Climate Change Mitigation in Southern Africa

Zambia Country Study

CEEEZ

Centre for Energy, Environment & Engineering Zambia Limited

Ministry of Environment and Natural Resources, Zambia

UNEP

**UNEP Collaborating Centre
on Energy and Environment
Risø National Laboratory
Denmark**

RISØ

January 1999

CLIMATE CHANGE MITIGATION IN SOUTHERN AFRICA

ZAMBIA COUNTRY STUDY

ISBN 87-550-2430-0

UNEP Collaborating Centre on Energy and Environment
Risø National Laboratory
P.O.Box 49
DK-4000 Roskilde
Tel: +45 46 32 22 88
Fax: +45 46 32 19 99
website: http://www.risoe.dk/sys-ucc

Contents

Foreword

This report on a climate change mitigation study of Zambia is one of a set of three country studies carried out under the Danida project "Climate Change Mitigation in Southern Africa: Phase 2". The project was initiated in 1996 in parallel with the UNEP/GEF project "Economics of Greenhouse Gas Limitations". Both projects were coordinated by the UNEP Collaborating Centre on Energy and Environment (UCCEE) at Risø National Laboratory.

The limitation of greenhouse gas (GHG) emissions is a complex issue, intimately connected with economic development at local, national, regional and global levels. Key economic sectors such as energy, agriculture, industry and forestry all produce GHGs, and are likely to be affected directly and indirectly by any mitigation policy. The UNEP Greenhouse Gas Abatement Costing Studies, initiated in 1991 and coordinated by the UNEP Collaborating Centre at Risø National Laboratory, attempted to address these complex issues, developing a methodological framework and testing it through practical application in ten countries. The results of Phase Two were published in 1994 and a third phase, extending the approach to other gases and sectors, and applying it in two countries, was completed at the end of 1995.

In 1996 the UNEP Centre launched a project entitled "Economics of GHG Limitations" comprising eight national and two regional studies in parallel with a methodological development programme. The project was financed by the Global Environment Facility (GEF) through UNEP, and the UNEP Centre was responsible for coordination of the individual studies as well as development of the methodological framework, working in close collaboration with Lawrence Berkeley National Laboratory (LBNL). The national and regional studies were carried out by centres and government agencies in the participating countries and regions. Participating countries were: Argentina, Ecuador, Estonia, Hungary, Indonesia, Mauritius, Senegal and Vietnam. The two sub-regional studies focus on the SADC (Southern African Development Community) countries in southern Africa and the Andean Group countries in South America.

In parallel with the UNEP/GEF project a number of other country studies were initiated. These comprise Botswana, Tanzania and Zambia in Southern Africa (financed by Danida), Peru (also financed by Danida) and Egypt and Jordan (financed by GEF through UNDP). Thus a total of fourteen countries, spanning the three "developing" continents, Africa, Asia and Latin America, and also including former centrally planned countries, are following a common set of assumptions and methodological guidelines, over the same time schedule, with coordinated project management and support from the UNEP Centre and LBNL.

The fourteen countries represent a wide mix of systems with respect to energy and other sectors, and in terms of level of development, rural/urban mix, availability of natural resources, etc. This diversity facilitates the broad development of methodological guidelines to treat a variety of circumstances and settings. In particular, the broadening of the analysis from simply energy, as in the early phases of mitigation studies, to treat forestry, land-use and agriculture introduces significant challenges. The Methodological Guidelines followed by the country teams are generally an extension of those developed in the UNEP GHG Abatement Costing Study. These have been enhanced and extended with respect to forestry and land-use mitigation options, macroeconomic assessment and multi-criteria assessment.

The Zambia country study was carried out by Centre for Energy, Environment & Engineering Zambia Limited, led by Professor Francis D. Yamba, on behalf of the Ministry of Environment and Natural Resources, Zambia. The work is a continuation of a preliminary study

(UCCEE (1995) carried out by the UNEP Centre and the Centres and Ministries in the region. This first phase was instrumental in establishing the background for the detailed mitigation studies of the three countries, Botswana, Tanzania and Zambia, as well as for initiating the regional study of the SADC countries which was carried out as a part of the UNEP/GEF project "Economics of GHG Limitations".

The UNEP Centre wishes to acknowledge the productive cooperation and support offered by the Ministry of Environment and Natural Resources, Zambia in the execution of this study. Thanks are also due to the Ministry of Energy and Water Affairs and its Department of Energy for close collaboration throughout this project and its predecessor, Phase 1.

Gordon A. Mackenzie
Project Manager
UNEP Collaborating Centre on Energy and Environment
Risø National Laboratory
January 1999

Project Team

Prof. Francis D. Yamba

Mr. Dominic J. Mbewe

Mr. Charles Mulenga

Mr. Oscar S. Kalumiana

Mr. Beston Chitala*

*Participated in the early stages of the project

Project Manager (UNEP Centre)

Gordon A. Mackenzie

Acknowledgements

The Centre for Energy, Environment and Engineering (Z) Ltd (CEEEZ) extends its utmost gratitude to the Danish International Development Agency (DANIDA) and United Nations Environment Programme Centre for Energy and Environment (UCCEE) for the financial support which has enabled this study on "Methodological Development, National Mitigation Analysis and Institutional Capacity Building in Zambia". CEEEZ wishes further to thank UCCEE for backstopping on the project. Special thanks go to Dr. Gordon A. Mackenzie, Project Manager, for his tireless efforts to ensure successful completion of this study. Last but not least, CEEEZ is greatly indebted to Dr. John Christensen, Dr. Henrik Meyer, Dr. John Turkson and other members of staff of the UCCEE.

CEEEZ further wishes to put on record the excellent co-operation received from colleagues from Southern Centre (Zimbabwe), EECG Consultants (Botswana), Centre for Energy, Environment, Science and Technology (CEEST) (Tanzania), and participants of the Project (Economics of Greenhouse Gas Emissions).

EXECUTIVE SUMMARY

The Zambia Country Study, which was part of the Danida-funded project Climate Change Mitigation in Southern Africa: Phase 2, aimed at methodological development, national mitigation analysis and institutional capacity building in Zambia. The study comprised the following five elements:

- Comprehensive evaluation of national social and economic development framework for climate change.
- Baseline scenario(s) projection(s)
- Mitigation scenario(s) projection(s)
- Macroeconomic assessment
- Implementation Issues

Social and Economic Development Framework for Climate Change

Under evaluation of national social trends, social conditions related to employment and health were considered. In the employment sector, as a result of the liberalisation policy put in place by Government, there was a decline in the number of employment opportunities between the years 1990 and 1995. In the health sector, between 1990 and 1995, the Government introduced Public Health Reform Programme aimed at improving the delivery of services.

Under demographic trends with specific reference to population, population was estimated at 8.2 million by 1994. The study considered various factors affecting population growth in Zambia and adopted an average growth rate of 3%. With this growth rate, the total population is expected to reach 13.2 million by the year 2010 and 24.0 million by the year 2030.

Other areas considered under this category include major land use activities. The three major land use categories in Zambia are cropland, forest reserves and national parks. Forest reserves and national parks cover about 10% and 8% of the country, respectively, and are managed by the Forest Department and the National Parks and Wildlife Services, respectively

The major uses of forests in Zambia are agriculture, woodfuel and timber harvesting. Out of a total land area of 753,000 km^2, land potentially available for agriculture is 420,174 km^2, which is 55.8% of total land area. However, land area suitable for crop production is 250,000 km^2, which is 33% of the total land area. While land currently utilised for crop production ranges between 110,000 to 150,000 km^2 constituting between 15 to 20% of the total land area cover.

Main national economic development trends included basic statistics on GDP structure and overall sectoral performance. The Zambian economy is categorised by mining, manufacturing industry, agriculture and transport. Copper mining and it’s export contributed 8% and 7% to GDP in 1990 and 1991, respectively. Despite this increase, efforts and measures have been put in place by Government to resuscitate the mining industry. Manufacturing sector experienced a decline in GDP performance between 1990 and 1995 as a result of liberalisation policies put in place by Government and the relatively shorter time available for existing companies in the country to adjust. However, the sector’s performance is likely to improve as a result of Government policy on privatisation of parastatal companies, since the new owners of such companies will endeavour to put more investments in their operations.

Agriculture plays an important role in the GDP structure in Zambia like other sectors. Agriculture has also passed through turbulent times resulting in fluctuation of GDP between the years 1990 and 1995. To stop this decline the Government has put in measures particularly the Agricultural Sector Investment Programme (ASIP) aimed at improving the performance of the sector.

Baseline Scenario Development

One of the main objectives of the study was to develop baseline scenarios in energy and forestry sectors. The main elements considered under baseline scenarios in the energy sector were energy demand and CO_2 emissions projections. To determine these parameters, the following assumptions were taken into consideration: population and household energy; household energy mix; economic activities measured in GDP; energy intensity; energy policy and; fuel prices. Together with these assumptions, energy demand and CO_2 emissions projections were calculated using the Long-Range Energy Alternatives Planning (LEAP) system. Another model used in the study is the Greenhouse Gas Abatement Costing Model (GACMO) which was specifically used to determine the cost of implementation of mitigation options on an individual basis.

Results of energy consumption projections by sector under baseline are shown in Table 1.

Table 1 Energy consumption projections (baseline) (million GJ)

YEAR	Household	Industry / Commerce	Govt. Service	Agricul-ture	Mining	Transport	Total
1995	131.25	21.51	3.99	5.21	23.23	13.1	198.29
2010	195.2	47.15	7.49	9.01	43.01	20.75	322.61
2030	330.8	147.21	18.9	18.71	97.81	40.39	653.1

The total energy demand under baseline is expected to increase from 198.29 million GJ to 322.61 million GJ by 2010 and 653.10 million GJ by 2030. The largest contribution came from household (50.70%) followed by industry/commerce (22.50) and mining 14.98.

Results for emission projections from energy, industrial processes, and land-use change activities are shown on Table 2.

Table 2 Emission projections from energy, industrial processes and land-use change activities (tonnes CO_2) (baseline)

SECTOR	1995	2010	2030
Energy	2,133,190	4,190,550	10,502,190
Industrial Processes	297,636	535,745	1,174,472
Land-use Activities			
i) On-site burning	53,829,140	94,624,370	200,792,360
ii) Off-site burning	14,892,140	20,013,800	36,147,150
iii) On-site decay	5,486,670	8,501,110	15,954,500

iv) Sub-total	74,208,670	123,139,280	252,894,010
Total	76,639,496	127,865,575	264,570,672

It is clear from the results above that CO_2 as GHG arises predominantly from energy and industrial processes since emissions from land-use activities are more or less compensated by sinks as shown on Table 3 for final budget emissions and sinks.

Table 3 Projected GHG budget (tonnes CO_2)

Source	1995	2010	2030
Emissions	76,639,496	127,865,575	264,570,672
Sinks	74,087,480	126,888,750	262,240,530
Balance	-2,552,016	- 976,825	- 2,330,142

Regrowth natural forests regenerating after forest clearing and/or abandonment of managed cultivated land (follow) and re-forestation plantations are the major carbon sinks in Zambia. The projections for sinks are based on forest land clearing (shifting cultivation and permanent agriculture, charcoal production, commercial firewood and timber harvesting estimated at 3.82%, 40%, 2.4% and 1.0% respectively.)

Mitigation Scenario

Energy Sector

Mitigation analysis in the energy sector considered five economic sectors namely: households, mining, industry, transport and government service. The mitigation options considered in the household sector included energy substitution and efficiency of cooking appliances. In the industrial sector, the options of partial replacement of coal, diesel and fuel based boilers with electric were considered. Under transport and government/service, use of ethanol-gasoline blend in petrol-propelled motor vehicles and improved maintenance of motor vehicles options respectively, were considered.

The energy demand for the year 1995 and the projections for the years 2010 and 2030 under the baseline and mitigation scenarios, respectively are shown in Table 4.

Table 4 Total energy demand under baseline and mitigation (million GJ)

	1995	2010	2030
Baseline	198.29	322.61	653.11
Mitigation	198.29	297.07	579.23
% Reduction		7.92	11.3

The total energy demand under the baseline is expected to increase form 198.29 million GJ to 322.61 million GJ by 2010 and 653.11 million GJ by 2030. Under mitigation, the increase is expected to rise from 198.29 million GJ in 1995 to 297.07 million GJ by 2010 and 579.23 million GJ by 2030 thereby giving a reduction of 7.9% and 11.3% in 2010 and 2030 respectively.

Total biogenic and non-biogenic emissions under baseline and mitigation scenarios for the year 1995 and projections into the years 2010 and 2030 are shown in Table 5.

Table 5 Total biogenic and non-biogenic emissions 1995, 2010, 2030 (million tonnes CO_2), (baseline and mitigation)

	1995		2010			2030		
Source	Base	Miti gation	Base	Miti gation	% Red.	Base	Miti-gation	% Red.
Biogenic Non-biogenic								
Total	17.02	17.02	26.46	23.16	12.47	48.45	39.6	18.27

Under baseline scenario, CO_2 emissions from all the sectors considered increase from 17.02 million tonnes in 1995 to 26.45 and 48.47 million tonnes for the years 2010 and 2030 respectively. Whereas under mitigation scenario, CO_2 emissions increased from 17.02 million tonnes in 1995 to only 23.16 and 39.6 million tonnes for the years 2010 and 2030, respectively, giving a reduction of 12.47% in 2010 and 18.27% in 2030.

Using the GACMO, individual reduction and cost assessment of all mitigation options identified were analysed.

Mitigation options and associated emissions reduction and cost of reduction are shown in Table 6.

Table 6 Mitigation options, emissions reductions and cost of reduction (2010 and 2030).

Option	Emission reduction (tonnes CO_2) 2010	2030	Cost of reduction US$ / tonne CO_2
1. Improved motor Vehicle maintenance			
(i) Petrol	8,400	20,000	- 1,126.55
(ii) Diesel	5,400	10,000	- 473.79
2. Ethanol blend	71,240	120,000	- 97.04
3. Use of improved charcoal stove	460,000	760,000	- 29.11
4. Use of coal briquette stove	40,000	60,000	- 11.97
5. Use of electric stove	1,850,000	4,810,000	- 10.55
6. Replacement of boiler with electric ones			
(i) Fuel oil	220,000	110,000	- 3.87
(ii) Diesel	100,000	50,000	- 12.16
(iii) Coal boiler	80,000	40,000	14.74
7. Cement production	50,000	110,000	9.14
TOTAL	2,885,040	6,090,000	

The total emission reduction for all the options amounted to 2.89 million tonnes in 2010 and million tonnes in 2030. It is evident from the results that most of the options in the Zambian scenario have negative costs with an exception of cement production and replacement of boiler with coal. This scenario puts Zambia in a well-placed position to positively contribute to abatement of CO_2 emissions through implementation of relatively lower cost options.

Forestry Sector

Baseline development in the forestry sector, considered the following scenario assumptions: forest land clearing for commercial firewood; cutting natural wood for timber harvesting, charcoal production and forest for shifting and permanent agriculture.

The results of biomass pool balance arising from land clearing and regeneration are shown in Table 7.

Table 7 Biomass pool from deforestation and regeneration 1995, 2010, 2030 ('000 tonnes)

	1995	2010	2030
Regeneration	43,038.14	73,626.55	130,060
Land clearing	60,255	82,210	134,090
Balance	- 17,216.86	- 9,583.45	- 4,030

It is evident from the results that although forest land clearing is high, its net reduction on woody Biomass stock is low due to natural regeneration. Despite the high rate of biomass growth under natural regeneration, there is a moderate proportion of biomass loss as shown on Table 6

Mitigation options considered to reduce the resulting deforestation included maintaining existing stocks and expanding carbon sinks. With the help of the Comprehensive Mitigation Analysis Process (COMAP), biomass (carbon stock) and biomass supply and demand for the years 1990, 2010 and 2030 were determined. Also determined was the cost of saving of one tonne of CO_2 and investment cost per hectare.

Under baseline scenario, results indicate that there is a decline in forest land area from 55.0 million hectares in 1995 to about 50.0 million and 47.0 million hectares in the years 2010 and 2030, respectively. However, with implementation of the considered mitigation options, the trend is reversed with a positive increase in forest land cover from 55.0 million hectares in the year 1995 to 67.0 million hectares in the year 2030.

The results of ranking of forestry mitigation options based on costing of saving 1 tonne of CO_2 and investment cost per hectare are shown in Table 8.

Table 8 Ranking of forest mitigation options

Mitigation Option	Cost of saving 1 tonne of CO_2 US$	Investment Cost per Hectare US$
Forest Protection	0.50	92.0
Natural Regeneration	- 0.04	7.0
Re-forestation	3.40	160

From the result, national regeneration presents the most lost effective and most sustainable approach to increasing the forest cover.

Macroeconomic Assessment

The macroeconomic impact assessment of the projects recommended for implementation was undertaken as part of sustainable development and greenhouse gas limitation strategies for Zambia.

The macroeconomic assessment considered qualitative assessment of macroeconomic impacts of considered mitigation options relating to employment, savings on consumption, health aspects, improvement of social conditions, foreign exchange savings, export, competitiveness and internal savings.

Projects with high employment prospects included ethanol and cement production, whilst household energy projects particularly use of electric stove, and use of electric boilers ranked high on health improvement due to reduced internal pollution and exposure.

In addition, ethanol production had a stronger base in improving social conditions and foreign exchange savings. On the other hand, use of improved charcoal and coal briquette stoves, and cement production had low ranking on health aspects.

Implementation Issues

Implementation of identified projects both in the energy and forest sectors requires investments. Estimated total investment cost for the identified projects are given as slightly over US $500 million. Although most of the options have negative costs and the UNFCCC framework is expected to be implemented internally, the economic setting in the country precluded this development. Therefore, lack of financial resources for project implementation, and for low income earner's to afford purchase of electric stoves despite ZESCO'S rural and peri-urban electrification programme.

To address some of these issues, some of the proposals include:

- Provision of financial resources to up coming entrepreneurs for implementation of projects in the energy sector.
- Provision of financial support to Government to implement forest based protection programme.
- Formulation of a financing recovery scheme to assist low-income earners purchase introduced efficient and improved cooking stoves.

1 Introduction

1.1 Country Background

Zambia is situated in Southern Africa with a land area of 750,000 square kilometres and a population of over 8 million people. According to the Central Statistical Office, Zambia's population grew from 4.1 million in 1969 to 5.7 million in 1980. The Census of population and housing for 1990 put the total number of people at 7.8 million.

1.2 Project Background

The present projects follows earlier Zambian climate change studies which addressed the greenhouse gas emission inventory and the potential for emission reductions and sink enhancement. The mitigation analysis builds particularly on the results of the Zambia country study programme that was supported by the German Government through the German Technical Assistance (GTZ). The first phase of the GTZ financed project was aimed at the establishment of greenhouse gas emissions (GHG) inventories and mitigation options. The GTZ (1995) study established that CO_2 from the combustion of liquid fuels makes a significant contribution (3.4 million tonnes) to Zambia's GHG emissions. Mitigation options were identified with the abundant hydroelectricity forming the basis for selecting the options. Options identified include electrification of households to substitute electricity for charcoal stoves, introduction of coal briquettes, production of more efficient charcoal stoves and improved traditional kilns for the households sector, and energy substitution and conservation in industries.

The present project has the triple objective of enhancing the mitigation analysis through more detailed assessment of the potential and costs of mitigation options within an integrated analytical framework, enhancing the capacity in Zambia for such analysis, and contributing to the development of methodological framework through collaboration in the wider multi-country and regional project coordinated by the UNEP Centre. In particular the regional collaboration, with teams from Botswana and Tanzania, contributes to increasing the comparability of the analyses.

1.3 Scope of Work

The study ran for a period of 2 years and addressed the following issues:

1) Assessment of present main GHG emissions related to physical sources and economic sectors, and projection of these according to a baseline scenario linked to long-term national development plans and goals. Existing GHG inventories will be evaluated and steps taken to enhance these if necessary.

2) Identification of options for abatement of GHG emissions, concentrating on major emitting sectors. Assessment of costs and implementation conditions for these options, and broader financial and legislative policy aspects related to climate change mitigation.

3) Evaluation of mitigation options in the context of social, industrial and economic development.

4) Institutional capacity building both in Zambia and the region through the exchange of information and results through participatory approach, workshops and seminars, and national awareness enhancement.

1.4 Framework for Climate Change

1.4.1 Description

Zambia, like many other countries, made a commitment at the Rio Summit of June 1992 aimed at contributing to the global reduction of greenhouse gases emissions as a way of promoting sustainable development. This commitment to the United Nations Framework Convention on Climate Change (UNFCCC) entailed undertaking studies to establish the emission levels in the country. The first phase of the project financially supported by the German government through the GTZ successfully carried out a study to identify and quantify greenhouse gas emissions and abatement options. The study, therefore, established an inventory of greenhouse gases (GHG) emissions in Zambia and identified technological options for reducing the emissions. These studies are part of Zambia's effort to fulfil its obligation under the UNFCCC to develop a national communication.

1.5 Overview of Climate Change Studies, Impact, Inventory and Mitigation

1.5.1 Climate Change Mitigation In Southern Africa: Phase 1

The UNEP Collaborating Centre on Energy and Environment undertook the study "Climate Change Mitigation in Southern Africa, Phase 1" (UCCEE 1995) in collaboration with centres and ministries in the region. These comprised: Botswana (Ministry of Mineral Resources and Water Affairs, and EECG Consultants); Tanzania (Ministry of Energy, Minerals and Water Affairs, and the Centre for Energy, Environment, Science and Technology); Zambia (Ministry of Energy and Water Development, and the Centre for Energy, Environment and Engineering Zambia Limited); and Zimbabwe (Ministry of Transport and Energy, and the Southern Centre for Energy and Environment).

The work was supported by the Danish International Development Agency (Danida) through the UNEP Collaborating Centre on Energy and Environment. The study focused on the economy, overview of the institutional set up for national planning related to environment, organisation overview of the existing climate change activities, review of existing studies and plans on climate change, energy supply and demand, and environmental issues in major sectors of the economy and mitigation.

1.5.2 Zambia Country Study on Climate Change

A multi-disciplinary project team was constituted to carry out the climate change study. The project was funded by the GTZ to enable Zambia fulfil its commitment to the UNFCCC. As a result of the study, GHG emission inventories were compiled as input and contribution to the preparation of the national communication for Zambia. The communication would in turn set the stage for a national information database on Zambia's contribution to GHG emissions. The study further identified a number of climate change mitigation options falling under two broad categories (1) supply-side options and (2) demand-side options.

1.5.3 Activities on GHG Emissions, Inventory, Vulnerability, Mitigation and Adaptation

This study was carried out under the auspices of the Environmental Council of Zambia (ECZ) with financial support from the United States Country Studies Programme (USCSP). The study undertook some activities on GHG emissions inventory, vulnerability assessment and evaluation options. A series of models for predicting adaptation and vulnerability scenarios were adopted. Results of emissions inventory have been reviewed, while data on vulnerability and mitigation assessments have also been analyzed and sectional trends identified. This project was also designed to enhance capacity building through training of the Zambian personnel who had input in the study.

1.5.4 Aggregate GHG Inventory

In 1990 Zambia contributed 3.2 million tonnes of CO_2 to the atmosphere or about 1% of Africa's total emissions. Approximately 88% of these emissions were attributable to energy use. Industrial processes, mainly cement and lime production and use, accounted for 12% of CO_2 emissions. In the energy sector transportation contributed 29.5% of total CO_2 emissions followed by mining with 15.8%.

Biomass fuels, waste and agriculture were the major sources of CH_4. In 1990 a total of 457,000 tonnes of CH_4 were emitted into the atmosphere. Agriculture predominantly through enteric fermentation contributed 20% followed by biomass burning and waste with 16.5% and 10% respectively.

Total N_2O emissions mainly from agriculture amounted to 3,570 tonnes. Under land use change and forestry a total of 59.4 million tonnes of CO_2 were released through forest clearing, biomass decay and on site burning.

However, in view of regrowth of natural forests after forest clearing and/or abandonment of cultivated lands (fallow) and reforestation plantations, which act as the main carbon sinks, there was in Zambia, in 1990, a net balance of 60 million tonnes of CO_2 out of all emissions.

The total emissions per capita in 1990 were 2.5 tonnes and per unit GDP were 0.0015 tonnes per Zambian Kwacha (0.078 tonnes per US$).

1.6 Evaluation of National Social and Demographic Trends

1.6.1 Social Conditions

a) Employment

The Zambian economy has been declining for several years and this has resulted in the closure of several companies. The advent of plural politics brought about economic policies which where viewed as necessary to resuscitate the ailing economy. As a consequence, the new economic conditions introduced in 1992 have continued to negatively impact on employment opportunities. In 1991 the formal sector employed more than 544,000 people (Sikabanze, 1996). The number of persons in employment had fallen to 495,000 (Sikabanze, 1996) by 1994 representing an actual drop of 8%. The new economic order has affected employment levels in the country mainly due to closures of many ailing companies and consequent re-trenchment of personnel and redundancies. During the same period a total number of 6,528 people (Sikabanze, 1996) were made redundant by 250 companies (Sikabanze, 1996). In 1995 more than 6900 (Sikabanze, 1996) were retrenched.

In the Zambian Government's opinion, too many people are employed in the civil service and steps are being taken to reduce the number from the present 300,000. The Government has established the Public Service Reform Programme (PSRP) in order to restructure the civil service to reduce the number of employees.

Employment figures show a steady growth between 1990 and 1992. As mentioned above, the coming of the new government in 1991 came with new economic policies that were aimed at reviving the economy. As can be seen from the data in Table 1.1 the employment figures started falling due to the above mentioned factors. The trend is not unique to one sector but common to all as can be clearly seen.

Table 1.1 Employment trends in the formal sector

Employment (Formal Sector)	**1990**	**1991**	**1992**	**1993**	**1994**
Total Employment ('000) of which	543.3	544.2	546.0	526.4	495.5
Agriculture, Forestry and Fisheries	79.8	77.7	82.0	82.8	78.3
Mining and Quarrying	64.7	64.8	62.1	58.2	51.2
Manufacturing	77.1	75.4	73.6	67.6	57.1
Electricity and Water	7.1	7.6	8.4	5.7	5.1
Construction and Allied repairs	33.4	33.1	27.8	22.1	17.5
Distribution, Restaurants and Hotels	55.1	55.2	51.3	49.3	49.6
Transport and Communication	33.8	34.4	31.0	29.0	29.0
Finance, Insurance, Real Estate and Business services	32.9	35.8	39.0	37.0	33.8
Community, Social & Personal Services	159.4	182.2	170.7	168.3	173.9
Redundancies	3	4	6	5	9
Source: CSO (1995)					

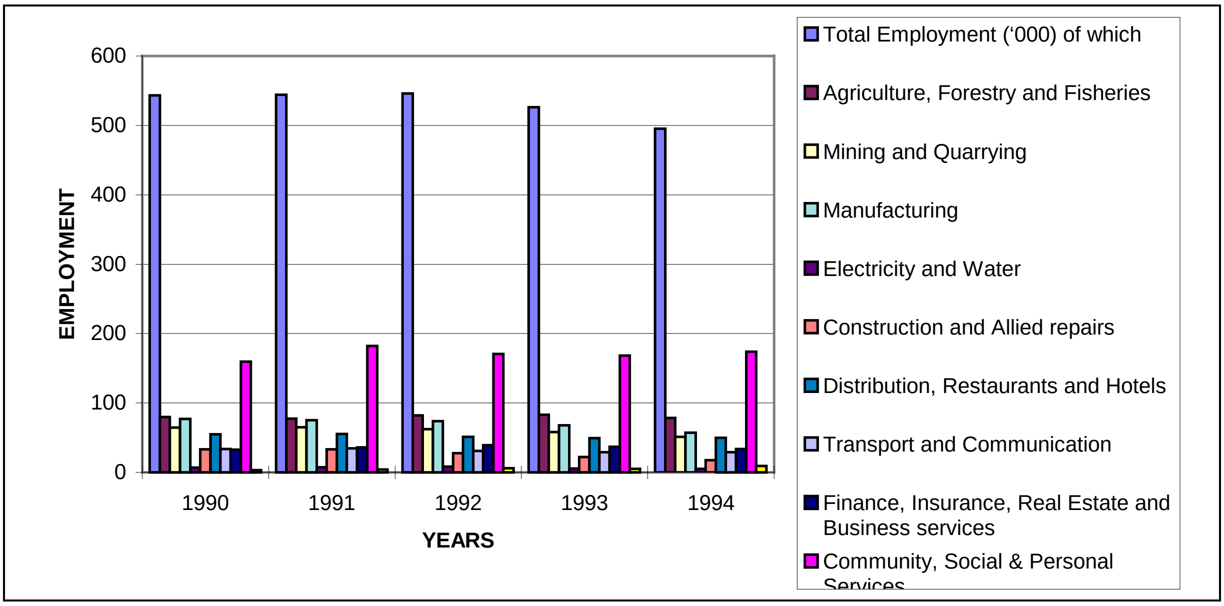


Figure 1.1 Employment trends in the formal sector

b) Health

In the post independence years, the country experienced some improvement in the health services. The now run-down health services have greatly contributed to high mortality rates. Infant mortality is worsening. Mortality among the middle age group, the productive group, is similarly worsening and is largely attributed to the impact of AIDS.

The economic malaise affecting the country has had a negative impact on virtually all sectors of the economy. The health sector has not been spared. Health facilities and infrastructure are rundown and in poor state. The health sector makes minimal direct contribution to the national economy. With the adoption of the Economic and Structural Adjustment Programme, the Ministry of Health introduced user fees, which were aimed at improving the run-down health sector. In the past, the health sector has been neglected to the point where the sector lacked proper management. The reason for establishing the health reform programme is to try to decentralise the running of the health sector to districts in order to improve the management and operation of the sector. If the health reform programme is well implemented and managed there are opportunities that the health sector will become more responsive and efficient.

In addition, the Government, in conjunction with the UNDP, initiated the Country Strategy Note as an intervention measure aimed at stemming or abating infant mortality.

1.6.2 Demographic Trends with Specific Reference to Population

According to CSO (1990) census figures, Zambia's population rose from 3.4 million in 1969 to 7.3 million in 1990. This shows that the current population growth rate has a potential to double in a period of twenty years. In the 1980s the population growth rate averaged 3.4% per annum while it has been estimated to grow at 2.8% in the 1990s. However, the 1990s estimated growth rate is a subject of discussion among demographers some of whom do not agree with the 2.8% (Sikabanze, 1996). Some demographers argue that the estimated 2.8% is an underestimate and that the realistic growth rate for the 1990s should be about 3.1%. Taking into consideration the high growth rate, the population is estimated at 8.2 million by 1994 and projected at 13.2 million by 2010 (Sikabanze, 1996). By this figure it is clear that the population will have nearly doubled in 2010 from the 1990 population of 7.3 million people. These projections take into account mortality and birth rates.

Indications from the birth rate statistics for Zambia are that the fertility rate is quite high with 6-7 children per woman. In the same vein, population projections show that the population will grow at an annual rate of 3.1% between 1990 and 2000. The population is projected to grow at 3% between 2000 and 2005. Projections indicate that by the year 2000 the rural population would have reached 42% of the expected total population. The total population is expected to reach 11.5 million by the year 2005, 13.2 million by the year 2010 and 16.5 million by the 2015, respectively. It is further projected that the population will reach 24 million by the year 2030.

Table 1.2 Population projections for the period 1994 - 2030

Year	Under 15	15 - 49	50 - 59	60+	Total	Under 15 as %
Actual (1990)	3,349,672	3,393,786	333,275	306,355	7,383,088	45.3
1994	3,613,172	3,944,348	333,363	332,697	8,259,753	43.7
1995	3,718,592	4,085,268	378,704	342,928	8,525,492	43.6
1996	3,844,718	4,223,559	386,717	348,634	8,803,628	43.7
1997	3,964,446	4,363,855	395,536	358,751	9,082,586	43.6
1998	4,081,171	4,504,474	404,876	372,268	9,362,786	43.6
1999	4,199,605	4,643,003	414,253	387,898	9,644,761	43.5
2000	4,322,357	4,778,434	423,467	404,843	9,929,101	43.5
2001	4,482,725	4,907,014	430,767	414,510	10,235,016	43.8
2002	4,651,664	5,033,469	438,292	424,352	10,547,779	44.1
2003	4,825,032	5,160,454	447,031	434,887	10,867,405	44.4
2004	4,996,246	5,292,267	458,514	446,802	11,193,830	44.6
2005	5,160,821	5,432,103	473,691	460,186	11,526,801	44.8
2006	5,329,093	5,575,026	490,250	467,098	11,861,464	44.9
2007	5,841,320	5,726,504	510,645	478,742	12,197,211	44.9
2008	5,618,356	5,886,871	534,485	494,044	12,533,756	44.8
2009	5,741,951	6,056,270	561,112	511,539	12,870,872	44.6
2010	5,852,964	6,234,874	590,063	530,463	13,208,364	44.3
2015					16,500,000	
2030					24,000,000	
Source: CSO (1995)						

Population in the urban areas has grown from the 1969 low of 29% to a high of more than 40% in 1990. In addition, Zambia's population structure indicates that well over 40% of the total population is under the age of 15. As can be seen from Table 1.2, Zambia's population is predominantly young. The population trend is expected to remain essentially unchanged up to the year 2010. Figure 1.2 below shows the population projection as discussed above.

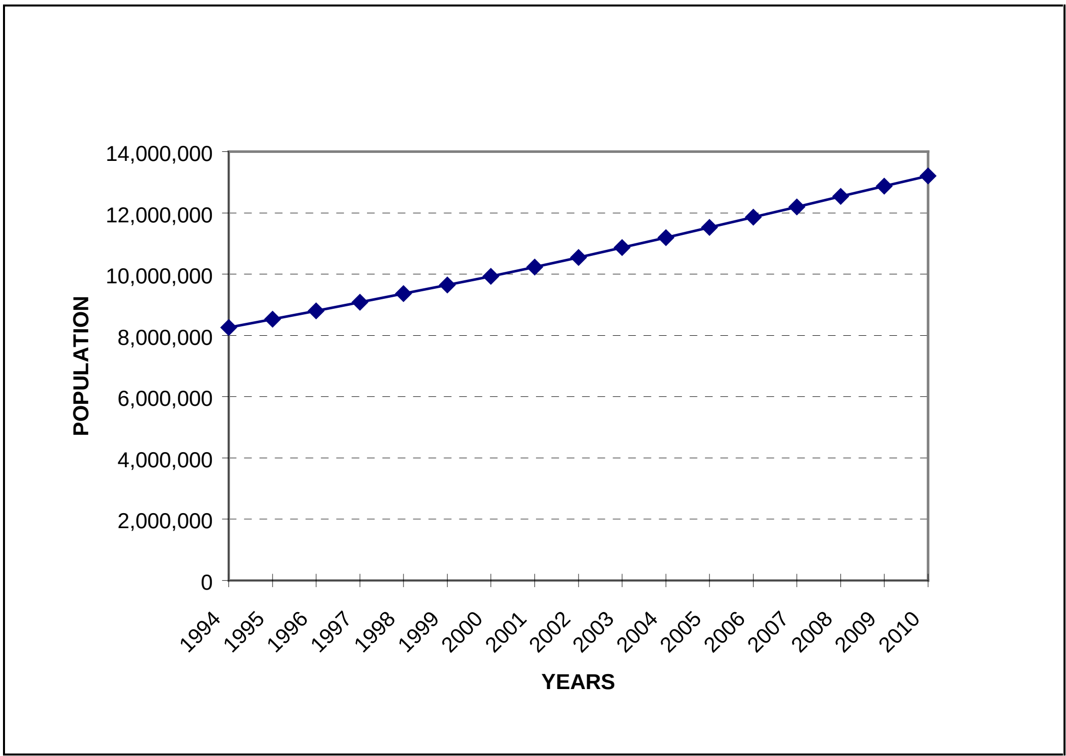


Figure 1.2. Population projections for the period 1994 - 2010

1.7 Major Land Use Activities

1.7.1 Major Uses of Land

The three major land use categories in Zambia are cropland, forest reserves and national parks. Forest reserves and national parks cover about 10% and 8% of the country, respectively, and are managed by the Forest Department and the National Parks and Wildlife Services (GTZ, 1995).

The major uses of forests in Zambia are agriculture, woodfuel and timber harvesting. Out of a total land area of 753,000 km^2 , land potentially available for agriculture is 420,174 km^2, which is 55.8% of total land area. However, land area suitable for crop production is 250,000 km^2, which is 33% of the total land area. While land currently utilised for crop production ranges between 110,000 to 150,000 km^2 constituting between 15 to 20% of the total land area cover (GTZ, 1995).

In agriculture, one of the major contributors to deforestation is a system of land clearing called chitemene or shifting cultivation practised in Luapula and Northern Provinces of Zambia. This involves the slashing and burning of tree offshoots harvested from a large area on a small plot to neutralise and fertilise the soil for crop production. Currently, average woodland clearing for chitemene is estimated at 4.15 hectares per household culminating in an estimated annual deforestation of 0.60 million hectares (Kalumiana, 1994).

Woodfuel and charcoal are the main sources of energy for rural and urban areas, respectively. Charcoal was introduced on the Copperbelt in 1947, and has since become a major urban household fuel in Zambia. The charcoal is made in earth kiln (Chidumayo and Chidumayo, 1984). Trees are selectively or clear-cut with axes at about knee height and cross-cut into 1 - 2 metre billets while the brush wood is abandoned at the spot of the tree fall or piled and later burnt. The kiln is made by piling layers of billets crosswise or stringers up to a height of 1.5 - 3.0 metre and covered with a soil layer of 40 - 45 centimetre thickness on the sides and 20 - 25 centimetre on top. The kiln is ignited through a hole at the base, which is later sealed with soil after partial combustion has started. During carbonisation the kiln temperature may reach between 500 -700°C. This method of charcoal production is 23% efficient on oven-dry weight basis. In 1990, at least 40,000 hectares were cleared for urban woodfuel and most deforestation occurs in both forest reserves and unprotected areas. This type of deforestation does not affect forests in national parks because these are preserved for wildlife conservation.

Timber harvesting is also another major use of forests in Zambia. Although valuable indigenous timber species are very few, indigenous hard woods are used for various subsistence and commercial purposes.

Table 1.3 shows the area of various land uses in Zambia from 1990 to 1994. From the land area in the table it is clearly shown that there has been no increase over this period. A possible explanation for this is that there has been little activity on land due to the poor state of the economy in the last few years. It is also noticeable that there has been no major change in agricultural area mainly due to the absence of incentives that would otherwise encourage people to expand their agricultural land. It can also be stated that there has been no new investment to encourage further expansion of activities. There has been an absence of capitalisation in the sector which has led to very little in terms of land use activities as manifested by the stagnation in the land use changes in the expansion of areas under permanent crops.

It is also seen that the area under land use involving permanent crops has remained unchanged from 1990 until 1994 for obvious economic reasons already mentioned above. However, there was marginal increase in the agriculture area by 5,000 hectares over the 1991 figure of 35,268,000 ha to 35,273,000 ha. The increase in arable land during the same period was insignificant. There was more than 50% increase in the area under irrigated agriculture due to the increase in the expansion of irrigation schemes involving maize, rice and wheat crops. Marginal increases in land use in specific areas after 1991 could be linked to new policies that have tended to encourage particular activities.

Table 1.3 Land Use Area (10^3 ha.)

Land Use	**1990**	**1991**	**1992**	**1993**	**1994**
Land area	74339	74339	74339	74339	74339
Agriculture area	35268	35268	35273	35273	-
Arable land	5260	5260	5265	5265	-
Permanent crops	8	8	8	8	-
Permanent pasture	30000	30000	30000	30000	-
Forest and woodland	28850	28780	28700	28700	-
Irrigated agriculture	30	30	46	46	-
Other land	39071	39071	39066	39066	-
Total Area	75261	75261	75261	75261	75261

Source: Ministry of Agriculture Food and Fisheries (1995)

Deforestation resulting from various forest-clearing activities is shown in Table 1.4. It has been assumed that the area cleared will increase from 1990 up to the year 2030 at an average rate of 3.1%. The area cleared for forest clearing types has been projected to decline at the same rate within the period of the study.

Table 1.4 Deforestation due to forest clearing

Forest Clearing Type	**Area cleared (10^3 ha /yr.)**			
	1990	**1995**	**2010**	**2030**
Shifting cultivation	593	687.65	1086.41	1959.38
Permanent cultivation	234	271.2	428.56	772.91
Charcoal production	55	63.73	100.6	181.63
Logging in plantations	0	0	0	0
Selective timber cutting	192	226.58	337.99	645.75
Commercial firewood cutting	14	16.08	26.83	48.31
Total	1191	1368.24	2083.39	3710.98

Source: GTZ/MEWD (1995)

1.7.2 Land Cover and Potential

Distribution of land cover in Zambia is characterised by natural forests, woodlands, grasslands and lakes as shown in Table 1.5 below.

Table 1.5 Land cover in Zambia (10^6 ha.)

Distribution	**Forest cover**	**National parks**	**Unprotected area**	**Potential extent**	**Cropland and fallow**	**Actual**
Forest	0.58	0.30	3.80	4.68	0.68	4.16
Miombo woodland	5.47	3.10	34.99	39.29	13.55	25.85
Savannah Woodland	0.40	1.30	7.49	9.22	0.34	8.88
Grassland	0.94	1.21	18.53	20.68	1.43	19.25
Natural lakes		0.66	0.66		0.00	0.66
Man-made lakes		0.83	0.83	0.63	0.00	0.63

Source: Based on 1:500,000 Vegetation Map of Zambia (Edmonds, 1976; Schultz, 1974; Adeyoju, 1991; Chidumayo, 1994).

Natural forests cover 4.68 million hectares and are divided into dry evergreen, dry deciduous and montane. In addition to natural forests, the Government established plantation forests which cover about 0.061 million hectares of which 90% are on the Copperbelt under the management of Zambia Forest and Forest Industries Corporation (ZAFFICO). The remainder is scattered through the country.

Woodlands are divided into miombo and savannah. Grassland in Zambia is predominantly confined to areas of poor drainage, such as swamps and flood plains. These cover 20.68 million hectares whilst lakes have a coverage of 1.29 million hectares.

Given in Table 1.6 is estimated standing stock and mean annual increment (MAI) in Zambian forests and woods for 1990. The standing stock is estimated at 3 billion tonnes (dry mass) out of which 1-3% is MAI or annual sustainable production giving an estimated 90 million tonnes (dry mass).

Table 1.6 Estimated standing stock and mean annual increment in forests and woodlands

Forest/Woodland type		Standing Stock (million tonnes)	Mean Annual Increment (million tonnes
Deciduous Woodland	Wet miombo	1,810.5	56.6
	Dry miombo & munga	133.0	3.9
	Seasonal miombo	247.8	6.1
	Degraded miombo	69.8	2.2
	Mopane	271.2	8.0
	Kalahari	369.6	11.1
	Dry Evergreen/ Montane/Riparian	50.1	1.3
Evergreen forest	Swamp/Lake Vegetation	0.0	0.0
Termitaria		22.9	0.8
Total		2,974.9	90

Source: Kalumiana, Unpublished

1.8 Main National Economic Development Trends

1.8.1 Basic Statistics on GDP Structure

The Zambian economy has been going through a very turbulent phase for a period of more than 15 years. The economy has experienced negative growth rates in successive years since 1991 with the exception of 1993 when a positive 6.5% GDP growth was achieved. The GDP in constant 1977 prices is estimated to have declined by 2.9%, 3.1% and 3.9% in 1992, 1994 and 1995, respectively. Economic experts estimate that the GDP will grow at a rate of 5% per annum from 1996 onward. This may not be attainable. For real economic growth to be achieved, the GDP growth must at least average the population growth, which currently stands at between 3.1% per annum. Given the prevailing economic scenario and other factors in the economy maintaining the status quo, it is in this study estimated that the most realistic growth rate attainable is 4%.

Table 1.7 below shows the relative performance of various economic sectors in terms of their contribution to the Gross Domestic Product. In 1991 the agricultural sector contributed a net K407 million to the GDP which in nominal terms accounted for 18.4%.The manufacturing sector made by far the largest contribution to the sector accounting for more than one quarter of total GDP contributing 26.4% or K584 million. Community, social and personal services contributed K388 million, which amounted to 17.5% of the total GDP. In 1991 the GDP growth did not register any nominal growth of the economy. The performance of all sectors in 1991 varied between 0.8% and 26.4%. Only three sectors registered 2-digit contribution rates to the GDP while the rest of the sectors only managed single digit rates.

The performance of all the sectors in 1991 was poor in general terms owing to the fact that the economy was significantly in bad shape as a result of the decline of previous years. In 1992, the agriculture sector contribution to the GDP was comparatively better growing by more than 65% over the 1991 figures. The actual contribution of the agriculture sector to the GDP in 1992 was K672 million, which accounted for 26.3% of the total GDP. Some reasons for this performance could have been due to the new enabling economic policies just introduced by the government and well as possible favourable climatic factors. In 1992 the manufacturing sector recorded a 2-digit contribution to the GDP except that the contribution in percentage terms was about 1% less than the 1991 figure. The figures of the agriculture sector performance in terms of its contribution to the GDP indicate that between 1991 and 1995 the sector only showed improved performance in 1992. There has been noticeable decline in contribution of various sectors to the GDP. Electricity, water and gas have exhibited steady performance with a decline in 1992 from the 1991 level. Neither financial institutions nor the transport sector have performed well in the last couple of years due to closures and divestiture of public investments. The overall decline in GDP performance is shown on Figure 1.3.

Table 1.7 GDP by kind of economic activity in constant 1977 prices (million Kwacha)

	1991		1992		1993		1994		1995	
GDP	**K mil.**	**%**	**K mil.**	**%**	**K mil.**	**%**	**K mil.**	**%**	**K mil.**	**%**
Agriculture, Forestry and Fishing	407	18.4	672	26.3	458	19.9	489	21.9	434	20.3
Mining and Quarrying	148	6.7	167	6.5	152	6.6	127	5.7	118	5.5
Manufacturing	584	26.4	657	25.7	605	26.3	551	24.7	526	24.6
Electricity, Gas and Water	64	2.9	61	2.4	63	2.7	65	2.9	65	3.0
Construction	62	2.8	59	2.3	45	2.0	39	1.8	34	1.6
Wholesale and Retail Trade	178	8.0	166	6.5	184	8.0	176	7.9	161	7.5
Restaurant and Hotels	49	2.2	79	3.1	76	3.3	67	3.0	66	3.1
Transport, Storage and Communication	97	4.4	85	3.3	81	3.5	74	3.3	82	3.8
Financial Institutions and Insurance	55	2.5	52	2.0	54	2.3	51	2.3	55	2.6
Real Estate and Business Services	178	8.0	186	7.3	192	8.4	197	8.8	204	9.5
Community, Social & Personal Services	388	17.5	385	15.0	391	17.0	399	17.9	408	19.1
Import Duties	17	0.8	22	0.9	20	0.9	14	0.6	11	0.5
Less Imputed Banking Services	-15	-0.7	-32	-1.3	-23	-0.9	-21	-0.9	-23	-1.1
Total GDP	2,213	100	2,157	100	2,297	100	2,226	100	2,139	100
Real GDP Growth rate	0		-2.5		6.5		-3.1		-3.9	

Source: Sikabanze (1996)

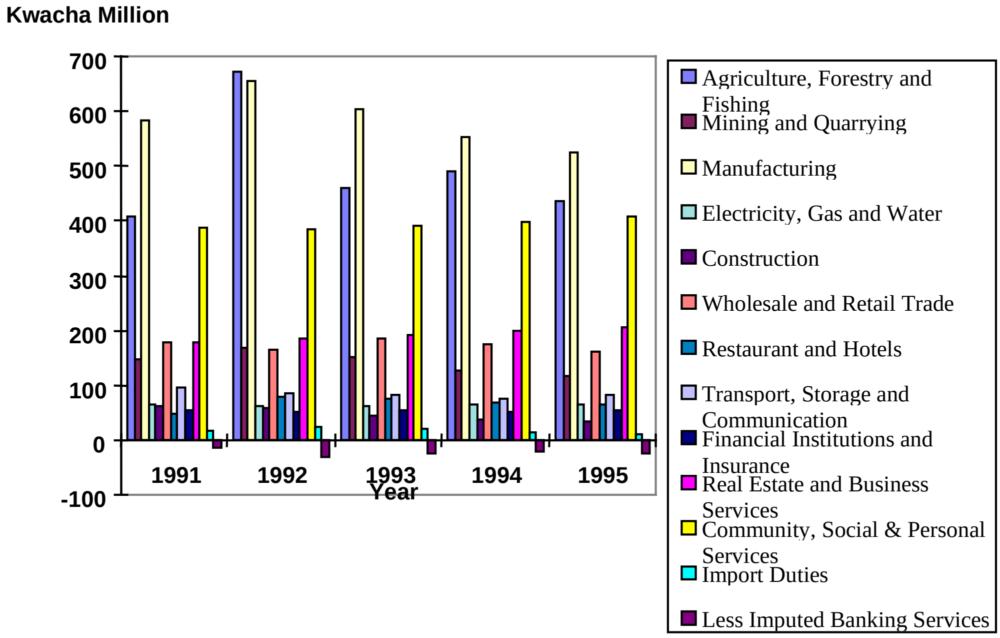


Figure 1.3. GDP by economic activity (Constant 1977 prices)

1.9 Overall Sectional Performance

1.9.1 Mining

The Mining sector occupies an important position in terms of being a major source of foreign exchange earnings from copper exports. Copper mining and its export contributed 8% and 7% to the GDP in 1990 and 1991, respectively. The GDP contribution of copper like from other sectors has fluctuated. Although the contribution of copper showed an increase from 1990 to 1991, its real value nevertheless still declined by about 2.5%. The main reasons for the decline are the lack of investments, the depth of the mines and the copper ore content had become unprofitable. In 1993 the share contribution of the mining sector to the GDP decreased from the previous year's 7.8% to 6.6%. The share contribution has been decreasing in successive years from 1993 to 1996. However, in 1996 the mining sector recorded an improvement in the total output from all the mining operations undertaken. The value added by the sector in the same year is estimated to have increased by 8.6% compared to a decline of 8.8% in 1995. Copper production increased from 307,558 tonnes in 1995 to 313,003 tonnes in 1996. In addition, cobalt production showed a tremendous increase of almost twice the 1995 level of 2,866 tonnes to 4,829 in 1996. The fire that took place at the Mufulira Smelter had a negative effect on the production of metals in the sector.

The mining industry is undergoing a transformation process. There are new investment and re-investments in the mining sector which are expected to yield positive results in the long term. The growth or expansion of the mining sector is likely to have spin-offs in the agriculture sector and other support industries. This will be the consequence of increased population in areas where explorations for minerals lead to the establishment of mines and the growth of the towns and cities located nearby. Explorations usually take considerable amount of time to start bearing any tangible results. Generally, new mining explorations tend to have long lead-times, which could be anywhere between 7 - 15 years. However, in the case of mining dumps (reprocessing of mineral waste), lead-times are shorter being in the region of between 1 - 2 years. However, the exploration and eventual development of a mine is fraught with uncertainties. Uncertainties relate to the fact that not every mining exploration will eventually lead to the development of a mine and also subject to variations in the international price of mined minerals. This simply implies that in mineral explorations there are no guarantees as to the final result of each exploration. Considering the ongoing exploration activities in the mining industry and all factors taken into account growth is certain but the rate at which the mining industry will grow as result of all the exploration activities is difficult to estimate with exactitude.

In 1996 a number of international mining companies were engaged in carrying out mining explorations in the country. The expenditure by all the mining houses has been estimated at about US$25-30 million.

1.9.2 Manufacturing Industry

The manufacturing sector has not experienced any tangible growth in the last 12 years. The manufacturing sector's contribution to the GDP grew by 12.5% from 1991 to 1992. However, there was a noticeable decline in 1993, 1994 and 1995 from the 1992 level by 7%, 16.1% and 20% respectively. Indications from the foregoing statistics in Table 1.8 are that the manufacturing industry has been continually declining. This decline and absence of growth is primarily due to lack of investment in technology and quality control which has made the sector and locally produced goods uncompetitive compared to imported goods. In addition, the lack of incentives to manufacturers has made the sector unattractive. The poor performance of the sector is also due to the restructuring, privatisation of industries and also the liberalisation of the economy that has exposed local industries to stiff competition from foreign companies trading in Zambia.

The service sector has performed reasonably better than the manufacturing sector in terms of its percentage share to the GDP during the same time period. Although the rate of growth has been significantly small, the service sector has nonetheless grown steadily from 1991 to 1995.

The manufacturing sector desperately requires the injection of more funds in order to resuscitate the ailing industry so that it can make a much more meaningful contribution to the economic development of the country. It is clear from Figure 1.3 the production of the manufacturing sector has been declining over the years. It is much more noticeable that manufacturing production index fell from 125.4 in 1990 to 117.8 in 1991 (figure 1.4). There was successive drop in the manufacturing production index from 1992 to 1994. Similarly, the production index for the manufacturing sector declined during the period 1992 to 1994. However, the electricity sector shows some growth from 1992 to 1994 except that it declined from a high of 94.2 in 1991 to 82.5.

Table 1.8 Industrial production trends

Industrial Production	**1990**	**1991**	**1992**	**1993**	**1994**
Electricity generated (million GWh)	7,923.2	8,731.1	7,610.6	7,868.6	8,128.3
Electricity consumption (million GWh)	6,741.3	6,631.3	6,643.0	6,960.4	6,730.0
Mineral production ('000 tonnes)					
Copper Electrolytic	426.2	399.4	441.6	403.5	358.8
Zinc	10.6	6.0	7.3	5.6	0.1
Lead	3.9	2.7	2.7	1.6	0
Coal	330.0	401.0	421.0	329.0	133.0
Cobalt	4.6	4.6	4.7	4.2	2.5
Index Industrial Production (1980=100)					
Total Index	96.3	90.0	96.7	88.7	77.0
Mining	78.9	72.0	80.5	73.5	61.4
Manufacturing	125.4	117.8	125.8	113.1	99.7
Electricity	84.3	94.2	82.5	85.3	88.3

Source: CSO (1995)

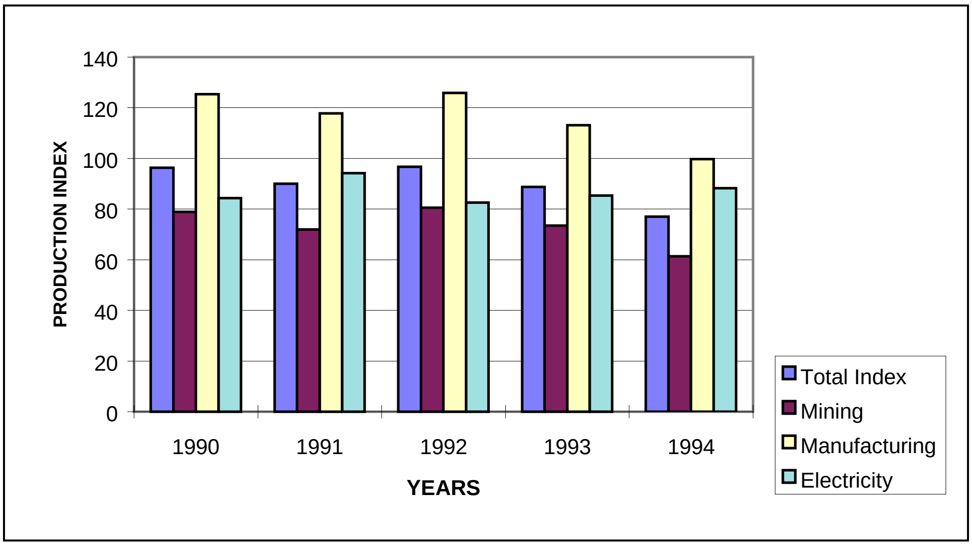


Figure 1.4. Industrial production index (1980=100)

1.9.3 Agriculture

The agriculture sector in Zambia has a crucial role to play in the country's endeavour to develop and transform the structure of the economy. The performance of the agriculture sector has been varying. From 1985 to 1990, the agriculture sector's contribution to the GDP increased by 34.3 percent from US$260 million to US$349 million (Mackenzie, J. et al, 1990). There has, however, been some hindrance to the development of the sector. The main hindrance to the development of the agricultural sector has been the rate at which the population is increasing as well as the drought situation that Zambia has been experiencing. Thus, the growth of the agricultural sector has lagged behind the population growth. The years following 1990 recorded a drop in the percentage share of agriculture to the economy with the share varying between 13% and 18%. The drop in the percentage share was primarily due to adverse weather conditions specifically the drought situation in the country during the same period.

In Zambia, land tenure and accessibility to land, and government policy are serious impediments to the expansion of agriculture sector. The sector has potential to grow if only practical measures to revamp it can be put in place. It is however estimated that the agricultural sector has a potential to grow at a rate of 5% between 1996 - 1998 for it to make any meaningful contribution to the economy. To achieve this development scenario, there will be need for diversification in the sector in order to grow high value crops. The above estimated growth of the sector is over-optimistic in view of the current uncertainties in the economy such as high inflation rate, the high cost of agricultural inputs and overall economic instability. This will only be possible if the level of research and development could be raised . To date, it has only existed on a limited scale. In order to do that it is essential that more investments are pumped into the sector.

The Agriculture sector is receiving special attention to ensure that the country meets its food security requirement. The GTZ/MEWD study (1995) mentions that this attention has been complemented by a US$300 million Agricultural Sector Investment Programme (ASIP) which will be directed to supporting investment and extension services in the sector. ASIP is one practical way of addressing the concern in the sector.

The difficulties the agriculture sector has been experiencing are clearly shown in the statistics in Table 1.9 which shows considerable variation in the marketed production. Of all the marketed production, wheat is the only produce that has shown steady growth in the quantities marketed.

Table 1.9 Trends in marketed production in agriculture

Agriculture Marketed production (tonnes)	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
White maize	639,589	601,084	464,000	839,303	476,244	844,676
Tobacco Virginia	3,366	851	3,649	4,121	3,722	2,270
Tobacco Burley	1,266	810	22,500	2,513	3,552	1,560
S/groundnuts	433	8,850	7,327	26,453	13,683	13,198
Sunflower	18,647	9,510	5,108	13,216	9,703	12,052
Wheat	51,751	52,752	64,240	69,535	-	-
Seed Cotton	30,666	48,004	27,834	58,324	-	18,578
Mixed Beans	428	6,018	12,714	115,930	13,532	13,792
Sorghum	1,004	1,007	563	5,310	3,722	7,750

Source: CSO (1996)

1.9.4 Road Infrastructure and Transport

The transport sector is an important sector in the economy with respect to the transportation of passengers as well as cargo. The sector is largely free from state controls and practically under private proprietorship and control. Future development and success of the sector will depend on both the local and central government programmes maintaining existing road infrastructure and opening up of new routes. Crop marketing also depends on this sector but has been hampered by bad roads leading to and from crop production centres. Further, the growth of population requires more transport. The importance of good road infrastructure cannot be over emphasised. In the same vein, the development of new mines will require more transport and a good road infrastructure to be constructed. The recognition of the importance of forward and backward linkages will be crucial to the development of the sector.

The majority of the Zambian roads are in poor state of repair due primarily to lack of routine and regular maintenance. However, the Government is taking steps to address the problem through an country-wide enhanced road maintenance programme. The Government envisages that this initiative will be carried through the newly established and adopted Road Sector Investment Programme (ROADSIP). The programme is planned to run for a period of 10 years in two specific phases of five years each. Considering the importance of the sector the government has estimated that the first phase will cost a staggering US$411 million. The ROADSIP programme aims at rehabilitating 3,600 km of paved road and 10,000 km of feeder roads and 500 km of unpaved urban roads. With this programme measures will be put in place to ensure that routine maintenance of a core network of 33,000 km are carried out. In addition, repairs and preventive maintenance will be carried on the 750 km of paved roads, 3,300 km of unpaved roads, 5,000 km of feeder roads and 500 km of urban roads.

The overall objective of this ROADSIP programme is to have a positive impact on the development of other dependent sectors. As mentioned above, agriculture, tourism, commerce and trade will be the obvious beneficiaries. The effective implementation of the programme is likely to lead to improved access to hitherto inaccessible rural areas. The Government is expected to make an initial allocation of funds to the programme amounting to more than US$23 million in the 1997 budget which is only about 6% of the cost of the overall programme. Funds for the ROADSIP programme are expected to come from donor support as well as from the fuel levy, which every motorist pays when they purchase fuel from fuel filling stations.

2 Overview of Zambia's Energy Sector and GHG Emissions

2.1 Energy Situation

2.1.1 Energy Consumption

The overall energy consumption for Zambia is illustrated in Tables 2.1 and 2.2, and in Figures 2.1 and 2.2, for 1990 and 1995 respectively.

Table 2.1 Energy consumption situation by sector and fuel for 1990 (TJ)

Sector	Super Petrol	Regular Petrol	Diesel/ LSG	Jet A1/ Avgas	Kerosene	Fuel Oil	LPG	Electricity	Coal	Firewood	Charcoal	Total
Household	0	0	0	0	1,473.6	0	0	2,090	0	90,919	19,337	113,819.6
Agriculture	47.7	60.4	384.8	0	4.3	0	0	645	0	3,453	0	4,595.2
Mining	99.2	12.93	3334.5	0	368.4	3,058.3	0	15,377	5,501	12,570	50	40,371.33
Industry	293.3	51.8	1568.13	0	99.7	408.2	172.6	2,229	3,750	10,353	884	19,809.73
Transport	3,614	797.7	6566.4	2,500	8.6	187.8	0	38	0	0	0	13,712.5
Government	289	146.04	48.13	0	4.3	28.6	4.5	1,680	951	0	0	3,151.57
Total	4,343.2	1068.87	11901.96	2,500	1,958.9	3,682.9	177.1	22,059	10,202	117,295	20,271	195,459.93

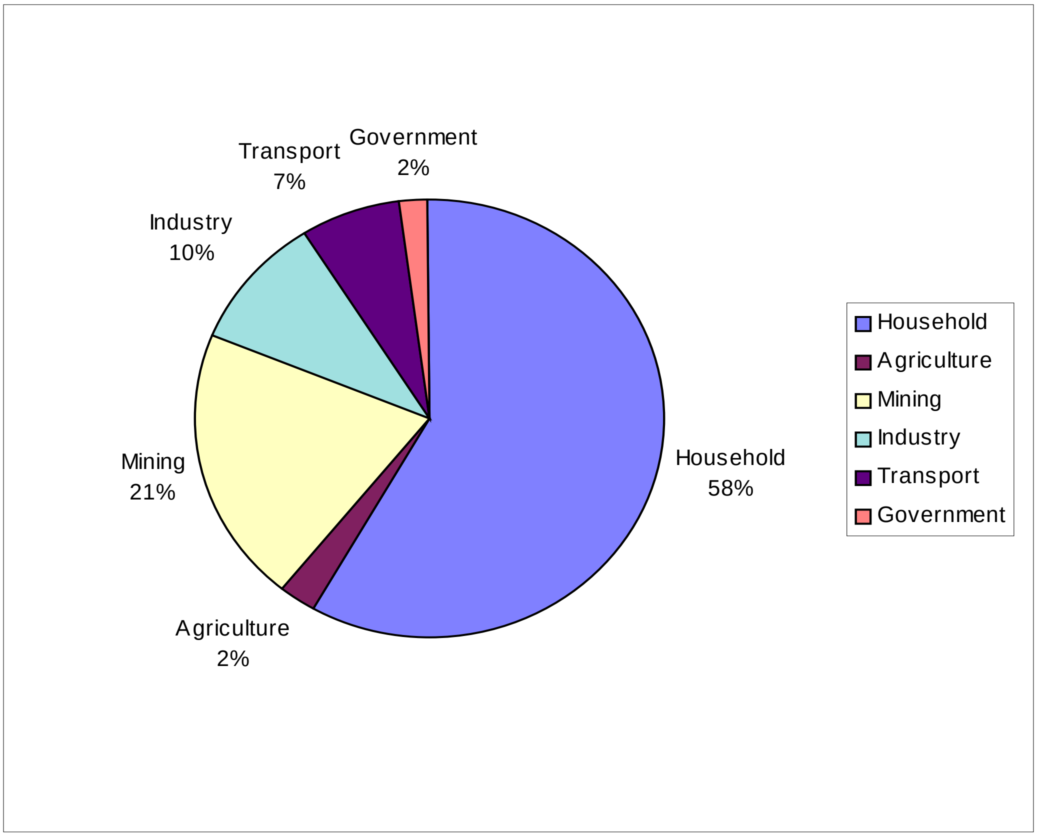


Figure 2.1. Distribution of energy consumption by sector

The energy consumption pattern in Zambia is dominated by households and mining. As shown in Table 2.1 and Figure 2.1, households account for 58% of total final energy consumption. The largest share of energy consumption by households is attributed to the dependence on firewood which alone accounts for about 80% of total household energy consumption for 1990 which indicates the overall importance of firewood in the provision of energy in Zambia. Charcoal accounted for 17% of total final household-energy use. Firewood and charcoal accounted for a combined total of 97% of total household energy consumption and 56% of total energy consumption.

The mining sector, second in importance in terms of energy consumption, accounted for 21% of total final consumption of which 38% was attributed to the consumption of modern fuels in the form of electricity. This was followed by coal and petroleum products, which contributed 14% and 12% of total mining consumption respectively. The next largest contribution came from industry (10%) followed by transport (7%).

The energy consumption figures for 1995 are presented in Table 2.2.

Table 2.2 Energy Consumption situation by sector and fuel for 1995 (TJ)

	Super Petrol	Regular Petrol	Diesel/ LSG	Jet A1/ Av gas	Kerosine	Fuel Oil	LPG	Electricity	Coal	Firewood	Charcoal	Total
Household	0	0	0	0	105.6	0	0	2,157.9	0	93,554.3	20,015.6	115,833.4
Agriculture	41.9	0	293.3	0	0	0	0	678.8	0	3,586.6	0	4,600.6
Mining	2.6	4.2	3,255.6	0	293.3	1,856.2	100.6	14,853.6	535.5	4.2	50.3	20,956.1
Industry	322.6	8.4	1,479.1	0	586.6	507	0	2,237.5	444.1	10,269.7	875.7	16,730.7
Transport	3,079.7	775.2	6,125.8	1,257	0	0	0	37.7	0	0	0	11,275.4
Government	284.9	21	402.2	0	4.2	29.3	0	1,713.7	234.6	0	0	2,689.9
Total	3,731.7	808.8	11,556	1,257	989.7	2,392.5	100.6	21,679.2	1214.2	107,414.8	20,941.6	172,086.1

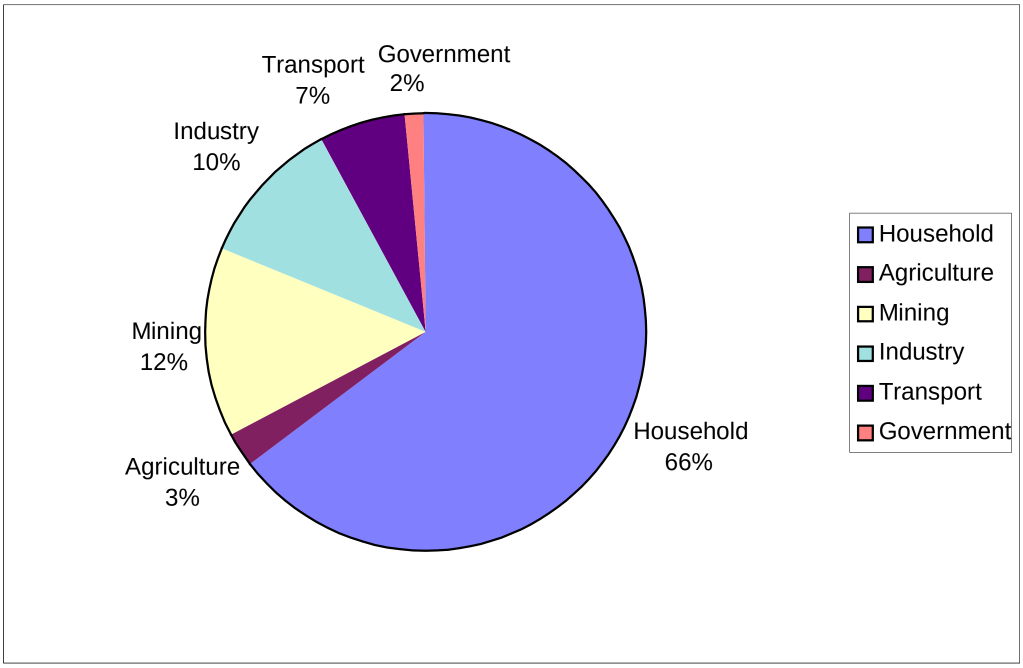


Figure 2.2. Distribution of energy consumption by sector (1995)

The energy consumption pattern in 1995, like in 1990, was similarly dominated by the household sector, which consumed 115.8 PJ thereby accounting for 66% of total energy consumption in the country (figure 2.2). This was followed by mining and transport, which consumed 20.96 PJ and 11.3 PJ, representing 12% and 7% respectively.

In the period between 1990 and 1995, there was an overall decrease in energy consumption by 11.99%. The consumption of all fuels decreased, with the exception of firewood and charcoal. It is noted that energy consumption from non-household sector, particularly, mining and transport decreased, indicating the connection to the economic situation which prevailed at the time. On the other hand, household energy related to cooking (firewood and charcoal) increased while household use of kerosene decreased considerably, presumably being replaced by charcoal and firewood.

2.1.2 Energy Supply

Zambia is well endowed with hydropower resources. The main river catchment areas that have been developed are Zambezi and Kafue. On the Kafue River, Zambia has developed the Kafue Gorge Hydroelectric Scheme (900 MW), on the Zambezi river, Kariba North Bank (600 MW) and Victoria Falls power station (108 MW). The country has also developed mini-hydro power stations in north-eastern part viz.: Lusiwasi-12 MW, Musonda Falls-5 MW, Chishimba Falls-6 MW and Lunzua-0.75 MW. The minihydro power stations serve the rural areas. The main power stations are interconnected into the main grid via a 330 and 220 kV network. The total installed capacity of hydropower is 1632 MW. There is an untapped hydropower potential of about 6000 MW.

Table 2.3 Total installed hydro-power capacity

Power Plant	Capacity MW
Kariba North Bank	600
Kafue Gorge	900
Victoria Falls	108
Lusiwasi	12
Musonda Falls	5
Chishimba Falls	6
Lunzua	0.75
Total	1632

Other rural areas are supplied by diesel power stations. There is about 5 MW of diesel power stations for areas that are too far from the national grid to make interconnection economically viable.

The country also has large deposits of coal at Maamba in the south of the country, along the Zambezi valley. Deposits of coal are estimated at 30 million tonnes. Other areas where coal deposits have been located are Luangwa North, Luano, Lukusashi, Chunga and Lubaba. These deposits are estimated at several hundred tonnes. Due to production constraints and paucity of investible funds, the design output of 1.2 million tonnes per annum of beneficiated and saleable coal has drastically dropped over the last few years. Coal only contributes about 6% of the country's energy needs, mainly in the mining and industrial sectors. At domestic sector level, research has been completed aimed at developing suitable appliances that can use coal briquettes.

Peat is another potential source of energy in the country. However, there has not been a systematic investigation to date. A general cartographic analysis reveals that there are peatland areas along the Zambezi and Kafue River valleys. Its use in Zambia can therefore not be quantified.

Zambia receives a lot of sunshine, such that solar power presents itself as a substitute to other energy sources. It is competitive when remote areas are being considered, especially for water pumping and electrifying village communities and refrigeration in health clinics. The main constraint is the initial investment cost, which is quite prohibitive. The other form of renewable energy source is wind power. Its use is basically limited to water pumping.

The woodlands and forests are estimated to cover over 50 million hectares, which is equivalent about 66% of the total land area. The predominant type is miombo (58%), which is a woodland type. This is followed by Kalahari woodland. The standing volume of timber is estimated to be in the range of 2700 - 4700 tonnes. Annual yields vary widely from under 0.3 m^3/ha to over 0.8m^3/ha, being generally higher in the north to lower in the south, due to lower rainfall in the south.

Woodfuel and charcoal are estimated to meet the energy needs of about 70% of the rural and urban population. The copper mines utilise nearly 2000 tonnes of charcoal annually in the refineries.

Petroleum, one of the main sources of energy is not indigenous to Zambia. This has to be imported as crude and refined into petrol, kerosene, diesel, aviation gas, and heavy fuel oil. Petroleum has to be imported at international prices, transported through a 1,500 km pipeline to the refinery in Ndola. The refinery has a processing capacity of 1.0 million tonnes per year.

2.2 GHG Emissions

2.2.1 Emissions from the Energy Sector

Emission from various sources considered in this study have been determined using the following expression

Emission = Activity (Amount of fuel consumed (GJ)) x Emission factor (tonne/GJ)

All the emission factors used in this study with an exception of those used to calculate household emissions were IPCC default figures. Emission factors for combustion of household energy were country-specific determined (GTZ, 1995). Raw data obtained from the Department of Energy in tonnes of oil equivalent (TOE) were processed by multiplying them with an energy conversion factor of 41.9 GJ per tonne of oil equivalent (toe) to convert them to GJ.

Given in Table 2.4 are the total energy consumption and GHG emissions by sector in GJ and tonnes, respectively, for the year 1990.

Table 2.4 Energy consumption (PJ) and GHG emissions (tonnes) by sector 1990

Sector	Energy PJ	%	CO_2	%
Household	113.9	58	104,840	3.0
Agriculture	4.6	2	35,903	1.0
Mining	40.4	21	1,306,406	43.0
Industry	19.8	10	492,550	16.0
Transport	13.7	7	798,017	32.0
Govt	3.6	2	156,198	5.0
Total	195.9	100	2,893,914	100

In 1990, there was a total of 2.89 million tonnes of CO_2 emitted into the atmosphere from the energy sector. The largest contribution came from mining (43%) followed by transport (32%) and industry (16%).

It should, however, be noted that CO_2 emissions from biomass fuels, namely fuelwood and charcoal, were not included under the energy sector since in accordance with IPCC methodology, they are counted under land-use change and forestry.

Given on Table 2.5 is a summary of energy consumption and GHG emissions by sector for the year 1995.

Table 2.5 Energy consumption (PJ) and GHG emissions (tonnes) by sector 1995

Sector	Energy PJ	%	CO_2	%
Household	131.2	66	59,390	2.8
Agriculture	5.2	2.6	25,300	1.2
Mining	23.2	12	420,360	20
Industry	21.5	11	594,000	28
Transport	13.1	6.4	858,600	40
Govt	3.9	2	180,040	8
Total	198.2	100	2,137,690	100

It can be noted that between 1990 and 1995 there was a decline in emissions from the energy sector by 26%. The decline can be attributed to a general decline in GDP between 1990 and 1995, and this tended to alter the distribution by sector. In the year 1995, transport was the largest contributor with 40% followed by industry 28% and mining 20%

2.2.2 Emission from Industrial Processes

The general methodology used to determine emissions from industrial processes according to IPCC methodology involves the product of activity level data, e.g. consumed, and associated emission factor per unit of consumption/production.

$TOAL_{ij} = A_j \times Ef_{ij}$

where:

$TOAL_{ij}$ - is the process emission (tonnes) of gas i from industrial sector j

A_j - is the amount of activity or production of process material in industrial sector j (tonnes/year)

Ef_{ij} - is the emission factor associated with gas i per unit of activity in industrial sector tonne gas/tonne of material.

Given in Table 2.6 are the emissions from the industrial sector for the year 1990 and 1995.

Table 2.6 CO_2 Emissions from industrial processes (1990 and 1995)

Process	1990 (tonnes)	1995 (tonnes)
Cement	218,054	142,512
Line Production	157,761	147,424
Ammonia Production	10,540	7,700
Total	**386,355**	**297,636**

CO_2 emissions from industrial processes for the years 1990 and 1995 were given as 386,355 and 297,636 tonnes, respectively registering a decline of 23%. Again this decrease was due to the decline in the general performance of the economy.

2.2.3 Emissions from Land Use Activities

Emissions from land-use activities in Zambia originate mainly from forest clearing and on site burning, forest biomass decay, and off-site burning of fuelwood and charcoal. In accordance with the IPCC guidelines, CO_2 emissions from these sources where calculated as follows:

(i) Forest clearing and on site burning
CO_2 = [Carbon released by forest clearing and on site burning] $K_tC \times 44/12$

(ii) Off-site burning (firewood and charcoal combustion)
CO_2 = [Carbon released by biomass burnt] $K_tC \times 44/12$

(iii) On-site biomass decay
CO_2 = [Carbon released from decay of above ground biomass]$K_tC \times 44/12$

Carbon released by forest clearing and on-site burning was determined from a knowledge of annual loss of biomass (GTZ, 1995), fraction of biomass burnt on-site, fraction of biomass utilised on-site and carbon content for the years 1990 and 1995. Carbon released by biomass burnt off-site was determined from a knowledge of biomass burnt off-site and fraction of biomass oxidised for the years 1990 and 1995. Similarly, carbon released by on-site biomass decay for the years 1990 and 1995 was calculated from a knowledge of average annual loss of biomass and fraction left to decay and carbon fraction in above ground biomass.

Results of the CO_2 emissions from the three sources are given in Tables 2.7, 2.8 and 2.9 for the year 1990, and Tables 2.10, 2.11 and 2.12 for the year 1995.

Table 2.7 CO_2 emission from on-site burning in 1990 '000 tonnes

Forest Clearing	**CO_2**
Shifting Cultivation	21,356.84
Permanent Cultivation	19,279.05
Charcoal Production	3,834.51
Logging In Plantations	-
Commercial Firewood	131.96
Selective Timber Cutting	-
Total	44,602.36

Table 2.8 CO_2 emission from off-site burning, '000 tonnes - 1990

Charcoal	CO_2
Household Mining Industry	1,681.85 4.39 77.54
Sub-total	1,763.78
Firewood	
Household Mining Agriculture Industry	8,642.46 0.84 338.56 984.22
Sub-Total	9,966.08
Total	11,729.86

Table 2.9 CO_2 emission from biomass decay '000 tonnes - 1990

Selective Cutting in natural Forests	1,389.696
Burnt re-growth area	142.69
Commercial Firewood Cutting	57.16
Shifting Cultivation	1,355.6
Permanent cultivation	1,334.38
Selectively Cut	330.88
Total	4,610.406

Table 2.10 CO_2 emission from on-site burning '000 tonnes - 1995

Forest Clearing	**CO_2**
Shifting Cultivation	25,761.91
Permanent Cultivation	23,253.92
Charcoal Production	4,665.24
Logging In Plantations	-
Commercial Firewood	148.52
Selective Timber Cutting	0
Total	**53,829.59**

Table 2.11 CO_2 emission from off-site burning '000 tonnes - 1995

Charcoal	**CO_2**
Household Mining Industry	1,701.37 2.64 68.13
Sub-Total	**1,772.14**
Firewood	
Household Mining Agriculture Industry	11,560.0 0 460.0 1,100
Sub-Total	**13,120**
Total	**14,892.14**

Table 2.12 CO_2 emission from biomass on-site decay ‘000 tonnes - 1995

Selective Cutting in natural Forests	1,460.61
Burnt re-growth area	162.25
Commercial Firewood Cutting	65.33
Shifting Cultivation	1,635.04
Permanent cultivation	1,815.95
Selectively Cut	347.76
Total	**5,486.94**

2.2.4 CO_2 Sinks

Regrowth of natural forests, regenerating after managed cultivation and/or abandonment of managed cultivated lands (fallow) and reforestation plantations are the main carbon sinks in Zambia.

In accordance with the 1996 IPCC revised guidelines, carbon dioxide uptake from biomass stock was calculated by:

$$CO_2 = \text{Carbon Uptake} \times 44/12$$

Carbon uptake was determined by having a knowledge of annual biomass increment by taking account of forest/biomass abandoned over 20 years and annual growth rate on one hand, and carbon fraction of dry matter, on the other hand.

Given on Tables 2.13 and 2.14 are CO_2 uptakes for 1990 and 1995.

Table 2.13 CO_2 uptake for 1990 (‘000 tonnes)

Category of Natural Forests	**CO_2**
Shifting Cultivation	34,134.06
Permanent Cultivation	21,134.27
Charcoal Production	1,430.88
Commercial Firewood	1,109.83
Selectively Cut	3,308.8
Plantations	
Eucalyptus	47.85
Pines	910.8
Total	62,076.49

Table 2.14 CO_2 uptake for 1995 (‘000 tonnes)

Category of Natural Forests	**CO_2**
Shifting Cultivation	41,171.16
Permanent Cultivation	25,491.31
Charcoal Production	1,740.90
Commercial Firewood	1,249.54
Selectively Cut	3,475.92
Plantations	
Eucalyptus	47.85
Pines	910.8
Total	**74,087.48**

Given on Tables 2.15 and 2.16 are the final CO_2 budgets for Zambia, for 1990 and 1995 respectively.

Table 2.15 Final CO_2 budget for Zambia - 1990 (tonnes)

Emissions Source	**CO_2**
Energy Industrial Land-use	2,893,914 386,355 60,924,630
Sub-total	64,204,899
Sinks	
Uptake by regeneration Uptake by managed plantations	
Sub-total	62,076,490
Balance	**-2,128,409**

Table 2.16 Final CO_2 budget for Zambia - 1995 (tonnes)

Emissions Source	**CO_2**
Energy Industrial Land-use	0 297,636 74,208,670
Sub-total	**76,643,996**
Sinks	
Uptake by regeneration Uptake by managed plantations	
Sub-total	74,087,480
Balance	**-2,556,516**

It is clear from the results contained presented here that CO_2 as a GHG arises predominantly from energy combustion, industrial processes and land-use change and forest activities, followed by energy and industrial processes.

CO_2 emission from energy includes combustion of liquid fuels and coal from mining, industry and transportation. CO_2 emissions are also reported under land-use change and forestry activities through combustion of fuelwood and charcoal in the household sector.

It is evident from the results on the final budget that the net sink for the years 1990 and 1995, whose total emissions take account of emissions from energy, industrial processes and land use, is wiped out.

3 Baseline Scenario (Energy Sector)

3.1 Introduction

The baseline scenario being developed adopts a business as usual approach, and is mainly influenced by an economic development path that would follow without Zambia implementing any mitigation options to reduce GHG emissions.

In view of the important role household energy plays, the baseline scenario requires that present and future energy demand and CO_2 emissions are determined both from the energy and forestry sectors of the economy to enable policy makers decide measures required to limit the effects of future emissions, and net sink potential.

3.2 Main Assumptions

In order to assess the current and future CO_2 emissions in the energy sector, the following assumptions are used both in the baseline and mitigation scenarios:

(i) population and household size
(ii) household energy mix
(iii) economic activities measured in GDP
(iv) energy intensity
(v) energy policy, and
(v) fuel prices

3.2.1 Population and Households Size

In the baseline scenario, Zambia's population is projected to reach 13.2 million by 2010 at an average rate of 3.1% per annum. Between 2010 and 2030, an average population rate of 2.9% is assumed taking into consideration improved birth control measures. Thus, in 2030, Zambia's population will reach 24 million people. As urbanisation increases, the ratio of urban-to-rural will increase from the present ratio of 40/60 to 48/52 in 2010 to 52/48 in 2030.

In 1995, Zambia's population was estimated as 8.5 million. Based on a family of 6 per household, the number of households in Zambia is estimated at 1.4 million. By 2010 and 2030, the number of households will increase to 2.2 and 4.0 million, respectively.

3.2.2 Household Energy Mix

In the baseline scenario, the major appliances identified for cooking purposes are electric, firewood and charcoal stoves. Paraffin stoves are also used to a small extent. Out of a household population of 1.4 million in 1995 only 130,000 or 9% of all households are electrified. For electric stoves, which are relatively more efficient than firewood and charcoal stoves, their market share contribution is assumed to increase. This assumption takes into account the programme initiated by ZESCO to electrify 20,000 households per annum (which include peri-urban areas) in the next 10 years. With such a programme, the number of electrified households are expected to increase to 500,000 by 2010 thereby giving 22% electrified. By

2030, the number of households electrified will increase to 1,300,000, which is 32% electrified.

Under the baseline scenario, however, the rate of penetration of the use of electric stoves will be hampered by relative high cost of the appliance, and connection and wiring fees. Given in Table 3.1 are the costs of two plate stoves, and connecting and wiring fees.

Table 3.1 Cost of two plate stove and connecting and wiring fees

Item	Cost in US$
Two Plate Electric Stove	50
Connection Fee	250
Wiring Fee	500

Under the ZESCO programme, high connection and wiring fees have drastically been reduced through use and installation of the ready board, a low cost installation and wiring method.

Despite this, however, the present economic set up in Zambia is such that most of the inhabitants of these areas will be unable to purchase electric stoves at a cost of US$50 per unit as compared to US$3.00 for a charcoal stove, in spite of the availability of electricity.

Such a situation will undoubtedly have a significant effect on the household energy mix vis-à-vis electric stoves on the one hand, and firewood and charcoal stoves on the other as shown on Table 3.2.

Table 3.2 Market share of cooking stoves, 1995, 2010 and 2030

Area		1995		2010		2030	
	Stove	Number	%	Number	%	Number	%
URBAN	Electric	130,732	9	316,955	14	806,000	19
	Charcoal	388,785	27	646,956	29	1,143,454	28
	Firewood	34,559	2	76,113	3	134,524	3
	Kerosene	8,640	1	38,056	2	67,262	2
RURAL	Electric	0	0	0	0	0	0
	Charcoal	68,208	5	49,053	2	200,562	5
	Firewood	784,392	56	1,118,867	50	1,785,198	43
	Kerosene	0	0	0	0	0	0
Grand Total		**1,415,316**	**100**	**2,246,000**	**100**	**4,137,000**	**100**

It should be noted that the percentages present in Table 3.2 are with respect to all households.

Despite the relatively high rate of electrification, i.e. 22% in 2010 and 32% in 2030, the number of electric stoves only increased to 14% and 20% in 2010 and 2030 respectively. As a result of this poor achievement rate, the number of charcoal stoves in use decreased from 32% to 31% in 2010, and increased to 32% in 2030.

3.2.3 Economic Activities

The country's economic growth, although having been negative in the last ten years or so, is expected to increase and stabilise at 4% between 1995 and 2010, and 6% between 2010 and

2030. The increase in the former will be due to benefits to accrue from the economic reform programme, which by then will have reached an advanced stage. During this period, most of the companies in private sector hands, will strive to invest more in technology and expansion programmes with the aim of making their industries more competitive. Between 2010 and 2030, in view of the liberalisation policies and natural resource endowment and potential, more investments are expected in mining, manufacturing and agriculture. It is expected that by 2030, contribution to GDP will be greater from mining and manufacturing as compared to agriculture.

On a sector basis, GDP growth rates are expected to grow as shown Table 3.3.

Table 3.3 GDP growth rates for 1990 - 2010 and 2010 - 2030

Sector	**1995 - 2010**	**2010 - 2030**
Agriculture	4%	4.5%
Mining	4%	8%
Manufacturing	4%	4%
Transport	2.5%	2.5%
Services	4%	4%

3.2.4 Energy Intensity

In view of the business as usual approach in the development of a strategy to be followed, it is assumed that the energy intensity of production will remain essentially the same without efficiency improvement interventions. However, recognition will be taken of the autonomous Energy Efficiency Improvements (AEEI) factor. This factor will allow intensity of energy use in production to decline as a result of overall global effort to improve energy efficiency in production practices and technology.

The expected trends in the AEEIs from the various sectors over the years will largely be influenced by the sector and area of application. The AEEIs in this work covered the range 0, -0.25, -0.5 and -1.0.

In the area of improved charcoal and coal briquette stoves, research and development work is expected to continue resulting in an AEEI of -0.5% per annum.

Use of coal in boilers is also expected to vary by an AEEI of -0.5% due to expected improved combustion technologies. As expected, manufacturers of motor vehicles are putting a lot of effort in R&D work and this is likely to result in an AEEI of -0.5%.

3.2.5 Energy Policy Implications

Some features of energy policy that are likely to influence energy consumption and CO_2 emissions include:

- energy pricing
- energy substitution
- energy conservation

a) Energy Pricing

The Energy Policy clearly advocates for energy to be viewed as an economic good. In view of this policy, companies involved in the energy sector are striving to bring the price of energy to an economic level. The main consideration in this context is to ensure that energy prices must be economic to reflect the long run marginal cost (LRMC) of particular fuels. This pricing approach is expected to have a bearing on prices of various energy such as electricity tariffs that are currently set at about 3US cents per kWh and also considered as low. It is considered that embracing LRMC will result in upward revision of electricity tariffs to about 8 US cents/kWh. The implication of implementing the LRMC will be felt in the households. If the LRMC pricing is finally implemented the poor people who generally have low incomes will find the cost of energy unaffordable. While this pricing approach will enable companies to recover their investments, the opposite will also be true in the case of the poor people in terms of their inability to pay for the energy. The negative impact will be that the poor may be left with no choice but revert back to inefficient sources of energy such as fuelwood and charcoal. This barrier can, however, be removed if a social tariff policy is introduced for the poor to enable raise their overall standard of living as the general economy improves.

b) Energy Substitution

The Zambia Energy Policy, approved by the Government in 1994, encourages among other things instituting fuel switching. The underlying criteria for considering this option is the need to replace coal and heavy fuel oil-based boilers with electric ones, and encouragement of the use of electric stoves in the peri-urban households, where charcoal is predominantly used. This is in view of Zambia's excess hydro-electricity amounting to 300 MW. With such a deliberate policy and partial switch by industry and taking account of the expected overall general improvement in the economy the excess hydro-electricity capacity is expected to be exhausted in the year 2005.

c) Energy Conservation

The policy on energy conservation encourages adoption of good housekeeping practices and attainment of optimum combustion regimes in various thermal systems and reduction of heat losses.

As part of the World Bank Rehabilitation Project, a programme is being designed as a demonstration project to promote energy efficiency improvements in industry on a national basis. With the project, demand side management programme is being undertaken by ZESCO aimed at rationalising load management in industry.

3.3 Price Assumptions

The energy base price for 1995 was based on real prices in Zambia and converted in United States dollars in view of the volatility of the Kwacha exchange rate against convertible currencies. An international inflation rate of 2% was considered to account for the changes in the prices over the years. Most of the prices in particular liquid and coal based hydrocarbon fuels and traditional biomass fuels were based on market prices and therefore no subsidies are incorporated in their final determination. Electricity tariffs although considered fairly priced, it is felt in some quarters that the price does not fully take account of marginal production costs to enable have a reasonable return on investment of the country's utility. Prices for ethanol were based on Zimbabwe's price of ethanol using their past experience. That for coal briquettes was based on results of a recent pre-feasibility study in Kabwe (Kaoma, J. et al., 1997) which assessed the costs of producing coal briquettes.

A discount rate of 10% was chosen for the assessment period based on the Central Bank's borrowing rate and the shortage of capital for investment.

3.4 Methodology and Data

This part of the report describes the methodology and data behind the evaluations. The calculations are carried out using two microcomputer tools, namely: Long Range Energy Alternatives Planning (LEAP) system and Greenhouse Gas Abatement Costing Model (GACMO).

LEAP is a bottom-up model developed by the Stockholm Environment Institute based in Boston (SEI-B). The projections of energy demand and supply and the environmental effects (air emissions) were calculated using the LEAP. The model can also be used to calculate the integrated costs of the energy based mitigation options.

The energy consumption data and projections in the LEAP relating to the various sectors namely: household, agriculture, mining, industry & commerce, transport and government & services were primarily calculated on the basis of the energy intensities listed in Appendix I.

The CO_2 emissions using the LEAP were calculated on the basis of the carbon compositions and emission factors of the fuels used in the analysis.

GACMO is another bottom-up model which was developed by the UNEP Collaborating Centre in conjunction with the Southern Centre of Harare, Zimbabwe for carrying out analysis of costs of implementing mitigation options. The model is designed to annualise the capital cost, operation & maintenance cost, and fuel cost.

The model was also used to calculate emissions from the defined reference and reduction options. The emissions are calculated in terms of carbon dioxide equivalents by use of global warming potentials. The difference in the emissions with the reference and the reduction option gives the achievement of the option. The cost of the reduction is in terms the difference between the cost of the reference option and the reduction option.

The output of the model using spreadsheets gives the cost of each reduction option, reduction in emissions expressed in terms of CO_2 and the equivalent cost of the CO_2 per tonne reduced. The cost could be either negative or positive. In the case of being positive, it means the country will have to invest much more in terms of resources in order to achieve the reduction in GHG emissions. A negative result is a net gain to the economy by investing in the reduction of GHG emissions.

3.5 Energy Consumption Projections

Energy consumption projections by sector and fuel for the years 1995, 2010, and 2030 are presented in Appendix II. The results show that the household sector is the single largest fuel-consuming sector accounting for 131.25 PJ. This was 66% of total energy consumption for 1995. Firewood accounted for more than 75% of the energy consumed in the household sector and 52% of total energy consumption. Charcoal and electricity rank second and third to firewood accounting for 11% and 13% of overall energy consumption in 1995. This only shows the dominance of firewood as a source of energy.

Also given in Appendix II are the energy consumption by sector for 2010. The data shows that the energy consumption is expected to increase by about 64% from 198.29 PJ in 1995 to 322.61 PJ by 2010. In the baseline scenario, the energy consumption shows the household sector will continue being the major energy-consuming sector. Biomass fuel, namely, charcoal and firewood are the two major sources of energy contributing 94% of energy to the household sector.

Energy projection calculations for Agriculture, Mining, Government and Services and, Industry and Commerce, have taken sectoral GDP growth rates into account in the drivers and elasticities projection method. In the case of energy projections in the household sector, population, population growth rate and the number of households have been used as the principal factors. Population is a major driving factor in the energy demand of households. In the household sector, the projection of energy consumption has also taken into account the AEEI. Energy consumption projection in the agriculture sector has accounted for GDP growth.

Energy consumption will continue to increase, more than 650 PJ by the year 2030. The factors that influence the consumption pattern are population and household numbers, household energy mix and the economic growth measured in GDP.

Shown on Table 3.4 and Figure 3.1 is a demand and supply scenario for electricity that indicates that a surplus of electricity is expected to continue until 2005. By that time the country should plan to put a new plant between 2000 and 2005. This development of new plants will be necessary in order to meet the increased demand. It should be noted that the deficit/surplus reported in Table 3.4 refers to the present supply situation.

Two alternatives are available. The first one involves development of a 80 MW hydro-electricity capacity plant at Itezhi-Tezhi followed by a 450 MW plant at Kafue Lower. The combined effect of these installations will stretch the edge of supply over demand beyond the year 2012. Given on Figure 3.1 is the new supply/demand scenario, which takes account of new capacity. Even with this investment, the capacity will be exhausted by the year 2012. To meet further demand, there will be need to commission Batoka before 2010 or consider other alternatives, like exports from Inga Falls in the Democratic Republic of Congo.

Table 3.4 Electricity supply and demand scenario (MW)

Electricity	**1995**	**2010**	**2030**
Supply	1,500	1,500	1,500
Supply 1(Kafue Lower and Itezhi-Tezhi)		2,030	2,030
Supply 2 (Batoka)		2,830	2,830
Demand	845	1,665	4,440
Surplus (deficit shown negative)	655	1,165	-1,610

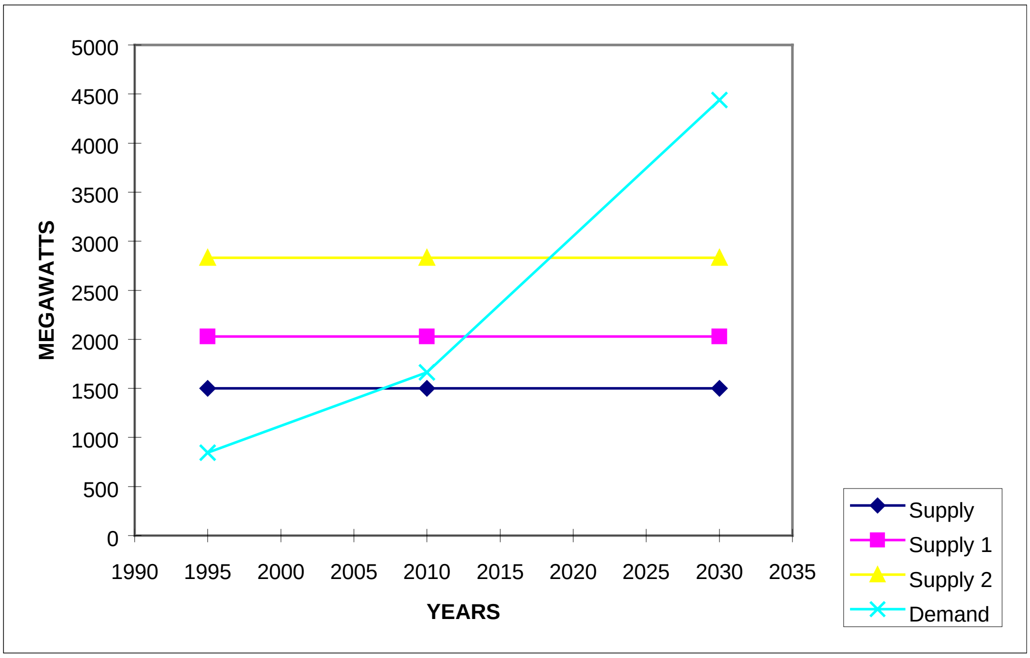


Figure 3.1 Electricity supply and demand scenario (MW)

3.6 Emission Projections

3.6.1 Energy

Emission projections for energy have been calculated using the LEAP model, IPCC methodologies and country specific emission factors. Results for CO_2 emissions for 1995 and projection for 2010 and 2030 are shown on Tables 3.5, 3.6 and 3.7 for CO_2 .

Table 3.5 CO_2 emissions: fuels by sector - 1995 (tonnes)

Sector	**Liquid fuels**	**Coal**	**Electricity**	**Total**
Households	59,390	0	0	**59,390**
Agriculture	25,300	0	0	**25,300**
Mining	305,280	115,080	0	**420,360**
Industry	432,030	161,970	0	**594,000**
Transport	858,600	0	0	**858,600**
Government	63,920	116,120	0	**180,040**
Total	**1,744,520**	**393,170**	**0**	**2,137,690**

Table 3.6 CO_2 emissions: fuels by sector - 2010 (tonnes)

Sector	**Liquid fuels**	**Coal**	**Electricity**	**Total**
Households	241,920	0	0	**241,920**
Agriculture	42,290	0	0	**42,290**
Mining	553,920	206,580	0	**760,500**
Industry	1,036,370	387,010	0	**1,423,380**
Transport	1,371,310	0	0	**1,371,310**
Government	157,170	193,980	0	**351,150**
Total	**3,402,980**	**787,570**	**0**	**4,190,550**

Table 3.7 CO_2 emissions: fuels by sector - 2030 (tonnes)

Sector	Liquid fuels	Coal	Electricity	Total
Households	406,380	0	0	**406,380**
Agriculture	83,870	0	0	**83,870**
Mining	1,226,440	450,690	0	**1,677,130**
Industry	3,400,780	1,271,330	0	**4,672,110**
Transport	2,699,020	0	0	**2,699,020**
Government	579,200	384,480	0	**963,680**
Total	**8,395,690**	**2,106,500**	**0**	**10,502,190**

3.6.2 Industrial Processes

Using 1995 as the base year, and taking account of GDP growth rate of 4% between 1995 and 2030, in the industrial sector, CO_2 emissions projections are given below as follows:

Table 3.8 Emissions from industrial processes

	1995	2010	2030
Industrial Processes	297,636	535,745	1,174,472

3.6.3 Emissions from Land-Use Activities

Emissions projections from land use change were determined based on a growth rate of 3.1%. The growth rate is based on the average rates of forest and land clearing for commercial fire-wood, and shifting and permanent agriculture between 1995 and 2030 (Chidumayo, 1984).

Table 3.9 Emissions from land-use activities

Emissions Source	1995	2010	2030
On-site burning	53,829,590	94,624,370	200,792,360
Off-site burning from other sectors	14,892,140	20,013,800	36,147,150
On-site biomass decay	5,486,940	8,501,110	15,954,500
Total	**74,208,670**	**123,139,280**	**252,894,010**

Given on Table 3.10 are final budget emissions and sinks for 1995 and projections for 2010 and 2030.

Table 3.10 Projected GHG budget

Source	1995	2010	2030
Emissions	76,643,996	127,865,575	264,570,672
Sinks	74,087,480	126,888,750	262,240,530
Balance	**-2,556,516**	**-976,825**	**-2,330,142**

The main carbon inks in Zambia are regrowth of natural forest, regenerating after forest clearing and/or abandonment of managed cultivated land (fallow) and reforestation (GTZ, 1995). The projections for sinks are based on forest land clearing for shifting and permanent agriculture, charcoal production, commercial firewood and timber harvesting estimated at 3.8%, 4.0%, 2.4%, and 1.0%.

4 Mitigation Scenario

4.1 Introduction

It is clear from the results of GHG Inventory Study (GTZ/MEWD, 1995) and work contained in this report that CO_2 as a GHG arises predominantly from energy and industrial processes. Emissions from land-use (252 million tonnes of CO_2 in 2030) are more than compensated by absorption of CO_2 through regrowth of forest.

For the year 1995, activities related to charcoal production, permanent cultivation and shifting cultivation contributed to clearing of approximately 1.08 million hectares of forest cover. The rate at which wood industry for such purposes is being done far outweighs wood replacement leading to moderate deforestation (Kalumiana 1994).

4.2 Mitigation

Based on the arguments from the previous section, the choice for mitigation analysis is both in the energy sector and land use change and forestry sector. Concomitant to this, the guiding criteria in the selection of mitigation options in the energy and land use change and forestry sectors were:

4.2.1 Energy Sector

- Need for energy efficiency and substitution in the household sector
- Need for energy efficiency and conservation in mining, industry, government and transport.
- Need to utilise available excess hydro-electricity (more important is that it is carbon free)

4.2.2 Land Use Change and Forestry

- Need to reduce rate of deforestation and consequently attempting to address problems associated with it such as soil degradation, siltation, drought etc.
- Need to preserve forests to enhance carbon sequestration

4.3 Mitigation in the Energy Sector

Under mitigation scenario in the energy sector, five economic sectors namely: household, mining, industry, transport and government service were selected. Mitigation options considered in the household sector included energy substitution and efficiency of cooking appliances. In the industrial sector, the options of partial replacement of coal, diesel and fuel based boilers with electric were considered. Under transport and government service, use of ethanol-gasoline blend in petrol-propelled motor vehicles and improved maintenance of motor vehicles options respectively, were considered.

4.4 Characteristics Of Mitigation Options

4.4.1 Household Energy

Three mitigation options have been identified, these are:

- Increased use of electric stoves.
- Introduction of improved charcoal stoves.
- Use of coal briquettes produced from Maamba Collieries.

However, penetration and share of the market of each of the options identified will depend largely on a number of developmental, economic, social and environmental considerations.

a) Electric Stoves

In the baseline scenario, the main thrust for implementation of ZESCO's electrification programme of peri-urban areas is basically to raise the standard of living and contribute to reduction of the rate of deforestation. On a global basis, however, such a programme can be linked to efforts to preserve forests to enhance carbon sequestration aimed at slowing down global warming.

In view of both national and global benefits, the use of electric stoves should rank highest amongst other options and should be encouraged in order to improve their penetration and market share. Although ZESCO has been able to raise the funds locally and internationally to electrify the houses as indicated in the baseline (i.e. 500,000 and 1,300,000 houses projected to be electrified in the years 2010 and 2030 respectively), the number of households actually using electric stoves is far below by 40% compared to the number of houses electrified. The low level of attainment of switch from use of charcoal stoves to electric stoves in peri-urban areas can be attributed to lack of initial capital to afford an electric stove with an average cost of US$50.00 per unit. Most residents in the urban areas have average incomes of between US$ 50.00 and US$70.00 per month, and spend in the range of between 35% and 45% of their income on fuel costs. To overcome such a barrier as part of mitigation strategy, it is recommended that a financing mechanism be introduced. The financing mechanism, will initially require adequate seed money to be lent on loan basis to residents of peri-urban areas to purchase electric stoves. Loan recovery can be linked to ZESCO's electricity monthly bill payment. Possible source of financing of such a scheme can be either the Global Environment Facility (GEF) or through joint implementation.

With such a scheme in place, the number of households using electric stoves is likely to increase from 130,000 in 1995 to 500,000 in 2010 and 1.3 million in 2030. From Table 4.1, the market share of electric stoves increases from 9% in 1995 to 22% in 2010 and 31% in 2030, as compared to an increase of 14% and 20% under the baseline scenario for the years 2010 and 2030 respectively.

Table 4.1 Market share of cooking stoves for 1995, 2010 and 2030

Area	1995			2010		2030	
	Stove	**Number**	**%**	**Number**	**%**	**Number**	**%**
URBAN	Electric	130,732	9	500,000	22	1,300,000	31
	Imp. Charcoal	0	-	250,000	11	410,000	10
	Coal Briquette	0	-	100,000	4	150,000	4
	Charcoal	388,785	27	201,368	9	262,554	5
	Firewood	34,559	2	17,808	1	19,124	1
	Kerosene	8,640	1	8,904	1	9,562	1
RURAL	Electric	0	0	0	-	0	-
	Charcoal	68,208	5	116,792	5	198,576	5
	Firewood	784,392	56	1,051,298	47	1,787,184	43
	Kerosene	0	0	0	-	0	-
Grand Total		**562,716**	**100**	**1,078,080**	**100**	**2,151,240**	**100**

In view of the expected economic improvement scenario in the next 10 years and more, the rate of penetration of electric cooking stoves (22% and 31% of all households in the years 2010 and 2030 respectively) is quite reasonable. These figures correspond to 37% and 60% of urban households, which by definition are the households suitable for electric grid connection. It is essential that standard of living be improved through increased rate of electrification. In view of limitation of internal financial resources, by ZESCO, it would need additional financial resources from either Government or Global Environmental facility (GEF) or under joint implementation to increase from their electrification rate to 30,000 per annum.

b) Coal Briquette Stove

The National Council for Scientific Research (NCSR) has for many years undertaken research and development work in the use of coal slurry to produce coal briquettes for use as a household fuel. Coal slurry is a by-product of coal mining at Maamba Collieries. Method of mining at Maamba involves the removal of overburden in the form of low value coal waste, which is dumped to enable reach lower seams where high value coal is obtained. The high value coal is then processed in a washing plant to remove slurry and other impurities.

Currently, coal slurry has no use and is a nuisance at Maamba Collieries as it is dumped in ponds. NCSR has developed a pilot plant capable of producing 10,000 tonnes of coal briquette per annum. Parallel to this NCSR has also developed a suitable coal briquette stove.

Coal briquette is a smokeless and compact fuel in the form of a ball and has comparable combustion characteristics to charcoal. It has a calorific value of 25.2 GJ/ton and carbon content of 56% and can be used in ceramic stove with air control vents, developed by NCSR. The main ingredient of coal briquette is coal slurry, which is initially carbonised, to remove the volatiles, crushed and then blended with molasses and lime and then compacted.

Research results on coal briquette production and appropriate coal briquette stove have been encouraging and can be used as a base to commercially produce coal briquettes for use as a household fuel. The benefits of using coal briquettes are two-fold. From the local and global perspectives, the use of coal briquettes as a household fuel can make some contribution in reducing the pressure on the use of charcoal that contributes to deforestation.

At the same time, combustion of coal briquettes yields less carbon dioxide than combustion of charcoal for energy produced from the two sources to cook or heat one unit mass. As shown in Appendix III, for heating 1 kilogram of water to boiling point, using charcoal and coal briquette, there is a saving of about 3.5% in carbon dioxide formation when using coal briquettes as compared to charcoal.

Under the mitigation scenario, it is proposed that a 150,000 tonne capacity coal-briquetting plant be commissioned. At the same time, it is proposed that a centralised medium scale factory be established with the overall purpose of manufacturing not only coal briquette stoves but electric and improved charcoal stoves as well. Under the mitigation scenario, it is expected that the coal briquetting plant will be able to produce and market coal briquettes to serve at least 100,000 households, representing 4% of total market share, in the year 2010, and increasing to 150,000 households with essentially the same market share in the year 2030. The success of this option will depend largely on the introduction of an aggressive marketing strategy to forestall possible pressure and resistance from the charcoal-production industry with an estimated employment of over 50,000 people.

c) Improved Charcoal Stoves

In view of the divergence of social and economic backgrounds, the inability to achieve 100% electric stove use penetration under the baseline scenario, and due to relatively low penetration of coal briquettes, there will, naturally be some households which will continue to use charcoal.

It for this reason that improved charcoal stoves need to be introduced on the market. In recent years, a lot of focus, emphasis and efforts have been made on the design, development, dissemination and use of improved charcoal stoves.

During this period, a programme involving design and development of a series of improved charcoal stoves was undertaken at the University of Zambia. Results of performance tests carried out in the laboratory yielded higher thermal efficiency of between 10% - 22%. The design philosophy was based on improved combustion, heat transfer and boundary layer effects.

The design phase was followed by a pilot phase where nine different stove designs were tested in actual cooking situations in selected households in Lusaka. The pilot tests yielded good results and improved savings were observed in the range of 30 - 100% to existing stoves.

The pilot project was followed by a dissemination phase with support of the Netherlands Government, Danida and the Norwegian International Development Agency (NORAD). This involved training of tinsmen in various markets in major cities. Under this scheme, a total number of 2000 tinsmen were trained and were expected to continue production and marketing of the improved stoves. Although, the stoves produced costed more than the existing stoves by between 20 and 30% more, they were popular because of the noticeable savings made by the users in the range of 50 to 100% of the existing stoves, and an attractive payback of less than one year.

Despite these good results, further dissemination of the improved stoves could not be sustained. This was due to various reasons, some among them being increased production time due to the complexity of the stove design and lack of materials for the same. As a result, tinsmen ended to switch to production of familiar items that were easy for them to manufacture.

For this reason, therefore, under the mitigation scenario, it is being proposed as suggested earlier that a medium factory, with appropriate tool and equipment, be established to manufacture efficient and low cost electric stoves, improved charcoal stoves and coal briquette stoves, in sufficient numbers to attain reasonable and competitive prices.

Such a facility should be capable of producing and marketing 250,000 improved charcoal stoves, 500,000 electric stoves and 150,000 coal briquette stoves in the year 2010 (Table 4.1). The success of this option will depend on the price of the charcoal stove to be produced.

4.4.2 Transport Sector

Petroleum products dominate Zambia's energy balance. In accordance with 1995 energy balance, transport accounted for over 6% of the total energy consumption. All the petroleum products consumed in Zambia are imported. Zambia spends close to US$100.0 million in importing crude oil which is processed at Indeni into final products. The fuel bill consists about 8.5% of total foreign exchange earnings, which is an economic burden to the country, in view of the relative shortage of foreign exchange.

In 1995, petroleum consumption was 13.07 PJ and is expected to increase to 18.91 PJ in 2010 and 30.99 PJ in 2030, mainly driven by overall economic GDP growth.

It has been estimated that Zambia has approximately 150,000 vehicles (private communication). However, due to poor record keeping, actual statistics are difficult to come by. In a recent exercise undertaken by the Department of Road Transport, in the Ministry of Transport and Communication, the total number of vehicles registered was set at 60,000 of which 60% were gasoline propelled. In view of the constant checks of motor vehicles by the Roads Transport Department, it is unlikely that the deficit could be as high as 90,000 as indicated in the estimated number. We therefore assume for this analysis that the number of vehicles is 60,000.

Due to the liberalisation of the economy and expected growth in the overall GDP, the population of vehicles is expected to increase as shown on Table 4.2.

Table 4.2 Motor vehicle population, energy consumption and CO_2 emissions

	1995			2010			2030		
	No.	**Energy ’000 GJ**	**CO_2 ’000 tonnes**	**No.**	**Energy ’000 GJ**	**CO_2 ’000 tonnes**	**No.**	**Energy ’000 GJ**	**CO_2 ’000 tonnes**
Gasoline	39,000	5,570	361.77	56,484	7,570	703.87	92,555	12,400	1709.67
Diesel	21,000	6,700	496.85	30,414	9,700	667.44	49,837	15,900	989.35
Total	**60,000**	**12,270**	**858.62**	**86,898**	**17,270**	**1371.31**	**142,392**	**28,300**	**2699.02**

From Table 4.2, the total gasoline consumption for the year 1995 is 5.6 PJ and is expected to increase to 7.57 PJ and 12.40 PJ in the years 2010 and 2030 respectively.

Ethanol can be blended with gasoline, as gasohol and used in gasoline propelled motor vehicles. Experience in Brazil, Malawi and Zimbabwe shows that gasoline engines can run up to 20% gasohol blends with no modification.

Ethanol can be produced in significant quantities in countries that have agricultural and forestry potential production capacities in excess of what is required to meet needs of current projections, and physical resources (soil, water and labour) required to grow utilisation feedstocks such as sugar.

In a recent study conducted by Stockholm Environment Institute (SEI) in conjunction with SIDA, Zambia was identified as a promising country with suitable climatic, land and labour conditions for production of ethanol from sugar. A study will soon be underway to investigate the feasibility of producing sugar-cane based ethanol as a transportation fuel. The study will provide useful support information on the economic, social and environmental benefits of producing sugar, alcohol and surplus electricity.

In light of the anticipated large investment requirements of the project, the study will consider alternative investment options that can provide a broader range of benefits. Producing ethanol fuel and surplus electricity for sale to the national grid using crop residues in lieu or in addition to producing sugar are alternatives that would do so.

Producing ethanol from blending with gasoline would reduce the country's oil import bill and emissions of greenhouse gases as well as air pollutants from the transportation sector. Net savings of foreign exchange will, however, depend on the international price of ethanol, which can be exported depending on the competitiveness of the local price, vis-à-vis importation of gasoline.

Implementation of the project would greatly be assisted by experience already gained by Nakambala Sugar Estates established in the 60s and produces over 150,000 tonnes of sugar, and molasses per annum.

It is expected the investment required for the distillery will be in the region of USD8.0 million dollars and with a production capacity of 40 million litres per annum. The envisaged capacity is capable of sustaining ethanol production for the next 20 years.

4.4.3 Industry

Zambia's industrial base is characterised by manufacturing industry which includes, textiles, paper and pulp, food processing, beverage production, chemicals and pharmaceuticals and engineering based industry.

During the 1970s and 1980s, the manufacturing sector in Zambia was characterised by parastatal dominance, high levels of protection, price controls and interference from the public sector. Consequently, the sector was inward looking, inefficient and uncompetitive. Since 1991, Zambia has witnessed significant changes in economic structure. The Government has embarked on the Structural Adjustment Programme (SAP) which entails among other issues the introduction of a free market and liberalised economy. In addition, the Government has embarked upon a programme of divestiture of parastatal companies. To date, more than 200 companies have been privatised. Privatised companies are putting a lot of efforts and more life in their companies with the aim of making them more competitive in view of liberalised and globalised trade.

Most of the industries notably textiles, paper and pulp, food processing, beverage production, rubber processing and pharmaceuticals use boilers to produce steam for process application.

Currently Zambia has 242 boilers comprising of electric boilers 29%, coal based 29%, diesel based 21% and fuel oil based 21% (Table 4.3). The distribution figures are based on results of a recent study on the survey of boilers in Zambia (CEEEZ). The demand for boilers is expected to grow at 1% per annum in the next ten years. The fuel consumed will therefore increase from 1.89 PJ for diesel, 2.05 PJ for fuel oil and 2.86 PJ for coal in the year 1995 to

4.92 PJ for diesel, 5.34 PJ for fuel oil and 7.45 PJ for coal in the year 2010, registering an increase of over 100% in each of the respective fuel consumption.

In view of the excess hydro-electricity available in the country, it is envisaged to switch some of the liquid and coal based boilers with electric ones in the following proportions.

Table 4.3 Distribution of industrial boilers by type

Boiler type	**1995**	**2010**	**2030**
Electric	29%	64.5%	82.25%
Diesel	21%	10.5%	5.25%
Fuel Oil	21%	10.5%	5.25%
Coal	29%	14.5%	7.25%

Another energy intensive industry in Zambia is cement production. In 1995, energy consumption in the cement industry was 1.84 PJ producing an estimated 400,000 tonnes of cement per year. Based on a growth rate of 4%, cement production is expected to increase to 513,000 tonnes and 1.13 million tonnes in 2010 and 2030 respectively.

The present production capacity is 400,000 tonnes per year. In view of the shortfall of 113,000 tonnes by 2010 and 830,000 tonnes by 2030, there is need to invest in a 1,000,000 tonne capacity per annum to meet the growing needs on a long term basis using the dry method in the calcination process, and also taking account of the situation that the current plant will be decommissioned before the year 2010 due to old age.

4.4.4 Government Service

The cost effectiveness of the public service has declined over the last 10 years. At least one third of government employees are surplus to requirements (Zambia: Medium Term Plan 1998 -2000). Personnel costs take 38% of fiscal resources and stifle expenditure on essential supplies and capital spending. The Government has adopted a revised public service reform programme that provides for a reduction of public sector workers from 139,000 persons to 80,000 in 1999. Government also intends to continue restructuring of ministries and commercialisation of specific units. The restructured Government service will face serious challenge in ensuring that prompt and efficient service is provided to the private sector to ensure enhanced growth. Besides government service will need to strengthen monitoring and inspection roles to meet the safety, environmental and developmental well being of industry. All these efforts will require mobility and hence increased number of motor vehicles to meet these new challenges.

Currently Government has no policy on preventive and comprehensive maintenance of its fleet estimated at 4,243 comprising of approximately 2,834 diesel and petrol 1,409. In the year 1995, 323 thousand GJ of diesel and 189 thousand GJ of petrol were consumed. The lack of a maintenance policy no doubt increases fuel consumption due to faulty systems and lack of adjustment of combustion systems that tend to increase fuel consumption.

Mitigation scenario requires the introduction of an improved preventive and comprehensive maintenance scheme of its fleet requiring an agreed upon maintenance schedule. Although this scheme will increase maintenance costs, fuel consumption will be reduced and life span of the fleet increased from currently estimated five (5) years to eight (8) years. In petrol engines for example, it is estimated that the fuel consumption is 5 kilometres per litre and 6 kilometres per litre for diesel. With introduction of a preventive maintenance scheme, the fuel consumption rates can be increased to between 6 to 7 kilometres per litre for petrol engines and between 8 to 9 kilometres per litre for diesel engines. Successful implementation of the option will depend largely on whether a policy of standardisation of the Government fleet is introduced. In the absence of such a policy, management of repairs of such vehicles would be fragmented.

4.5 Input Data

The input data required by the LEAP and the GACMO are given in Appendix I. The data involved include energy intensity by sector, emission factors, real energy prices, investment costs including operation and maintenance.

4.6 Discussion Of Results

4.6.1 Energy Demand Projections

Shown on Table 4.4 and Figure 4.1 are the total energy demand for the year 1995 and the projections for the years 2010 and 2030 under the baseline and mitigation scenarios.

Table 4.4 Total energy demand under baseline and mitigation scenarios (PJ)

	1995	2010	2030
Baseline	198.29	322.61	653.11
Mitigation	198.29	297.07	579.23

The overall energy demand for the two scenarios is illustrated in Figure 4.1.

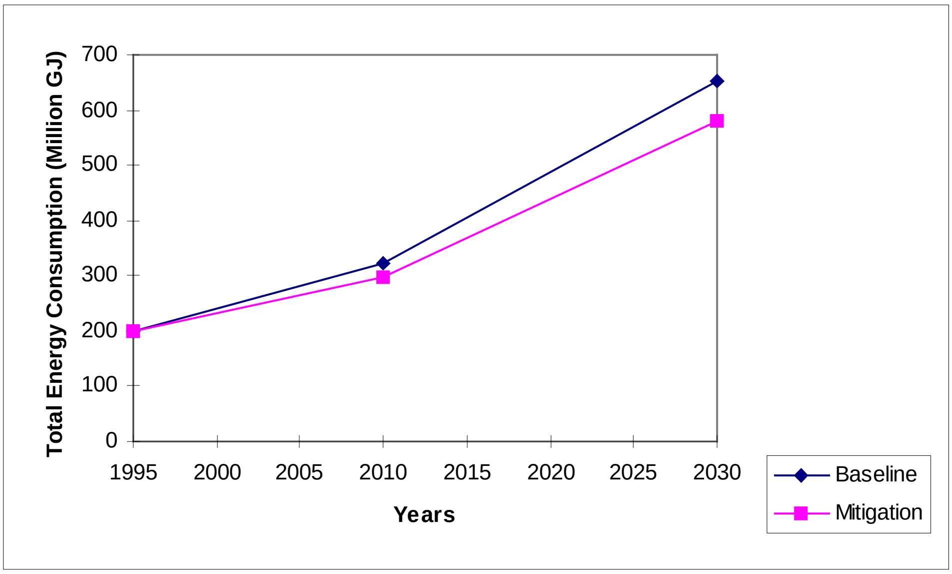


Figure 4.1 Overall energy demand under baseline and mitigation scenarios(PJ)

The total energy demand under the baseline is expected to increase from 198.29 PJ to 322.61 PJ by 2010 and 653.11 PJ by 2030. Under mitigation, the increase is expected to rise from 198.29 PJ in 1995 to 297.07 PJ by 2010 and 579.23 PJ by 2030 thereby giving a reduction of 7.9% and 11.3% in 2010 and 2030 respectively.

4.6.2 Carbon Dioxide Emissions

Under the baseline scenario, CO_2 emissions by sector in 1995, 2010 and 2030 are shown in the Table 4.5.

Table 4.5 Carbon dioxide emissions by sector in 1995, 2010 and 2030: Mt (Baseline)

Sector	1995			2010			2030		
	Biogenic	**Non-Biogenic**	**Total**	**Biogenic**	**Non-Biogenic**	**Total**	**Biogenic**	**Non-Biogenic**	**Total**
Households	13.26	0.059	13.32	19.43	0.24	19.67	32.04	0.41	32.45
Industry/ Commerce	1.16	0.594	1.75	2.02	1.43	3.45	4.21	4.71	8.92
Government/ Service	0	0.18	0.18	0	0.35	0.35	0	0.97	0.97
Agriculture	0.46	0.025	0.49	0.80	0.04	0.84	1.66	0.08	1.74
Mining	0	0.42	0.42	0.01	0.76	0.77	0.01	1.68	1.69
Transport	0	0.858	0.86	0	1.37	1.37	0	2.70	2.70
Total	**14.88**	**2.136**	**17.02**	**22.26**	**4.19**	**26.45**	**37.92**	**10.55**	**48.47**

From the above table it is clear that the largest contributor of CO_2 is the household sector representing 78.3% arising mainly from combustion of charcoal and firewood for cooking purposes and followed by industry and commerce (10.3%), transport (5.1%), Agriculture (2.9%) and mining (2.4%) for the year 1995.

Results for CO_2 emission under mitigation are shown in Table 4.6.

Table 4.6 Carbon dioxide emissions by sector in 1995, 2010 and 2030: Mt (Mitigation)

Sector	1995			2010			2030		
	Biogenic	**Non-Biogenic**	**Total**	**Biogenic**	**Non-Biogenic**	**Total**	**Biogenic**	**Non-Biogenic**	**Total**
Households	13.26	0.059	13.32	17.39	0.3	17.69	27.81	0.39	28.20
Industry/ Commerce	1.16	0.594	1.75	2.02	0.75	2.77	4.21	1.69	5.90
Government/ Service	0	0.18	0.18	0	0.34	0.34	0	0.94	0.94
Agriculture	0.46	0.025	0.49	0.80	0.042	0.84	1.66	0.084	1.74
Mining	0	0.42	0.42	0.01	0.76	0.77	0.01	1.68	1.69
Transport	0	0.858	0.86	0.05	1.22	1.27	0.12	2.34	2.46
Total	**14.88**	**2.136**	**17.02**	**20.27**	**3.412**	**23.68**	**33.81**	**7.124**	**40.93**
Reduction				**9%**	**19%**	**10%**	**11%**	**32%**	**16%**

The results of the emissioncalculations under the baseline and mitigation scenarios are shown in Figure 4.2, 4.3 and 4.4 for biogenic, non-biogenic and total CO_2 emissions respectively.

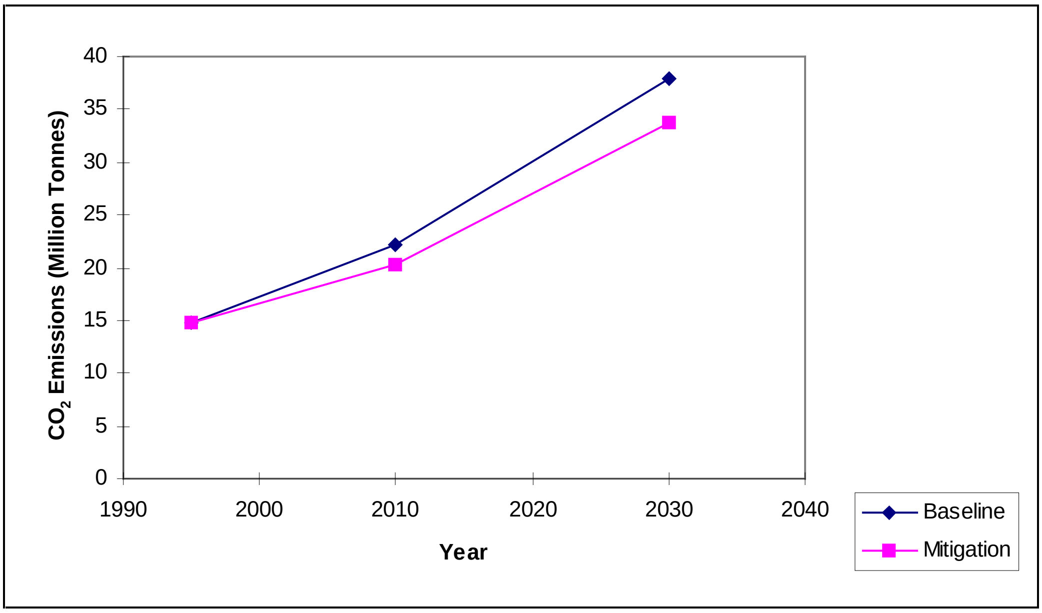


Figure 4.2 Biogenic CO_2 emission - Baseline and mitigation scenarios

Under the mitigation options considered, there was a reduction of 2.8 million tonnes in the year 2010 and 7.86 million tonnes in 2030. Given on Table 4.7 is the CO_2 emissions by fuel type.

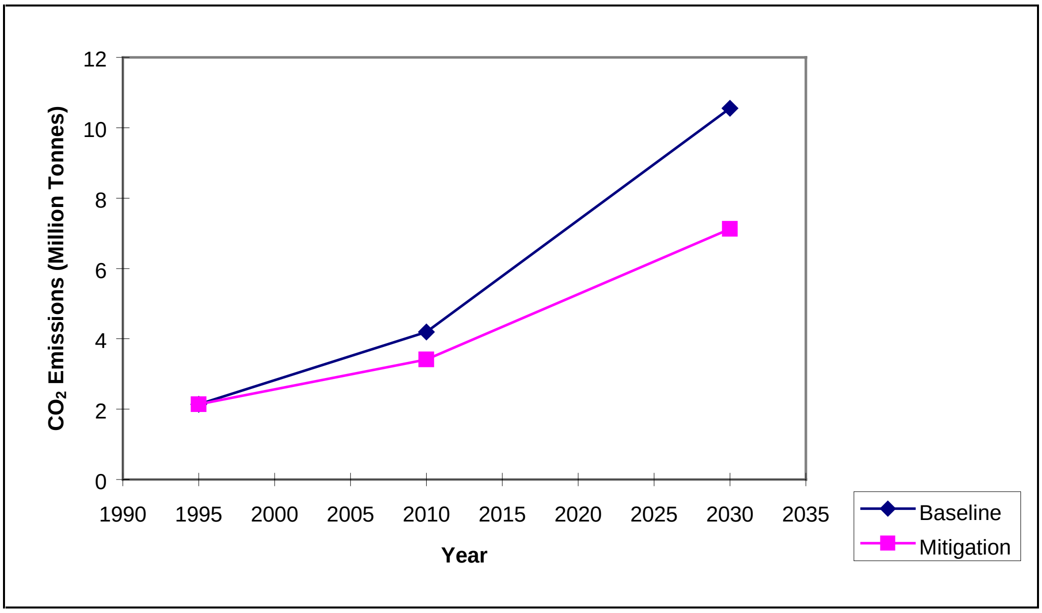


Figure 4.3 Non-biogenic CO_2 emission - Baseline and mitigation scenarios

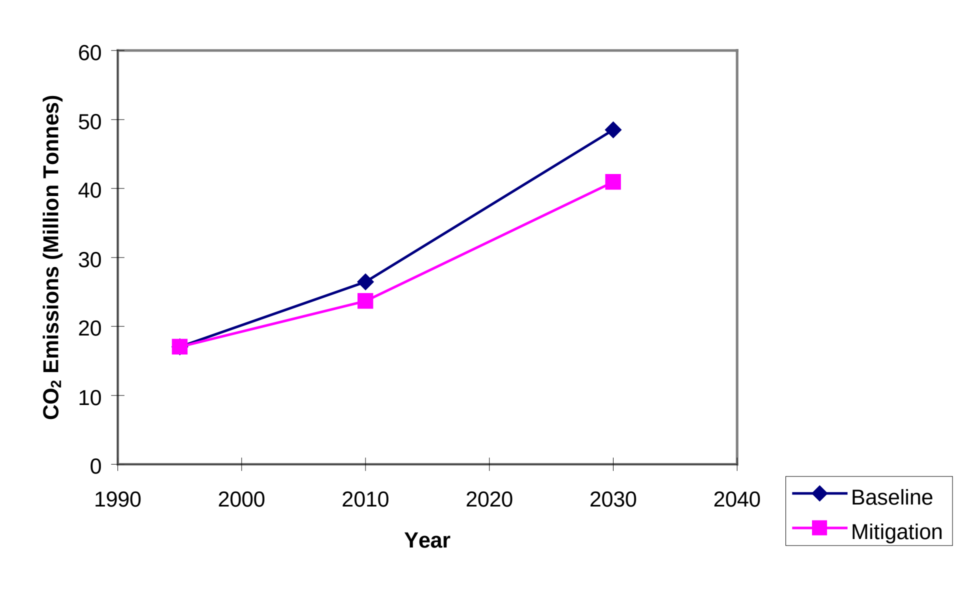


Figure 4.4 Total CO_2 emission - bseline and mitigation scenarios (biogenic and non-biogenic)

Table 4.7 Total CO_2 emission by fuel type (million tonnes)

	1995	2010			2030		
	Base	**Base**	**Mitigation**	**Reduction (%)**	**Base**	**Mitigation**	**Reduction (%)**
Ethanol	0	0	0.54		0	1.31	
Firewood	13.12	19.56	18.74		32.71	31.09	
Charcoal	1.77	2.69	1.47		5.21	2.60	
Petrol	0.42	0.88	0.25	71.6	2.48	0.93	62.5
Kerosene	0.08	0.29	0.11	62.1	0.54	0.20	63
Diesel	0.86	1.41	1.28	9.2	2.92	2.36	19.2
Fuel Oil	0.38	0.84	0.46	45.2	2.48	0.75	69.8
Coal	0.39	0.79	0.61	25.4	2.11	1.36	35.5
Hardcoal Briquette	-	0	0.24	-	0	0.32	-
Total	**17.02**	**26.46**	**23.7**	**10.43**	**48.45**	**40.92**	**15.54**

It may be seen from Table 4.7 that the largest percentage reduction occurred in petrol and kerosene based mitigation options followed by diesel and fuel oil.

4.6.3 Emission Reductions and Costs

Overall emission reductions and costs for all the options considered are assessed with the help of the LEAP model. Individual reductions costs assessments of each option were done using GACMO.

The LEAP model further subdivides the reduction and cost assessment by biogenic CO_2 (arising from the combustion of biomass) and non-biogenic CO_2 (arising from the combustion of fossil fuels). Given on the Tables 4.8 and 4.9 are the emission reduction potentials for the two categories of CO_2.

Table 4.8 Non-biogenic CO_2 emission reduction (Million tonnes)

	1995	2010	2030
Emission Reduction	0	0.79	3.42
Percentage Reduction (Mitigation Vs Baseline)	0	18.08%	31.94%
% Reduction from 1995 (Mitigation and Baseline)	0	-58.94%	-224.64%

In the first case of non-biogenic, overall CO_2 reduction amounted to 0.79 million tonnes for the year 2010 and 3.42 million tonnes from the year 2030 giving a reduction of 18.08% and 31.94% respectively.

Table 4.9 Biogenic CO_2 emission reduction (Million tonnes)

	1995	2010	2030
Emission Reduction	0	1.99	4.11
Percentage Reduction (Mitigation Vs Baseline)	0	8.94%	10.83%
% Reduction from 1995 (Mitigation and Baseline)	0	-36.10	-127.12

In the biogenic case, overall CO_2 reduction amounted to 1.99 million tonnes in 2010 and 4.11 million tonnes in the year 2030 giving reductions of 8.94% and 10.83% respectively.

Using GACMO, individual reductions and cost assessment (cost of CO_2 reduction per tonne) are given. Also given is the cost of the options chosen. The options are ranked starting with the least cost. The results of the CO_2 reduction per tonne for each option are shown in Appendix IV. Given on Figures 4.3 and 4.4 are the CO_2 abatement cost curves for all the options for the years 2010 and 2030 respectively.

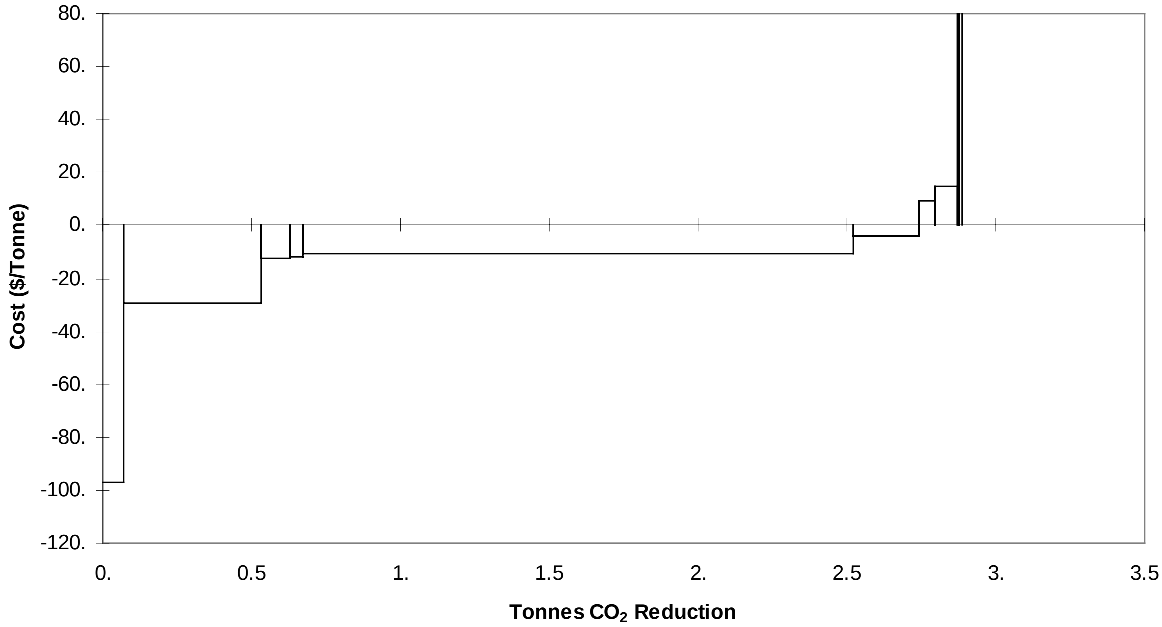


Figure 4.5 CO_2 abatement cost curve: 2010

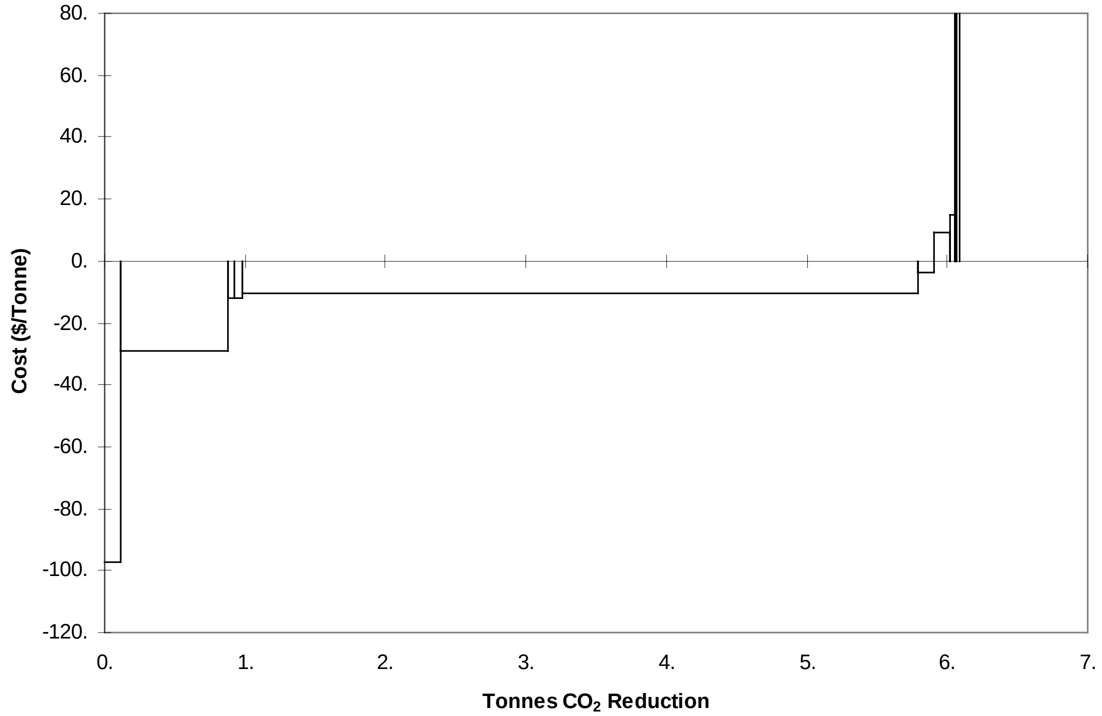


Figure 4.6 CO_2 abatement cost curve: 2030

The total emission reduction for all the options amounted to 2.89 million tonnes in 2010 and 6.08 million tonnes in 2030. It is evident from the results that most of the options in the Zambian scenario have negative costs with an exception of cement production (9.14 US$/ton$CO_2$) and replacement of coal fired boilers with electric ones (14.74 US$/ton$CO_2$). The lowest negative cost is that of improved maintenance of diesel (-1,126 US$/ton$CO_2$) and petrol (-474.0 US$/tonCO_2) propelled motor vehicles followed by ethanol blend (-97.04 US$/ton$CO_2$). Options on the use of improved stoves, efficient boiler in industry (diesel replacement), use of coal briquettes and increased use of electric stoves have essentially the same cost of reduction in the range -10.5 US$/ton$CO_2$ to -29.11 US$/ton$CO_2$. As most of these options have negative costs, Zambia is well placed in contributing to abatement of CO_2 emissions through implementation of relatively lower cost options

For the year 2030, the total reduction was 6.08 million tonnes and essentially the same pattern of cost of reduction as in the year 2010.

An interesting feature to note is the difference in results on total CO_2 emission reduction from LEAP and GACMO as shown below.

Table 4.10 Difference in results in total CO_2 emissions from LEAP and GACMO

	1995	**2010**	**2030**
LEAP	0	2.78	7.53
GACMO	0	2.89	6.08

At this stage, it is difficult to pinpoint the source of difference. The difference in results could be attributed to various factors among them consideration of CO_2 equivalent in the GACMO and emission factors used. It is recommended more work is undertaken under methodological development to reconcile the difference.

Another interesting feature is the larger contribution of biogenic CO_2 to the reduction potential resulting from combustion of charcoal and firewood and its linkage to mitigation efforts in the forestry sector such as charcoal production efficiency in the traditional earth kiln and enhanced natural regeneration (refer to chapter 5). It is evident that if these measures are implemented, they are likely to lead to increased forest land area and woody biomass. Such a situation is likely to result in charcoal production and utilisation becoming sustainable, and resulting in the contribution of CO_2 emissions from combustion of charcoal and firewood not only becoming zero, but also enhancing CO_2 absorption capacity due to increased forest cover resulting from improved mitigation options.

In view of the nature of treatment of energy and forestry sectors separately under methodological development, there is need in case of Zambia and other developing countries to carry out more work in establishing the linkage between the two sectors.

5 Forestry Sector

5.1 Baseline Scenario

5.1.1 The Forest Sector In Zambia

Zambia is well endowed with most natural resources, among them forests and woodlands. Forests and woodlands cover about 535,000 km^2, or about 70% of the total national land area (Figure 5.1). The Zambian woody vegetation can be divided into 3 main categories:

a) Forest Type

This category comprises 8 sub-forest types namely Dry Evergreen, Deciduous, Montane, Riparian, Chipya, Thicket, Swamp and Plantation forest types. They cover a total of about 43,000 km^2, representing 8% of the total wooded area in Zambia and 6% of the total land area. Forest vegetation has the highest biomass per unit area, being in the range of 158t/ha for evergreen forests to 58t/ha for deciduous woodlands (Figures 5.2 to 5.5).

b) Miombo Woodlands

These woodlands are the most extensive woody vegetation type covering about 400,000km^2, representing over 70% of the total vegetation cover and covering about half the total land area of Zambia. The main woodland categories here are Dry, Wet and Kalahari Miombo, respectively. Total woody biomass in Miombo woodlands ranges from 76t/ha in Wet Miombo to 43 t/ha in Kalahari Miombo. This is the most exploited forest type. Among the most important land uses include agriculture, timber and woodfuel production.

c) Savannah Woodland

This is the second largest forest type in Zambia covering about 95,000 km^2 or about 18% of the total wooded area and 13% of the total land area. This category includes Mopane, Munga and Termitaria woody vegetation. Biomass densities here are very low being about 46, 46 and 25t/ha for Mopane, Munga and Termitaria, respectively. The woody vegetation standing stock in Zambian forests & woodlands is estimated to be 3 to 4.3 billion tonnes, out of which 1-3% is mean annual increment (MAI) or sustainable annual production/yield, giving a range of 30 to 120 million tonnes of wood of MAI.

5.1.2 Causes for Forest Depletion

The main threat to the forest sector in Zambia is unsustainable harvesting of wood. The rate of wood harvesting outweighs wood replacement leading to deforestation. The main causes of deforestation, with the proportion of their contribution to deforestation are shown in Table 5.1.

Table 5.1 Main causes of deforestation

Deforestation cause	**Proportion**
Charcoal production	4.5%
Commercial firewood	1.4%
Timber	16.8%
Semi-permanent Agriculture	23.7%
Shifting agriculture	53.6%

Figure 5.1 Extent of forest cover in Zambia

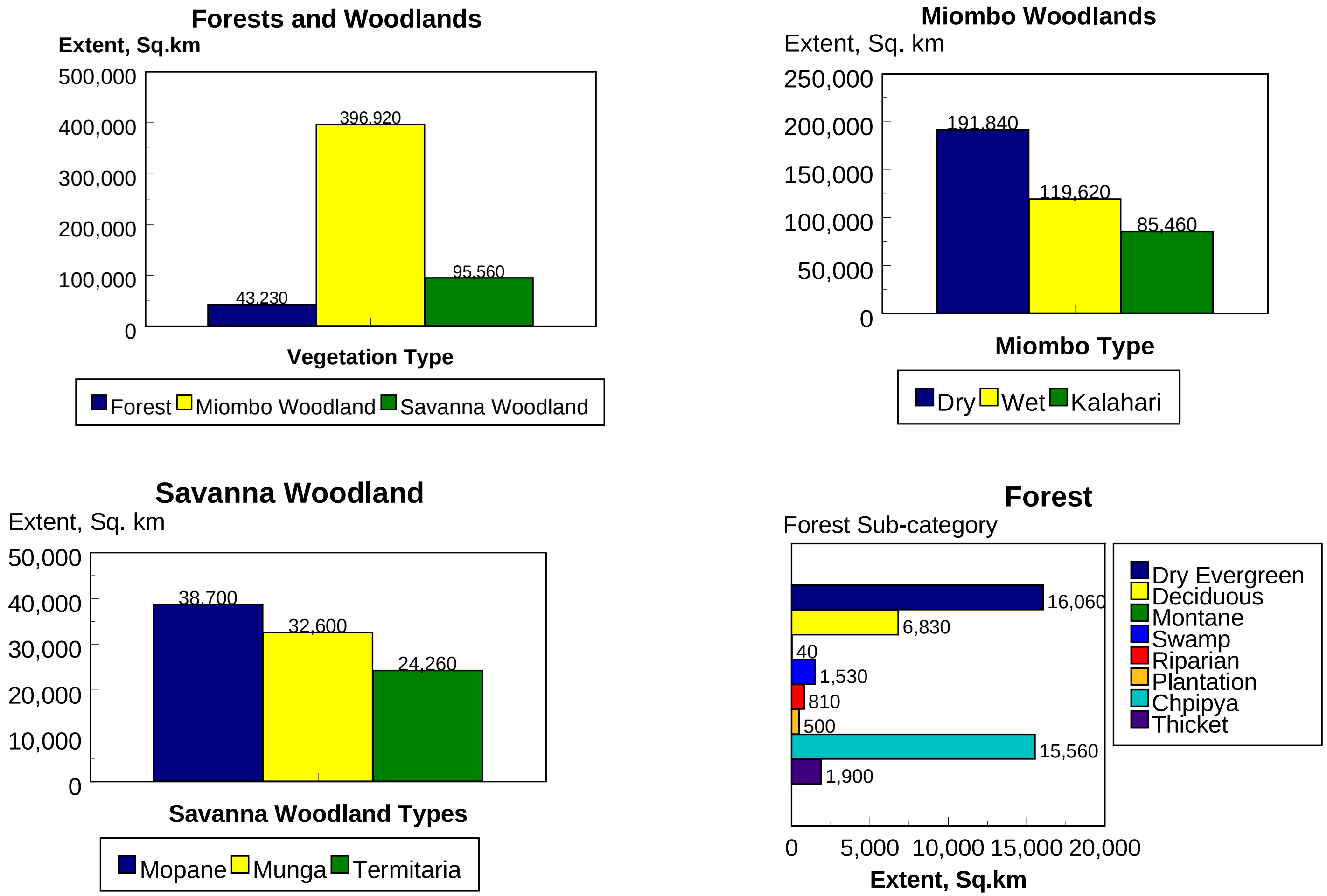
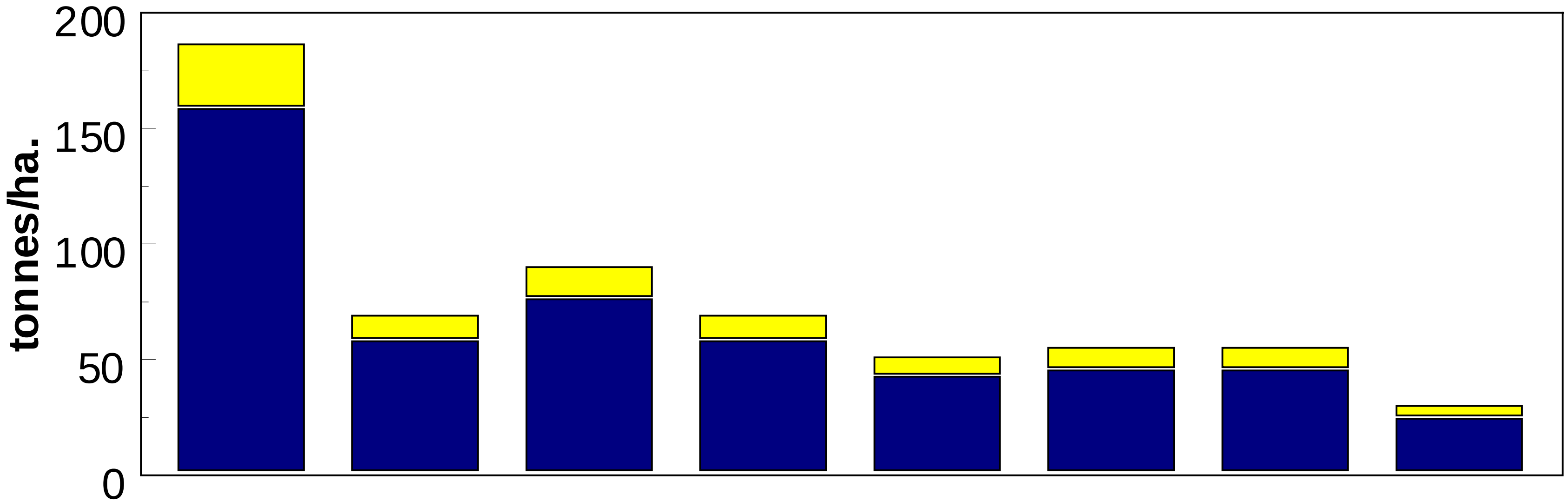


Figure 5.2 Woody biomass estimates by forest type: woody biomass per hectare.



Veg. Type	Evergreen Forest	Deciduous	Wet Miombo	Dry Miombo	Kalahari Miombo	Munga	Mopane	Termitaria
Cord	158	58	76	58	43	46	46	25
Brush	29	11	14	11	8	9	9	5

Figure 5.3 Woody biomass estimates by forest type: total wood stock by forest type (million tonnes)

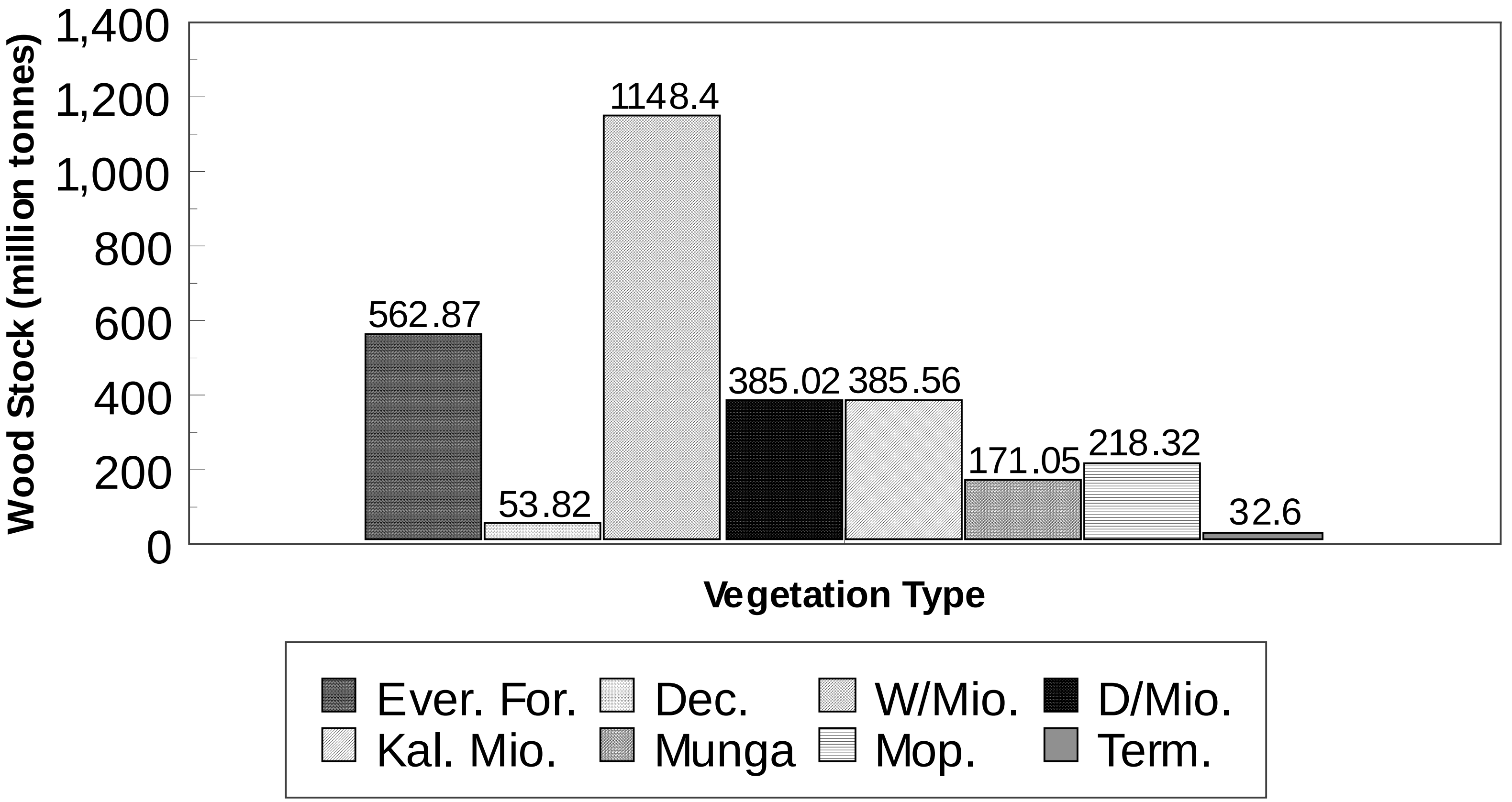


Figure 5.4 Woody biomass estimates by forest type: total area by forest type

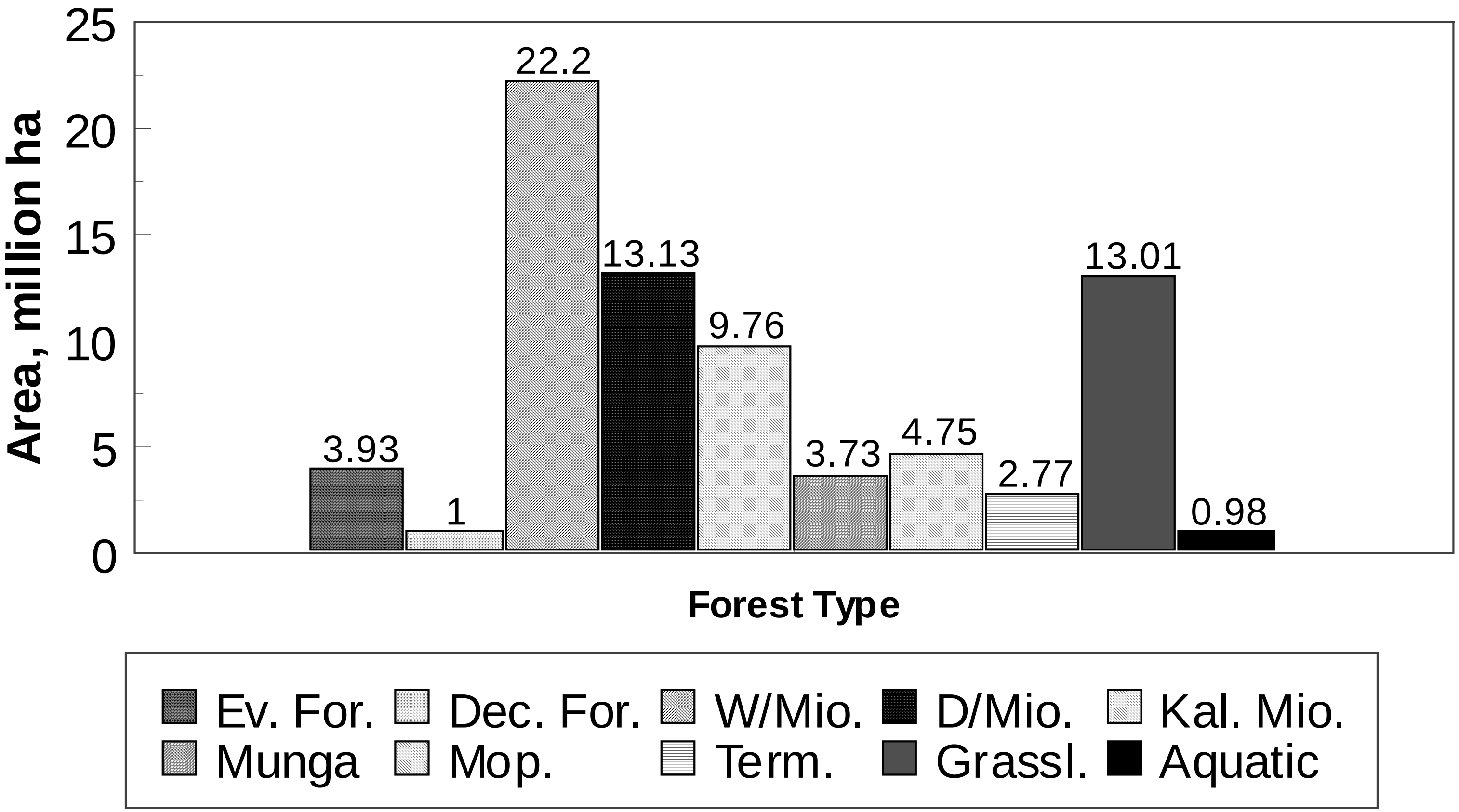
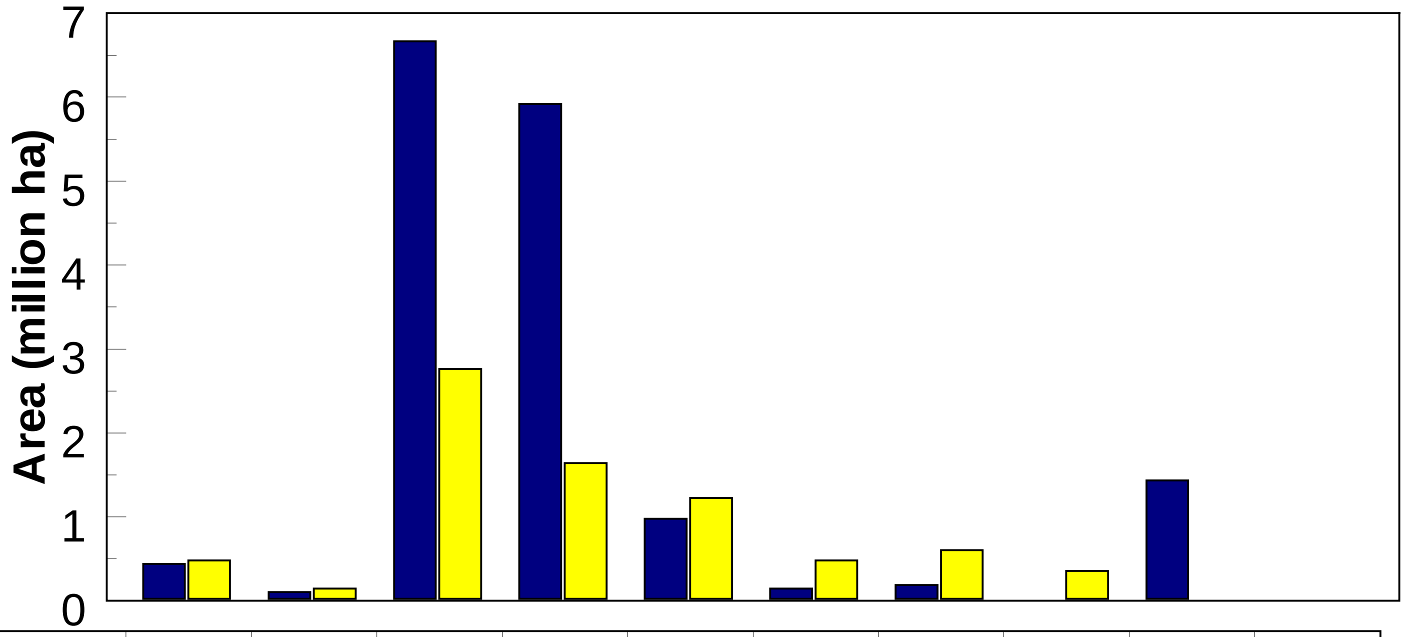


Figure 5.5 Area within forest types occupied by cropland and grassland



Veg. Type	Ev. Forest	Dec. For.	Wet Mio.	Dry Mio.	Kala. Mio.	Munga	Mopane	Term.	Grassl.	Aquatic
Cropland	0.43	0.09	6.66	5.91	0.98	0.15	0.19	0.00	1.43	0.00
Dambo Grassland	0.49	0.13	2.78	1.64	1.22	0.47	0.59	0.35	0.00	0.00

Source: Chidumayo, 1996

5.1.3 Scenario Assumptions

Based on these proportions and the current rate of forest land clearing, total loss in forest cover is shown in Table 5.2. These Figures are based on the following assumptions:

i) Forest land clearing (FLC) for commercial firewood increases at the annual rate of increase as that of firewood consumption i.e. 2.4% per annum during the target period

ii) Cutting natural wood for timber harvesting increases at 1% per annum during the target period.

iii) FLC for charcoal increases at the annual rate of increase in charcoal consumption @ 4% per annum during the target period

iv) No increase in the efficiency of woodfuel production or end-uses during the target period

v) FLC for shifting and permanent agriculture increases at 3.82% per annum during the target period

Table 5.2 Cumulative contributions to total deforestation under baseline scenario, '000 ha

Land use/year		1995	2000	2005	2010	2015	2020	2025	2030
Dense forest	Charcoal	24.7	51.9	81.2	144.8	152.2	194.4	239.6	293.1
	Firewood	7.7	16.1	25.3	35.7	47.4	60.5	74.5	91.2
	Timber	92.4	193.6	303.3	428.6	568.4	725.7	894.3	1094.1
	SP Agric	130.3	273.1	427.9	604.7	801.9	1023.7	1261.7	1543.4
	Shift. Agric	294.7	617.7	967.6	1367.6	1813.5	2315.2	2853.4	3490.6
Woodlands (10-40% canopy cover)	Charcoal	183.1	383.7	601.2	849.6	1126.7	1438.4	1772.7	2168.6
	Firewood	57	119.4	187	264.3	350.5	447.5	551.5	674.7
	Timber	683.6	1432.7	2244.3	3172	4206.3	5370	6618.2	8096.2
	SP Agric	964.3	20221.1	3166.1	4474.7	5933.9	7575.5	9336.4	11421.4
	Shift. Agric	2180.9	4570.9	7160.5	10120.1	13420.1	17132.9	21115.1	25830.8
Woodlands (less 10% canopy cover)	Charcoal	39.6	83	130	183.7	243.6	311	383.3	468.9
	Firewood	12.3	25.8	40.4	57.2	75.8	96.8	119.2	145.9
	Timber	146.9	307.9	482.4	681.7	904.1	1154.2	1422.4	1740.1
	SP Agric	208.5	437	684.6	967.5	1283	1638	2018.7	2469.5+
	Shift. Agric	471.6	988.3	1548.2	2188.1	2901.6	3704.4	4565.4	5585
					25,540.3				**62,262.5**

Although forest land clearing is high, its net reduction on woody biomass stocks is low due to natural regeneration. In 1995, total woody biomass stock from natural regeneration is estimated at 43 million tonnes. By 2030, it is estimated to reach 130 million tonnes (Table 5.3). Despite this high rate of biomass growth under natural regeneration, there is still a small proportion of biomass loss as shown in Table 5.3 and Figure 5.6.

Table 5.3 Biomass pool balance from deforestation & regeneration

		1995	2000	2005	2010	2015	2020	2025	2030
Regeneration	Biomass, '000t	43,038.14	51,412.55	61,491.95	73,626.55	87,612.91	95,588	114,365	130,060
	Area,'000ha	860.76	1,028.25	1,229.84	1,472.53	1,752.26	1,911.76	2,905.53	3,298.51
Deforestation	Biomass removed, '000t	60,255	65,290	74,615	83,210	93,605	100,400	118,890	134,090
	Area cleared, '000ha	1,205.1	1,305.8	1,492.3	1,664.2	1,872.1	2,008	2,996.03	3,379.11
Balance	Biomass pool, '000t	-17,216.86	-13,877.45	-13,123.05	-9,583.45	-5,992.09	-4,812	-4,525	-4,030
	Area deforested, '000ha	-344.34	-277.55	-262.46	-191,67	-119.84	-96.24	-90.5	-80.6
	cum. area loss deforested, '000ha	334.34	1,732.09	3,044.39	3,992	4,592	5,073	5,525	5,928
	cum. biomass loss, '000t	16,717	86,604	152,220	199,624	229,584	253,644	276,270	296,420

Figure 5.6 shows total deforestation over the target period taking into account natural regeneration.

5.2 Mitigation Options in the Forest Sector in Zambia

5.2.1 Categories of Mitigation Options

The mitigation options in this study fall under the two basic categories namely *maintaining existing stocks* and *expanding carbon sinks*. These are described below:

a) Maintaining existing stocks

Under this category fall forest protection and conservation and increased efficiency in forest management, harvesting and utilisation of forest products. Measures in this category will aim to increase biomass stocks so as to reduce the current deficit. These measures are expected to increase forest land area (or biomass stocks) by 42,000 ha (2 million tonnes) by 2010 and 10 million ha (516 million tonnes) by 2030 (Tables 5.4 & 5.5).

Measures in this category include increased efficiency in forest management, harvesting and utilisation of forest products which comprise reduced land clearing for agricultural purposes, timber and woodfuel production.

b) Expanding carbon sinks

This mitigation option category aims at increased forest woody biomass for expanded carbon sequestration. Many options can be considered, but only two are considered feasible in Zambia, namely enhanced natural regeneration and re-afforestation. The high rate of forest land clearing that has occurred over time has left substantial pieces of land bare. These can be planted with trees. Areas cleared for woodfuel, for example, have a great chance of regeneration if proper management is undertaken to aid coppicing stumps. One of the options is proper control of forest fires.

Under natural regeneration, it is estimated that 24,000 ha can effectively regenerate by 2005. This figure is about half the current estimated annual forest land area cleared for charcoal production. It is estimated that effective natural regeneration will cover 7 million ha by 2030. In terms of biomass stocks, 648,000 tonnes and 100 million tonnes are expected to be generated by 2010 and 2030 respectively.

Only moderate re-afforestation, about 5,000ha, is proposed here. This is expected to produce 2 million tonnes of biomass by 2030.

Table 5.4 Forest land area gains from mitigation measures, '000 ha

		1995	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
Forest Protection (Reduced forest land clearing)	Potential penetration				421.5	2,961	7,356.5	12,941.5	20,665.5
	Actual penetration, %				10	25	40	50	50
	Actual penetration				42	740	2,942	6,471	10,333
Enhanced Natural Regeneration	Potential penetration			242.2	1,212	2,537	4,000	5,619.5	7,418.5
	Actual penetration, %			10	25	40	50	50	50
	Actual penetration			24	303	1,015	2,000	2,810	3,709
Re-afforestation			5	30	35	40	45	50	55
Total			**5**	**54**	**380**	**1,795**	**4,987**	**9,331**	**14,097**

Table 5.5. Woody biomass gains from mitigation measures, 000t

	1995	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
Forest Protection (Reduced forest land clearing)				2,100	37,000	147,100	323,550	516,650
Enhanced Natural Regeneration			648	8,181	27,405	54,000	75,870	100,143
Re-afforestation		210	1,260	1,470	1,680	1,890	2,100	2,310
Total		**210**	**1,908**	**11,751**	**66,085**	**202,990**	**401,520**	**619,103**

Effects of mitigation options in the forest sector are also shown in Figures 5.6 and 5.7.

Figure 5.6 Annual land clearance, regeneration and cumulative deforestation ('000 ha)

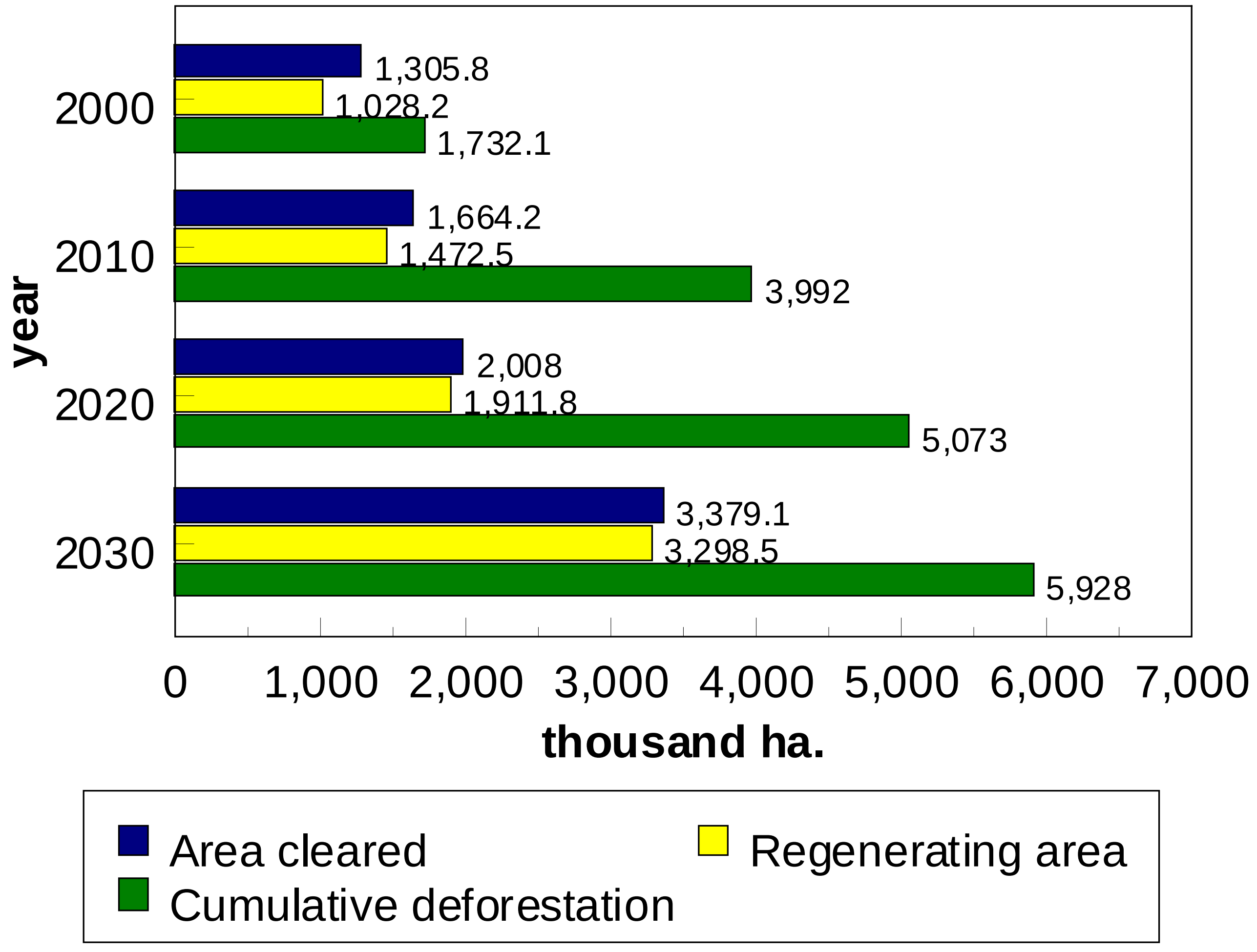
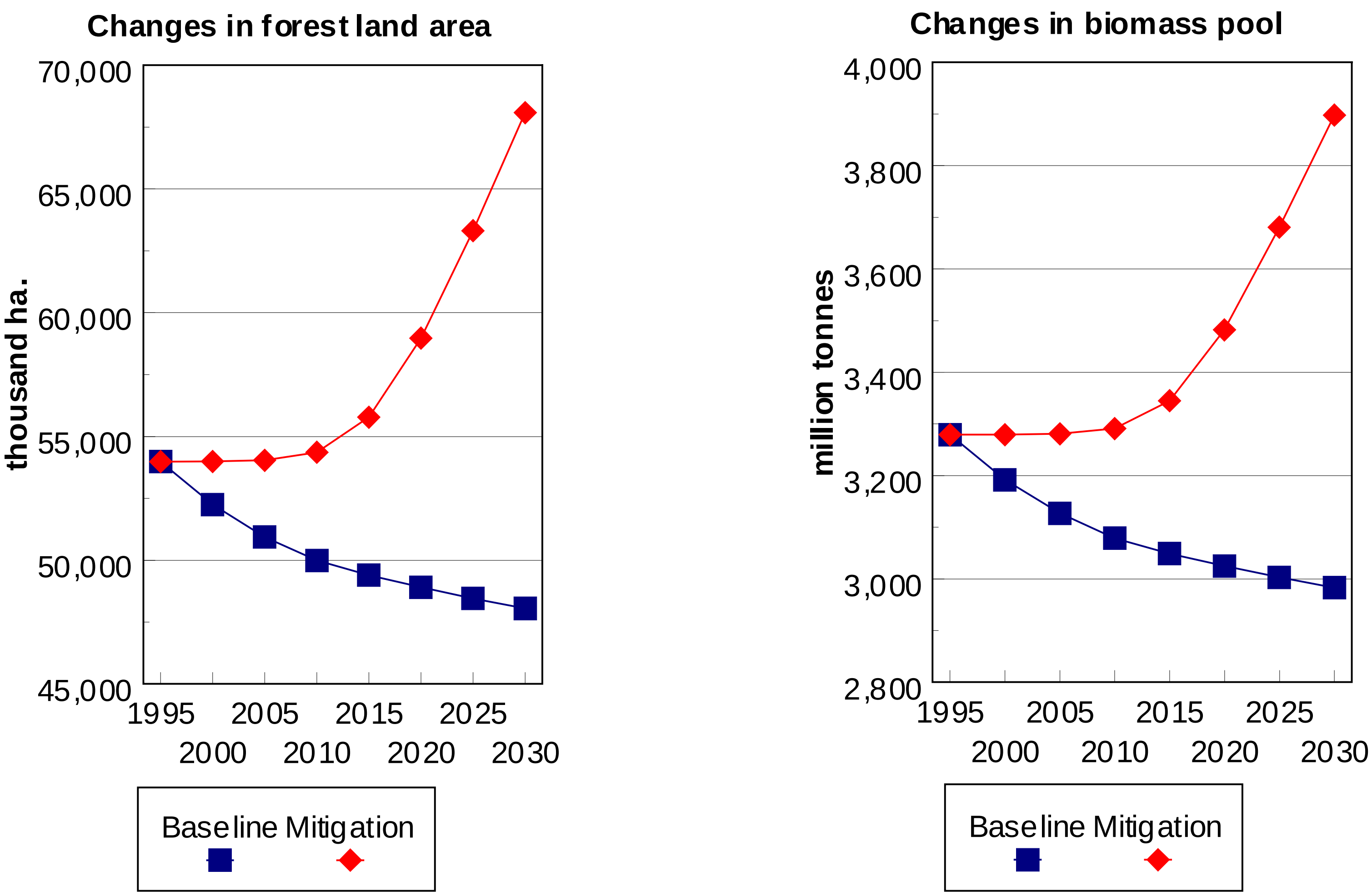


Figure 5.7 Changes in forest land area and woody biomass under baseline and mitigation scenarios



5.2.2 Characteristics of Mitigation Options

a) Forest Protection

This option ensures that the area under national parks remains at 5,942, 000 ha up to the year 2030. It also includes increased efficiency in forest management, harvesting and utilisation of forest products.

Under the latter sub-category, the goal is to reduce deforestation to the barest minimum. This includes production of firewood, charcoal, timber and clearing for agriculture. Underlying assumptions here are:

i) Charcoal Production Efficiency in the Earth Kiln

Charcoal conversion efficiency in the earth kiln increases by 8% (from 20% to 28%). Such efficiency increase become effective by the year 2002.

The bulk of the charcoal in Zambia is produced in the earth kiln.Currently this is a preferred low cost option for producing charcoal (Hibajene & Kalumiana, 1996). The fact that there is great demand for charcoal in urban areas of Zambia has attracted more people who engage in production, often with less success in terms of production efficiency.

A study conducted in Zambia revealed that production efficiency in the earth kiln can be as high as 28%, by adopting simple management techniques (Hibajene, 1994). Current production efficiency is estimated to be 20%. A 10% increase in efficiency is therefore possible.

The five year programme to increase efficiency using the *Manual for Charcoal Production in the Earth Kiln* is proposed here. This programme is expected to cost US$0.5 million (see Appendix V for detailed calculations).

ii) Woodfuel End-use Efficiency

Woodfuel (charcoal & firewood/fuelwood) end-use efficiency can be increased by the use of efficient stoves. In this study, it is assumed that charcoal end-use efficiency increase by 10% (from about 15% to 25%) by the year 2002 and remain the same during the target period. It is difficult at this stage to determine the increase in firewood end-use efficiency arising from a stove programme. It is however assumed that annual increase in firewood consumption decreases from 2.4% to 2% by the year 2002.

As indicated earlier, this option will entail production of 250,000 improved stoves by the year 2010, through establishment of a medium scale factory for this purpose.

This programme will initially focus on identifying firewood and charcoal stoves that can be successfully disseminated in Zambia. While charcoal stoves are suitable for large urban areas, firewood stoves will be targeted for small towns. Wood stoves will most likely not be adopted in rural areas (villages) on account of (high) stove prices. In most rural areas, firewood is collected (and not bought) and is therefore considered free. In small towns, however, firewood is purchased. Consumers can therefore see the need to use stoves more efficiently than the 3 stone fire to save on fuel costs.

This programme is expected to cost US$1.5 million to cover establishment of the factory and promotional costs as shown in Appendix V.

iii) Natural Timber

Data analysis carried out during this study shows that forest clearing is the second largest contributor to deforestation in Zambia accounting for slightly over 15% of total deforestation. This scenario is brought mainly by the inherent inefficiencies in the processing of timber by pit-sawyers and other small-scale wood processors.

Investments in new machinery, wood preservation as well as financing for small scale entrepreneurs can result in a decrease in forest land clearing for timber in the order of 2% per annum. This is the figure used throughout the target period, starting in the year 2005. The estimated investments requirements totalling USD 5.0 million are summarised in Appendix V.

iv) Clearing Land for Agriculture

Shifting and semi-permanent agriculture contribute the largest proportion to total deforestation. A programme to reduce deforestation arising from the agricultural sector will include the following aspects:

- Field extension to disseminate environmentally friendly ways of agricultural tillage. This will also include encouragement to become permanent cultivators.
- Support to farmers in terms of fertilisers and other farming implements.

It is estimated that such a programme can have a 10% reduction land clearing for the agricultural sector by the year 2002 (8% & 2% decrease in land cleared for chitemene and semi permanent cultivation respectively). This decrease will continue at the rate of 0.5% per annum after 2002. Farmers will adopt of more use of fertilizers in the sector and become more permanent cultivators. The programme is estimated at US$10 as summarized in Appendix V.

b) Enhanced Natural Regeneration

Current forest land clearance for timber, firewood and charcoal would not lead to much increased deforestation if management practices promoted natural regeneration. Often times fire destroys over 50% of regenerating biomass. The following is the scenario under this option:

Objective: All land cleared under non-destructive methods to be managed for natural regeneration.

Assumptions:

i) Land cleared for charcoal and commercial firewood is not used for other uses, e.g agriculture

ii) Land cleared only once for charcoal and commercial firewood

iii) Land cleared for timber is not cleared for any other purposes

iv) Regeneration occurs in Land cleared for shifting and semi-permanent agriculture

v) Fire management in cleared areas for charcoal, firewood and timber achieves 75% savings in regenerated biomass

The above scenarios are assumed to take effect by the year 2005.

This programme will aim at increasing efforts to manage cleared areas either for woodfuel, timber or other clearing end-uses where only above ground woody biomass is removed. This programme will include early burning practices in order to protect regrowth and seedling development.

To ensure enhanced natural regeneration, local communities have to be empowered and/or encouraged to participate in forest management. This is so because the Forest Department does not have the capacity to effectively manage forest resources on its own. Such a programme is estimated to cost US$2 million over the target period as shown in Appendix V.

c) Re-afforestation

This measure will be aimed at increasing land under forest cover by converting bare land to forest land. Five thousand (5,000 ha) ha are expected to be covered every year starting from the 2005.

To achieve this, investment of about US5 million is required as shown in Appendix V.

5.3 Assessments using the Comprehensive Mitigation Analysis Process (COMAP)

5.3.1 Impacts on Biomass Pool

Analysis under this component estimate changes in biomass (carbon) during the target period, considering all mitigation options. The COMAP model has 2 basic outputs under this sub-component of the analysis, which are:

i) It estimates the biomass (carbon) stock during the target period (1990-2030) under baseline and mitigation scenarios.

ii) It estimates biomass supply vs demand for the period 1990, 2010 and 2030 under the two scenarios.

Figure 5.7 shows changes in forest land area and woody biomass under baseline and mitigation scenarios. It is clear that under mitigation there is a decline in biomass pool due to the effect of deforestation as shown earlier under baseline scenario. With implementation of mitigation options, the results show a positive scenario for biomass/carbon pool.

5.3.2 Forest Protection

Model results

Step 6.1 Total Carbon Pool (tC)

Annual incremental C protected	2,445,688,766
Baseline Scenario Carbon	0
Mitigation Scenario. C	2,445,688,766

Step 6.2 Total costs & benefits of C Sequestration ($)

Incremental net cost	295,388,320
Baseline Sce. benefit	208,978,4602
Cost	1,744,049,478
Benefit from land conversion	208,978,460
Benefit from forest	1,744,049,478
Mitigation Sc. benefit	504,366,780
Cost	1,227,126,455
Alternative supply of imported products	219,427,383
Benefit	1,950,920,618

Step 7: Cost Effectiveness indicators

Net present value of benefits	$/tC	0.12
	$/ha	22
Benefit of reducing Atms. Carbon (BRAC)	$/tC-yr	0.009
Initial cost	$/tC	0.027
	$/ha	5
Endowment (present value of costs)	$/tC	0.50
	$/ha	92

Under this programme the initial costs are estimated as $5/ha and $0.027 per tonne of C saved. When these are considered over the target period and calculated as present costs, the investments required become $92 per ha and $0.50 per tonne of CO_2 saved.

5.3.3 Forest Re-afforestation

Reforestation with exotic tree species shows a high investment cost of $3.40 per tonne of CO_2 saved and $160 per ha.

5.3.4 Natural Regeneration

Natural regeneration under good management conditions shows a negative investment cost of $-0.04 per tonne of CO_2 saves and $7 per ha of regenerating woodland.

5.3.5 Ranking of Forestry Mitigation Options

Table 5.5 shows a summary of the three mitigation options considered namely forest protection, natural regeneration and re-afforestation. Natural regeneration is the least costly of all the options followed by forest protection.

Table 5.5 Ranking of forestry mitigation options

Mitigation Option	**Cost of saving 1 tonne of CO_2 ($)**	**Investment cost/ha ($)**
Forest Protection	0.50	92
Natural regeneration	-0.04	7
Re-afforestation	3.40	160

6 Macro-Economic Assessment

The macroeconomic impact assessment of the projects recommended for implementation was undertaken as part of sustainable development and greenhouse gas limitation strategies for Zambia. In view of the difficulties associated with data collection on the issue, an attempt has been made in this study to carry out a qualitative assessment.

The projects under consideration as already indicated in the previous sections are from the energy and forestry sectors. In the energy sector, the projects are basically meant to reduce emissions and promote sustainable development through increased efficiency and fuel substitution. The need to expand the utilisation of renewable energy resources such as hydro is emphasised in view of the excess capacity Zambia has. The socio-economic and environmental benefits of forestry sector projects are also assessed in this study.

6.1 Household Energy Project

The project is recommended with a view to increase efficiency in the use of fuelwood and fuel substitution by the households in the urban and rural areas. The study recommends the increase in the use of electric stoves for cooking purposes by the urban households. The health aspects of such an action are beneficial as it reduces indoor pollution and associated ailments. The switch from use of charcoal stove to electric stove, which is emission free, provides a smokeless cooking environment for the households thereby freeing them from smoke related ailments. Switching to the use of coal briquettes and to a higher efficient charcoal stove will also lessen emissions thereby contributing some improvements in health effects.

The employment effects are moderate. Jobs will be created by virtue of the introduction of a medium-sized manufacturing facility to manufacture these stoves. The other effect will be on the household's incomes. The stoves being recommended in this project have relatively high efficiency and as such will result in some savings on consumption. The other effects of implementing this project are summarized in Appendix VI. Introduction of electric stoves will no doubt contribute to reduction of the work force in the charcoal industry currently estimated at over 50,000 people.

6.2 Ethanol Production

The employment effects of implementing this project are moderate. The prospects of setting up a sugar plantation and a processing facility will create several jobs. Savings on the huge petroleum bill will be achieved in the long run as a result of blending some of the gasoline with the ethanol for engine propulsion in vehicles. The fact that this project will be implemented in one of the mostly rural areas of Zambia, social conditions will definitely improve as a result of the many amenities which will result through the implementation of this project. Potential for exporting sugar in the region is quite high and as such foreign exchange earnings will rise (Appendix VI).

6.3 Electric Boilers

The replacement of solid and liquid fuel fired boilers with electric ones is seen in the light of improving the end use efficiency of these devices. Electric boilers allow for more efficient energy use. This measure will impact on firms in the sense that their competitiveness will increase as a result of using an efficient source of energy. The effect on health are also high since emissions are being reduced by switching to electricity fired boilers. The effects on employment are moderate. At the same time, ZESCO will improve on its capacity utilisation in view of the increased use of the excess capacity available. The other beneficial effects are summarized in Appendix VI.

6.4 Cement Production

The introduction of a more efficient means of producing cement will have an effect of increasing the competitiveness of the firm thereby promoting low cost production. This will increase productivity of which will result in increased savings of foreign exchange for materials (Appendix VI).

6.5 Improved Maintenance of Government Vehicles

The employment effects of this measure are quite moderate. High effects will be felt on savings on consumption of energy in the Government and service sector. The savings in consumption will ultimately result in savings of foreign exchange earnings and also increase the Government's revenue base (Appendix VI).

6.6 Forestry Projects

Apart from employment effects, to be manifested through implementation of forestry projects, forestry based projects have great potential in increasing biomass pool capacity which ultimately can contribute to reduction of global warming through increased sinks.

7 Implementation Issues

Although there is no climate change policy in Zambia, elements of the national energy policy and forest action programme are considered adequate in the process of establishing a consistent national climate change policy to achieve a base for implementing identified mitigation projects.

Existing energy policies and forestry action programmes contain implicit mitigation options which if implemented will go a long way in contributing towards the reduction of CO_2 emissions and enhancement of sinks. For example, to implement projects for energy substitution and efficiency in the household sector requires establishment of a medium sized manufacturing facility with modest and modern equipment and machinery for the manufacture of improved charcoal stoves, two plate efficient electric stoves and coal briquette stoves. Estimated investment cost for such a facility is given as USD 1.0 million. Such a facility will enable such households cooking devices to be produced in reasonable quantities and of reasonable quality and price affordable to most of the stakeholders in this sector.

The Luena Sugar Project in Luapula Province under consideration for production of sugar, ethanol and electricity has far-reaching developmental, socio-economic and environmental benefits. The investment cost for establishing such a project is estimated at USD 10.0 million. Although the project is marginally viable form the financial viewpoint, it should be considered more form the developmental perspectives in view of social and economic benefits which will accrue in the area.

Production of coal briquettes will require establishment of a coal briquetting plant. The coal briquetting plant has an estimated investment cost of USD 5.0 million. The cost of implementation can be reduced further if plans by Kabwe Power and Metal Company to produce an estimated 100,000 tonnes of coal briquettes come to fruition. The company which has taken over some of the assets of the now defunct ZCCM lead and zinc mine in Kabwe has plans to use the existing carbonisation plant, but will require only compacting and other associated equipment to reduce the investment cost.

On the energy supply side, electricity demand is expected to outstrip supply by the year 2012. This is likely to occur following the expected turn around in the economy as a result of liberalisation and privatisation policies put in place by Government. Another contributing factor will be the increase in electricity use resulting from ZESCO’s programme to electrify 20,000 houses annually in the next 10 years. In view of this, and because of the long lead times of power-supply developments, it is essential that investments are put in place at an appropriate time. The projects to be considered are the development of Kafue Lower Project with 450 MW at an estimated cost of USD 450 million and Itezhi-Tezhi project with 80 MW at an estimated cost of USD 7.5 million

In the forest sector, financial support will be required particularly to Government for the implementation of reforestation, natural regeneration and forest protection programme estimated at almost USD 50.0 million.

Although some of these projects sound promising, actual implementation poses immense difficulties. Barriers to implement have been identified as lack of financial resources for both project implementation, and for low-income earners to afford purchase of electric stoves in particular, despite ZESCO's electrification programme, public awareness and marketing strategies. To address some of these issues, the following proposals are recommended:

- creation of an enabling environment in the energy sector and encouragement of private sector to implement some of these projects
- provision of financial resources to upcoming entrepreneurs for implementation of projects in the energy sector
- provision of financial support to Government to implement forest based protection programme
- formulation of a financing recovery scheme to assist low income earners purchase the introduced efficient and improved cooking devices.
- raise public awareness and support for mitigation measures and promote active information policy.
- devise a marketing strategy for dissemination of efficient and improved household cooking devices.

8 References

Chidumayo, E.N. and Chidumayo, S.B.M. The Status and Impact of Woodfuel in Urban Zambia. Department of Natural Resources, Lusaka, 1984.(Internal Report)

Centre for Energy, Environment and Engineering (CEEEZ), World Bank Study on the survey of boilers in Zambia, 1997. World Bank

Central Statistical Office, Zambia in Figures, 1995

Central Statistical Office, Zambia in Figures, 1996

Department of Energy, Energy Statistics Bulletin, 1996.

GTZ (1995). Zambia Country Study on Climate Change, Inventories and Mitigation Analysis, GTZ and Ministry of Energy and Water Development, GTZ Publication, 1995.

Hibajene, S. 1994

Hibajene, S. and Kalumiana, O.S. 1999

Intergovernmental Panel on Climate Change (IPCC) Guidelines For National Greenhouse Gas Emissions, 1996.

Kalumiana, O.S. Unpublished Emissions, 1996.

Kalumiana, O.S., Unpublished, 1994

Kaoma, J., Klengel D., Feasibility Study Report on the Construction of 100,00 tonnes/Year Coal briquettes Plant at Kabwe, 1997. National Council for Scientific Research.

Mackenzie, J, et al., The Potential for Growth in Zambia's Agricultural Sector: A Quantitative Assessment, 1990. Ministry of Agriculture. Internal Report

Markandya, A., The Indirect Costs and Benefits of Greenhouse Gas Limitation, 1998, Paper presented at the UNEP/GEF Economics of Greenhouse Gas Limitation Workshop, Helsingør, April, 1998

Sikabanze, M.A., An Overview of Zambia's Economic Development, Paper Presented at a Workshop on Climate Change in Southern Africa, Livingstone, September 1996.

UCCEE (1995) "Climate Change Mitigation in Southern Africa. Methodological Development, Regional Implementation Aspects, National Mitigation Analysis and Institutional Capacity Building in Botswana, Tanzania, Zambia and Zimbabwe. Phase 1". UNEP Collaborating Centre on Energy and Environment, Risø National Laboratory, Denmark. August 1995.

Zambia Medium Term Plan, 1998 - 2000

Appendices

Appendix I: Input Data

i) Energy intensities by sector

Device	Energy Intensity (GJ/Device)
Household Sector	
Electric Stove	26.280
Mbaula	46.090
Improved Mbaula	23.045
Firewood Stove	127.910
Kerosene Stove	89.900
Coal Briquette Stove	29.730
Industry/Commerce Sector	
Electric fired Boiler	5,054
Coal fired Boiler	29,565
Fuel Oil Fired Boiler	73,632
Diesel/Gasoil Fired	24,478
Cement Production	4.76
Government/Service Sector	
Petrol Propelled Engine	0.0067
Diesel Propelled Engine	0.0057
Ethanol Blend	0.00603
Transport Sector	
Petrol Propelled Engine	0.0067
Petrol Ethanol Blend Engine	0.00603

ii) Assumptions in the model

Country:	Zambia	
Currency:	USD	
Exchange rate : 1 US$ =	1.0	USD
Discount rate =	10.0%	

Emission factors: kg/GJ	CO_2	CH_4	N_2O
Fuel oil	77.4	0.002	0.0006
Diesel oil	74.1	0.002	0.0006
Gasoline	69.3	0.020	0.0006
Kerosene	71.9	0.007	0.0006
Charcoal	80.0	0.001	0.0006
Firewood	110.0	0.004	0.0001
LPG	63.1	0.001	0.0006
Natural gas	56.9	0.004	0.0001
Coal to power plants	94.6	0.001	0.0014
Coal to industry	94.6	0.010	0.0014
Hardcoal briquette	108.0	0.010	0.0014
Wood	0.0	0.300	0.0040
Ethanol	42.8	0.000	0.0000
Ethanol-Gasoline Blend	56.0	0.010	0.0003
Electricity	0	0	0
Renewable	0	0	0
South African coal	94.6	0.001	0.0014

iii) Real energy prices in Zambia in USD

YEARS	Coal to Industry USD/GJ	Diesel Oil USD/GJ	Petrol USD/GJ	Kero-sene USD/GJ	Charcoal USD/GJ	Firewood rural USD/GJ	Electricity Domestic USD/GJ	Woodfuel for Charcoal USD/GJ	Hardcoal briquette USD/GJ	Ethanol Blend USD/GJ
1995	0.25	9.66	5.75	6.03	2.15	0.08	1.92	0.27	3.38	6.29
1996	0.25	9.95	5.92	6.21	2.17	0.08	1.98	0.27	3.38	6.29
1997	0.25	10.25	6.10	6.40	2.20	0.09	2.04	0.27	3.38	6.29
1998	0.26	10.56	6.28	6.59	2.22	0.09	2.50	0.27	3.38	6.29
1999	0.26	10.88	6.47	6.79	2.24	0.09	2.16	0.27	3.38	6.29
2000	0.26	11.20	6.66	6.99	2.26	0.09	2.22	0.27	3.38	6.29
2001	0.26	11.54	6.86	7.20	2.29	0.09	2.29	0.27	3.38	6.29
2002	0.27	11.89	7.07	7.42	2.31	0.09	2.36	0.27	3.38	6.29
2003	0.27	12.24	7.28	7.64	2.33	0.09	2.43	0.27	3.38	6.29
2004	0.27	12.61	7.50	7.87	2.35	0.09	2.50	0.27	3.38	6.29
2005	0.27	12.99	7.33	8.10	2.38	0.09	2.58	0.27	3.38	6.29
2006	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2007	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2008	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2009	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2010	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2011	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2012	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2013	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2014	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2015	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2016	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2017	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2018	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2019	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2020	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2021	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2022	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2023	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2024	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2025	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2026	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2027	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2028	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2029	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
2030	0.28	12.99	7.33	8.10	2.40	0.09	2.58	0.27	3.38	6.29
Levelized	0.27	12.00	6.99	7.48	2.37	0.09	2.41	0.28	3.49	6.50

iv) Other prices (costs) used in the analysis

OPTION	INVESTMENT COST USD		PROJECT LIFE (YEARS)		ANNUAL O & M %		UNIT FUEL CONSUMPTION GJ PER ANNUM	
	BASE	MITIG	BASE	MITIG	BASE	MITIG	BASE	MITIG
Replacement of coal fired boilers	100,000	5,000	15	10	10	10	20,565	5,054
use of improved stoves	6	3	4	3	1	1	-	23.045
use of coal briquette stoves	6	3	4	3	1	1	-	29.730
replacement of diesel fired boilers	100,000	5,000	15	10	10	10	24,478	5,054
replacement of fuel oil fired boilers	100,000	5,000	15	10	10	10	73,632	5,054
ethanol blend	5,000,000	15,000,000	10	10	10	10	7,609,000	7,460
improved vehicle maintenance	15,000	15,000	8	5	5	10	131,722	187,753

Input data given in the table above (i.e. investment, project life, O&M and unit fuel consumption for baseline and mitigation scenarios) is required in determining CO_2 emission reductions between baseline and mitigation scenarios. It is also used in determining the cost of reduction of each mitigation option.

Appendix II: Baseline Energy Demand

Fuel by Sector for 1995 and Projections for 2010 and 2030 (PJ)

1995

Fuel	Household	Industry/ Commerce	Govt Service	Agriculture	Mining	Transport	Total
Electricity	4.37	1.77	1.90	0.70	17.88	0.04	**26.66**
petrol	0.00	0.64	0.19	0.03	0.05	5.23	**6.13**
Aviation Fuel	0.00	0.00	0.00	0.00	0.00	1.14	**1.14**
Kersosene	0.83	0.06	0.02	0.00	0.24	0.00	**1.14**
Diesel/Gas Oil	0.00	1.24	0.32	0.31	2.92	6.70	**11.50**
Fuel Oil	0.00	3.74	0.32	0.00	0.90	0.00	**4.96**
LPG/Bottled Gas	0.00	0.05	0.01	0.00	0.00	0.00	**0.05**
Bitumen	0.00	0.15	0.00	0.00	0.00	0.00	**0.15**
Coal	0.00	3.07	1.23	0.00	1.22	0.00	**5.52**
Firewood	104.80	9.94	0.00	4.17	0.00	0.00	**118.91**
Charcoal	21.25	0.85	0.00	0.00	0.03	0.00	**22.14**
Total	**131.25**	**21.51**	**3.99**	**5.21**	**23.23**	**13.1**	**198.29**

2010

Fuel	Household	Industry/ Commerce	Govt Service	Agriculture	Mining	Transport	Total
Electricity	6.89	5.52	3.29	1.21	33.33	0.06	**50.3**
petrol	0.00	1.93	0.57	0.04	0.08	10.17	**12.79**
Aviation Fuel	0.00	0.00	0.00	0.00	0.00	1.52	**1.52**
Kersosene	3.36	0.18	0.04	0.01	0.44	0.00	**4.03**
Diesel/Gas Oil	0.00	2.91	0.97	0.52	5.23	9.00	**18.63**
Fuel Oil	0.00	8.75	0.56	0.00	1.67	0.00	**10.98**
LPG/Bottled Gas	0.00	0.14	0.01	0.00	0.00	0.00	**0.15**
Bitumen	0.00	0.49	0.00	0.00	0.00	0.00	**0.49**
Coal	0.00	8.50	2.05	0.00	2.19	0.00	**12.74**
Firewood	152.87	17.25	0.00	7.23	0.01	0.00	**177.36**
Charcoal	32.08	1.48	0.00	0.00	0.06	0.00	**33.62**
Total	**195.2**	**47.15**	**7.49**	**9.01**	**43.01**	**20.75**	**322.61**

2030

Fuel	Household	Industry/ Commerce	Govt Service	Agriculture	Mining	Transport	Total
Electricity	17.01	25.22	6.86	2.52	76.46	0.09	**128.16**
Petrol	0.00	8.38	2.47	0.08	0.18	24.70	**35.81**
Aviation Fuel	0.00	0.00	0.00	0.00	0.00	2.26	**2.26**
Kersosene	5.64	0.84	0.08	0.01	1.00	0.00	**7.57**
Diesel/GasOil	0.00	9.02	4.22	1.04	11.42	13.34	**39.04**
Fuel Oil	0.00	27.15	1.17	0.00	3.83	0.00	**32.15**
LPG/Bottled Gas	0.00	0.65	0.03	0.00	0.00	0.00	**0.68**
Bitumen	0.00	2.35	0.00	0.00	0.00	0.00	**2.35**
Coal	0.00	34.58	4.07	0.00	4.77	0.00	**43.42**
Firewood	245.52	35.94	0.00	15.06	0.01	0.00	**296.53**
Charcoal	61.91	3.08	0.00	0.00	0.14	0.00	**65.13**
Total	**330.08**	**147.21**	**18.90**	**18.71**	**97.81**	**40.39**	**653.1**

Appendix III: Determination of the Equivalent Energy Requirements

In order to determine the mitigation advantage of using coal briquettes for fuel over charcoal, experiments can be carried out in which the amount heat required to boil a given amount of water is established. Such experiments are called water-boiling tests (WBTs). If the mass of water (m_w) is taken to be 1kg, being heated at room temperature (T_r=25°C) to boiling temperature (T_b=100°C), the amount of fuel required can be determined from:

$\eta = m_w \times C_p \times (T_b - T_r)/(m_f \times CV)$……………………………….(1)

where:

η = thermal efficiency of fuel
C_p = specific heat capacity of water (ca. 4,200 J/kg°C)
m_f = mass of fuel if used
CV = calorific value of fuel used
(CV = 30.4 MJ/kg for charcoal and 25.2 MJ/kg for coal briquettes).

The following are the acceptable ranges of thermal efficiencies:

Stove	η%
Ordinary traditional (mbaula)	10 - 15
Improved mbaula	22 - 25
Clay stove	25 - 30

Three cases have been considered in this project:

I. charcoal and coal briquette performance in ordinary mbaula.

II. charcoal and coal briquette performance in improved mbaula.

III. charcoal and coal briquette performance in clay stove.

The following performance results are obtained when 1kg of water is heated from room temperature to boiling temperature (shown in Table below).

Performance of charcoal and coal briquettes

Case	η%	m_f (g)	CO_2 emissions (g)	% reduction
Ordinary mbaula				
Charcoal	13	79.7	204.6	3.4
Coal briquettes	13	96.2	197.5	
Improved Mbaula				
Charcoal	23	45.1	115.8	3.7
Coal briquettes		54.3	111.5	
Clay Stove				
Charcoal	29	35.7	91.6	3.4
Coal briquettes	29	43.1	88.5	

Notes:

(i) The values of m_f are determined from equation below:

$$m_f = m_w \times C_p \times (T_b - T_r)/(\eta \times CV)$$

Thus, for the case of the improved mbaula, with n = 0.23, we have:

$m_{fmb} = (1) \times (4{,}200) \times 75/(0.23 \times 30.4 \times 10^6) =$ 0.04505 kg for charcoal

$m_{fcb} = (1) \times (4{,}200) \times 75/(0.23 \times 25.2 \times 10^6) =$ 0.05434 kg for coal briquettes

(ii) Knowing the amount of fuel required, m_f, the corresponding amounts of carbon dioxide emissions can be determined.

Comparison of Emissions

Both charcoal and coal briquettes burn according to reaction 2 as shown below.

$$C + O_2 \rightarrow CO_2 \qquad (2)$$

Knowing that charcoal and coal have a carbon content of 70% and 56% respectively, and using the amounts of fuel (m_f) calculated in Table A1 per kilogram of water boiled, we can determine the amount of CO_2 emissions (X_{CO2}) from the following relationship:

$$X_{CO2} = p \times m_f \times (44/12) \qquad (3)$$

where, p = fractional carbon content.

Thus, for the case of improved mbaula, we have m_f = 45.1g for charcoal and m_f = 54.3g for coal briquettes, which gives:

$X_{CO2} = 0.7 \times 45.1 \times (44/12) = 115.8$g for charcoal

$X_{CO2} = 0.56 \times 54.3 \times (44/12) = 111.5$g for coal briquettes

The estimated weekly consumption of charcoal by an average family is 50kg. This is equivalent to 60.2kg of coal briquettes. The corresponding CO_2 emissions per week are 128.33kg for charcoal and 123.61kg for coal briquettes.

Appendix IV: Mitigation Options and Associated Emission Reduction Costs

Reduction option	US$/ton$CO_2$	Unit Type	Emission Reduction t CO2/unit	Units Penetrating in 2010	Reduction in 2010 Mill.t/year	Cumulative Reduc. 2010 Mill. t/year	Reduction in 2010	Units Penetrating in 2030	Reduction 2030 Mill. t/year	Cumulative Reduc 2030 Mill. t/year	Reduct. in 2030
Improved vehicle maintenance - Diesel	-1,126.55	Kilometres	0.00008	102,080,000	0.0084	0.0084	0.2903%	223,686,480	0.02	0.02	0.30%
Improved vehicle maintenance - Petrol	-473.79	Kilometres	0.00011	50,740,000	0.0054	0.0138	0.48%	111,173,520	0.01	0.03	0.50%
Ethanol Blend	-97.04	Kilometres	0.000070	1,016,720,000	0.0712407	0.09	2.94%	1,666,000,000	0.12	0.15	2.42%
Use of Improved Stoves	-29.11	Stoves	1.85	250,000	0.46	0.55	18.96%	410,000	0.76	0.91	14.90%
Efficent boiler in industry (1)	-12.16	Boiler (Diesel)	1,818.90	53	0.10	0.64	22.29%	26	0.05	0.95	15.68%
Use of Coal Briquette Stoves	-11.97	Stoves	0.40	100,000	0.04	0.68	23.66%	150,000	0.06	1.01	16.65%
Increase Use of Electric Stoves	-10.55	Stoves	3.70	500,000	1.85	2.54	87.72%	1,300,000	4.81	5.83	95.82%
Efficient boiler in industry (3)	-3.87	Boiler (fuel Oil)	5,716.86	39	0.22	2.76	95.44%	19	0.11	5.93	97.61%
Cement Production	9.14	tonnes cement	0.10	513,000	0.05	2.81	97.19%	1,125,000	0.11	6.05	99.43%
Efficient boiler in industry (2)	14.74	Boiler (Coal)	1,959.80	39	0.08	2.89	99.83%	19	0.04	6.08	100.05%

Total reduction in 2010: 2.89 tonnes **Total reduction in 2030:** 6.08 tonnes

Appendix V: Summary of costs associated with mitigation options

	Programme	Costs	US$
1	Charcoal production efficiency in the earth kiln	• Personnel • Charcoal Manual Reprints • Equipment Support • Field Demonstrations **Total**	100,000 100,000 100,000 200,000 **500,000**
2	Woodfuel end use efficiency	• Personnel • Stove testing and marketing • Field Demonstrations **Total**	300,000 200,000 500,000 **1,000,000**
3	Natural Timber	• Personnel • Mill machinery and wood preservation • Financing & training for small scale entrepreneurs **Total**	400,000 2,000,000 2,600,000 **5,000,000**
4	Clearing Land for agriculture	• Personnel & support equipment • Extension services • Support to farmers in implements & input **Total**	1,000,000 2,000,000 7,000,000 **10,000,000**
5	National Parks	• Personnel & support equipment • Extension services • Support to community conservation efforts **Total**	1,000,000 2,000,000 2,000,000 **5,000,000**
6	Enhanced natural regeneration	• Personnel • Equipment support • Extension services • Support to local communities **Total**	500,000 300,000 700,000 500,000 **2,000,000**
7	Re-afforestation	• Personnel • equipment support • Extension services • Research support(including inputs like seed) • Communities institutional support **Total**	2,000,000 1,000,000 3,000,000 6,000,000 3,000,000 **15,000,000**

Appendix VI: Qualitative Assessment of Macro-Economic Impacts

Option	**Impacts**							
	Emploment	**Savings on Consumption**	**Health Aspects**	**Improved Social Conditions**	**Foreign Exchange Savings**	**Export**	**Competitiveness**	**Internal Savings**
1. Household I) Electric Stove ii) Improved Stove iii) Coal briquette Stove	 M M M	 H H H	 H L L	 M M M	 N N N	 N N N	 N N N	 N N N
2. Ethanol production	H	M	M	H	M	M	N	N
3. Electric boilers	M	M	H	N	H	N	M	N
4. Cement production	H	N	L	N	M	H	M	N
5. Improved maintenance of govt vehicles	M	H	M	N	M	N	N	H

Classification: *L - Low*
M - Medium
H - High
N - None