production with its attendant problems as found in the study area.

7.2.2 Cooking energy is at the lowest rung of the energy ladder.

Cross-sectional data from the surveyed households show that the transition from biomass to modern commercial sources is non-existent in the study area, given that biomass still accounts for about 90 percent of the total energy used by rural households. This study reveals a set of important factors that determine household cooking fuel choice. It shows that the level of education of wife, wealth status, time spent in cooking and the lighting used in households are all significant factors in determining the probability of switching from crop residue to firewood or to Charcoal. The consumption evidence tells a consistent story: all three fuels tend to be inferior goods[15]. As people wealth status tends to grow they prefer to go for firewood instead of residues and substituent charcoal for firewood. These consumption observations should have favorable implications for Ghana's environment as household wealth status increases. If lower wealth resourced households grow to behave like higher wealth resourced households as the economy grows, then as wealth increases , more households will convert from residues to fuelwood and then to charcoal. The additional residues remaining on the ground will help sustain soil productivity. However evidence suggest that wealth status of a household is not the only determining factor influencing the choice of cooking fuels, but other socio-cultural(time for cooking a meal, education, household size etc) factors also play a role.

The results of this study have important policy implications because they suggest the need to also focus on such factors in policy design. At least for households in poor developing countries, such as those in Ghana, perhaps more attention should be paid to these factors. In particular, government policies towards the use of a cleaner energy in Ghana require not only increasing supply of modern energy sources but also accelerating economic growth of poor rural households. Towards this end, promotion of public education may be an effective instrument to reducing dependence on biomass fuels and to facilitating opportunities to using modern fuels such as liquefied Petroleum Gas. Particularly, governments and district officials need to increase efforts to enhance households' awareness of increasing fuelwood scarcity since this has potential to reduce fuelwood use significantly. Last but not least, in the short run, investment on

[15] A type of good for which demand declines as the level of income or real GDP in the economy increases.

commercial wood plantations may be essential since some households may still rely on fuelwood before modern fuels become the major energy source to them.

7. 2. 3 Women are particularly affected by Energy Poverty

Limited access to energy has a disproportionate effect on women in general and especially economically, and the women in the Bongo district are no exception. Biomass fuels were the primary source of energy in the district, with 94.7 percent of the population using them for cooking and other purposes compared to the conventional modern energy sources (5.3 percent).In the study area, women spend on average, each month, 40 hours collecting fuelwood. This breaks down to 15 round trips, each of 2.7 hours, and a monthly distance walked of some 30 km. In the process of collecting and transporting fuelwood, women were found to face numerous difficulties including the strenuous physical exercise in procurement and the time involved in the overall process. The study revealed that about 70 percent of the women in the 30 – 45 age group are involved in cooking, and about 53 percent of women who are above the age of 46 are not involved in cooking. The women in the age group of 30-45 years, who are usually the main household cook, are thus more exposed to smoke and indoor air pollution than other family members. However, it is the women aged currently over 45, are most likely to suffer from respiratory diseases, presumably due to accumulated exposure for many decades. Women cited, as the main health problems related to fuelwood use, physical strains as coughing, backache, headache, neck ache, bruises, wild animal and snake encounters and burning eyes. The results of the study give a clear indication that although the district has progressed in terms of education, asset ownership etc.; in terms of access to clean fuels and energy technology it continues to lag, and the brunt of the effects of this is faced primarily by the women.

7.2.4 Traditional Fuels Negatively Affect Human Health

According to the Ghanaian Constitution, every person has a right to an environment that is not harmful to his or her health or well-being. However cooking with biomass fuels in traditional stoves emit sever gaseous pollutants like CO, CO_2, SO_2, NO_2 and even PM. Those pollutants are highly hazardous for human health especially for women and children who are exposed to that air for a long time. This study provided 24-hr indoor concentrations and exposures to $PM_{2.5}$, and CO for households in the study area. Real-time monitoring and fuel use records demonstrated that peaks of indoor air emissions are created when fuel is burned indoors. Levels of pollution increased as more inefficient burning fuels were used (firewood< crop residues). The findings suggest that IAP is indeed a problem in the study households, and that occupants are currently facing health risks from exposure to IAP.

Data analysis shows that users of biomass fuels are exposed to pollutant concentrations (CO, $PM_{2.5}$) ten times compared to those allowable by international organizations such as WHO. This concentration has a high risk for human health. Unfortunately in the rural areas mostly women and child spend most of their time in such polluted air and thus are the most affected by theses high concentrations. Extrapolation of diseases with PM concentration showed that households were in a higher risk of being infected by respiratory diseases from the use of biomass fuels. This observation confirms with the self-reported symptoms associated with biomass fuel use where respiratory diseases dominated (cough, wheezing, shortness of breath, eye irritation). These symptoms were high among women, followed by their children. Men were the least affected by IAP. However, local knowledge about how to mitigate IAP related issues is lacking in the communities surveyed. This is because such symptoms are considered to be normal and are not taken seriously in the community. Health authorities in the study area also hardly link IAP with respiratory diseases found in the study area.

Apart from IAP health related issues, the collection of firewood also has drudging effects on the health of users. Among the commonly cited cases were injuries (cuts from branches) headaches, chest pains, waist pains and stiff necks.

7.2.5 Traditional Fuels negatively affect the agricultural landscape.

The growing shortage of fuelwood in the local environment has been documented in various developing nations of the world, including Ghana. The shrinkage in forest cover has terrible consequences in a country where people are primarily dependent on agricultural pursuits. Soil erosion and fertility potentially are major problems created by deforestation. The study traces out a severe fuelwood crisis in the study area even though fuelwood has been contributing dominantly in the rural household fuel supply. Findings from the survey indicate that more than 90 percent of the respondents agreed not only that fuelwood was in great shortage, but also that there are fewer trees now than in the past in their villages. All households, irrespective of income level, face biomass fuel shortage. In general, the fuel shortage period over the rainy season spans between May and August. In the face of the biomass fuel crisis, the respondents adopted some mechanism to cope with the shortage. The general practices to compensate for fuel shortage were storage of fuel before the rainy season, and reducing the frequency of cooking during the crisis period. Agricultural residues are the major fuelwood substitutes, and their increasing use as an energy source is at the expense of valuable organic fertilizers and foodstuff. Thus, a shift of biomass use ultimately threatens the agricultural production system. For example, women cited situations where the use of crop residues for cooking results in the loss of livestocks, because of the lack of forage for them.

7.3 Contributions to empirical research in Ghana

This section summarises the contributions to the body of knowledge that fills the empirical gap in household cooking fuels demand studies in rural Ghana in terms of methodological approach and theoretical underpinnings.

1. This study is amongst the first; if not the pioneer in the use of economic analysis to model household energy choices that conform to fundamental consumer behaviour to empirically model rural energy demand in Ghana. Such flexible models rule out the possibility of inconsistent utility maximisation behaviour and avoid model misspecifications that lead to wrong policy conclusions.

2. This study combines aspects of energy quality and quantity in explaining rural household energy demand behaviour, an approach necessary for better understanding of their decision making processes.

3. Under conditions where cooking fuels have no price (i.e., when energy is sourced from traditional sources such as firewood), the challenge would be to price energy. This study attempted placing value on rural cooking by estimating daily and hourly opportunity costs associated with the task of firewood collection using the national daily minimum wage approach. This approach could serve as guidelines in valuing rural household energy use where the estimated firewood price gives an indication of their willingness to pay for access to clean fuels. It also suggests the cost incurred by rural households in securing their household energy needs.

This study is again amongst the first; if not the pioneer to quantitatively measure IAP concentrations in the northern part of Ghana, using real time monitoring. The findings of the IAP exposure assessment, strengthen the evidence that the traditional use of biomass fuels for household daily needs exposes all members of the family to levels of air pollution (measured by 24-hour mean of CO and $PM_{2.5}$) that well exceed health guidelines available for indoor air quality. Importantly, the study shows that this holds true even (1) in a warm climate like that of northern Ghana where no heating is required and these fuels are used only for cooking. The study ascertains in quantitative terms that women, in their traditional capacity as cooks, suffer from much greater exposures than other family members, whereas adult men experience the least exposure, emphasizing an important gender dimension of the IAP problem. Among non-cooks, those who are most vulnerable to the health risks of IAP—young children—tend to experience higher levels of exposure because they spend more time near mothers during cooking periods. This finding lends support to the results of some other studies linking household fuel use with infant and child mortality rates.

7.4 Recommendations

From the findings discussed above, it is possible to point out a number of specific recommendations. The earlier chapters of this thesis have laid out the facts of rural energy poverty in rural Ghana, using the Bongo district as a case study. It began by evaluating the scale and nature of the problem, including energy sources and patterns of energy use in rural areas. We then looked at the Ghanaian rural energy economy and the main interventions that have been implemented in the past and what they have achieved. Finally it looked at the energy situations and associated problems present in the study area. Yet when we relate the progress made to date to the scale of the problem, we have to conclude that a fundamental change in approach is needed. Based on the findings, the following recommendations are made.

7.4.1 Improved Wood Production and Women

Findings from the study suggest that, the rural energy base of rural livelihoods is facing a risk of over –exploitation in the study area, as well as in other parts of northern Ghana. As has been shown, women in the study area are aware of various survival and coping strategies, but these will not improve supplies enough to meet the increasing requirement. Proper and efficient ways of enhancing the wood resources would help women by lessening their workload. The government of Ghana, in collaboration with women groups, could implement projects by utilizing the experiences of women and providing technical assistance for an effective management of wood resources. The Ministry of Environment and Forests in conjunction with regional forest departments has several programmes to increase biomass production through afforestation. This is done through both natural regeneration and setting up plantations. Between 1980 and 1992 a major thrust of forestry projects involved social forestry. It is estimated that 17 million hectares were afforested. But there have been some problems with the programmes as well. They often have involved a mix of trees that are used as pulpwood and structural timber for industries and the urban market, leaving only low-quality fuel for rural domestic use. To overcome such anomalies, it is recommended that the government announce a policy under the existing poverty alleviation and social and economic development schemes such as employment guarantee and other schemes, whereby women's group can form a Co-operative/user group for fuel wood or oil plantations rather than searching and gathering fuelwood, the same efforts can be put in to develop sustainable energy supply at the local level. The State Government in conjunction with various ministries such as Ministry of Environment and Forestry (MoEF), Ministry of Rural Development (MoRD), and Ministry of Energy could support the programme by means of funds, manpower and training.

7.4.2 Promotion of the use of efficient energy appliances and their availability

Switching completely to cooking with clean fuels, such as LPG or biogas or electricity, is the most certain way to lower exposure to indoor air pollution dramatically and obtained maximum energy efficiency. However, the incremental costs of switching to modern and superior fuels are prohibitive for many rural households. Further, rural markets of commercial fuels are not developed. The economics of LPG service in the country, with its relatively high operating cost, is not favorable to the rural poor who cannot afford to pay for refilling a LPG cylinder every month or two. Improved biomass stoves (and cleaner biomass-based fuels) will thus continue to be an option for reducing exposure, for a large majority of the rural poor. However improvements in cooking and heating technology need to be complemented with simple housing improvements, such as kitchen configuration and ventilation conditions, which could be among most cost-effective measures to reduce exposure. Facilitating behavioral changes among women, children and other household members offers another opportunity to reduce exposure and alleviate the associated health impacts. Improving the status of women can be one of the most effective interventions to promote markets for better stoves and other household energy use services.

An effective IAP mitigation strategy should include all these options and attempt to match specific interventions (and/or their combinations) with the right segments of the market. Such a strategy should also take into account the multi-dimensional nature of household energy use and promote synergy among a variety of possible benefits, such as health, gender development, and impacts on the local and global environment. The Ministry of energy in collaboration with local Non Governmental Organisations (NGOs) and researchers interested and committed to addressing energy-poverty issues could take up the challenge of developing improved low-cost biomass cook stoves or interventions to promote ventilation in the kitchen may be appropriate.

7.4.3 Support for Skill Development and Training

Beyond technology, the public sector needs to support development of human capital related to household energy use. This applies to education generally, including sensitizing students to the IAP problem, as well as to the more specialized fields of engineering, economics, public health, environmental science and other subjects critical to research on IAP and household energy use alternatives. At a practical level, training is needed to create a pool of skilled technicians capable of properly installing and maintaining stove and ventilation systems and adapting stoves to new fuel alternatives. Another way to mobilise public interest is to improve education on issues around household cooking, especially among women. Lack of awareness of the costs and benefits associated with different fuels confounds consumer preferences, so it is important that consumers have full information regarding their choices. It is especially important that women be involved in the education process—because they are directly disadvantaged by use of traditional fuel for cooking, they stand to benefit the most from a transition to clean cooking fuel. This might be achieved through local campaigns or the organisation of groups that address these issues at a community level. Improvements in public education will hopefully bring to light the gravity of the issues.

7.4.4 Launching public mass awareness programmes

One of the most important elements of a strategy to mitigate IAP is to facilitate behavioral change, including greater demand for cleaner cooking. This requires awareness raising amongst rural families about the health impacts of traditional household energy and providing specific information on the range and effectiveness of mitigation options. Various methods – from including IAP issues in basic hygiene education by primary schools and health centers to mass media – should be utilized. Improving knowledge of the IAP problem and possible solutions among all major stakeholders, including the medical community, is as important. The awareness campaigns should provide a balanced overview of a number of options, pointing to the associated costs and benefits. Specifically, it could include the following topics:

- Different fuel options.
- Cleaner use of biomass (improved stoves, as well as improved biomass-based fuels)
- Pollutant emissions from different stove types using the same fuel (for example wick stoves are polluting but pressurized kerosene stoves which gasify kerosene are considerably cleaner) and different fuels (for example, gaseous fuels versus liquid versus solid)
- Incremental costs and benefits, including health impacts and other social benefits, of cleaner options (LPG versus kerosene and wood, kerosene versus wood, wood versus other biomass, improved biomass stoves versus traditional stoves, etc.).

7.4.5 Facilitate involvement of communities and users, especially women

At present women are managing about half of the energy systems in the Bongo district by gathering fuels. Hence, they need to be supported. Effective implementation of household energy programmes requires extensive involvement of end- users from the design stage to implementation. No central scheme – whether at the national or the state or provincial level – can do justice to what communities and individuals really need and want. Women are the mainstay of household energy programmes and it is therefore important to empower women to make choices and influence household decisions regarding the use of fuels. Activities to target women for training, capacity and skill building to use and maintain better stoves (using improved biomass, kerosene or gas), as well as for awareness raising of the detrimental impacts of traditional energy, should be strengthened. Innovative financing schemes (e.g., micro-credit) should also be explored to support local entrepreneurs, both female and male, as well as communities in the manufacturing and dissemination of stoves and other suitable technologies. It is therefore important to empower women to make choices and influence household decisions regarding the use of fuels. Activities to target women for training, capacity and skill building to use and maintain better stoves (using improved biomass, kerosene or gas), as well as for raising awareness about the detrimental impacts of traditional energy, should be strengthened.

7.5 Future Research Directions

The WHO has recognized that a fundamental flaw exists in all IAP research to date: there is no mechanism by which to draw comparisons across studies. This inability to compare research is attributed to a lack of uniformity in methods, small sample sizes, differences in the profiles of exposure determinants and local research capacity limitations (WHO, 2005). As a result, little consensus has been reached with respect to the severity of IAP and its implications for human health. This study is no exception. Like many previous studies which chose to employ real-time monitoring techniques, the sample size was relatively small. Consequently, the analysis performed in this study is largely descriptive. However, this study was designed to provide a detailed snapshot of IAP in the Bongo District, rather than to facilitate comparisons of IAP across many developing countries. Once IAP has been identified to be an issue in an area, future studies would benefit from a larger sample size. A large sample size, although very time-intensive, will ensure that issues such as variability within and across households will not prevent the identification of trends.

Despite the limitation, in the IAP monitoring, the results as related to the household energy give a reliable indication of the demand and choices for cooking energy in general in rural Ghana. It is therefore recommended that the data set be extended to cover several rural areas in Ghana and other countries so that the results can be generalized. Incorporation of other rural communities in the study should include areas with differing sizes, socio economic characteristics and different energy options so as to have a realistic representation of rural areas.

It is also suggested that a body of evidence and experience (conceptual, methodological, and case studies) be developed linking attention to gender in energy policy and projects to equitable, efficient, and sustainable outcomes in energy and development. Various case studies that highlight the drudgery of women, energy- gender nexus and valuate the time loss can be undertaken to highlight the importance of gender in energy policy and also build a body of evidence based on which the tenderized energy policy can be advocated. Further investigations are needed to establish whether interventions in improved rural energy supply in known communities have improved or worsened the welfare of households and communities. This is needed to give policy-makers the required feed back to improve on policy formulation and implementation strategies where necessary.

Also because the production and delivery of improved energy resources to rural households' is costly, future studies could investigate and find solutions to these two related questions: What is the willingness to pay (WTP) for improved energy supply (energy price) and their WTP for the infrastructure needed to make improved energy accessible (operation and maintenance). As noted by Winpenny (1994), if households and communities do not have a sense of entitlement to government services, do not feel "free energy" is their birthright, and do not have to make payments to nonlocal governments, households will be more willing to pay for improved energy supplies

Due to limited resources, daily integrated exposures, which encompass exposures in different microenvironments, could not be calculated. It is often impossible to conduct measurements in every microenvironment of exposure due to time and cost restraints. Therefore, the main consideration should be to gather data that will give the most accurate overall assessment, while limiting costs (Lawrence and Taneja, 2005). Upon this recommendation, the study sought only to determine IAP and exposure levels inside household kitchens. Future studies, with larger research budgets, would benefit by either using personal monitors and detailed time-activity diaries, or real-time monitors in multiple microenvironments and detailed time-activity diaries. Furthermore, increasing the cost efficiency of instruments will permit more researchers to use these methods. In Ghana and other countries, low-income dwellings tend to use multiple (mixed) fuels for different purposes. Reasons for multiple fuel use range from availability or accessibility of fuel to length of cooking time to the amount of financial resources available (Clean Air Group, 2004). Because multiple types of fuel are used inside a dwelling, it is difficult to determine the relative contribution of each type of fuel to IAP. In this study, all of the analyses were based upon the type of fuel used for cooking. It would be beneficial for future studies to ask households more questions concerning the type of fuel used for each household activity (which was done) and the frequency and duration of each type of fuel used (which was not done).

The data used in both the analysis of household fuel issues and IAP monitoring was collected at one point in time, which does not correctly represent seasonal changes household energy consumption issues and testing intra- and inter-household variation related to IAP. Given that limited variability in weather conditions existed during our study period, intrahousehold differences are possibly minimized. However, many studies have demonstrated large variability of biomass fuel usage and IAP within households and seasons. This finding stresses the need for future studies to take multiple measurements in each household and different season. In addition, sampling only took place during the early dry – season, which is expected to be when IAP is not really elevated. Ideally, IAP measurements taken during the rainy season would help determine "baseline" concentrations and exposure levels.

There are a number of future directions that should be the focus of any future IAP study and rural energy study in Ghana. These include:

Research into the sustainable management of woodlands. This includes exploring such issues as post-harvest management, sustainable harvesting methods and harvesting rations. It is also important to consider ways in which communities in areas where fuelwood is sourced can contribute to the management of woodland resources. This will help explore other options for sustainable supply of fuelwood to rural households thereby providing additional options for conservations of wood land resources in general.

Lastly, there is a need for a universal methodology to be established for IAP. If accomplished, future studies will be able to aggregate their data more effectively to inform future development policies.

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