PREPARED BY

Ministry of Mines, Environment and Tourism

ZIMBABWE'S INITIAL NATIONAL COMMUNICATION ON CLIMATE CHANGE

Prepared for the
United Nations Framework Convention on Climate Change

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Foreword

The signing and ratification of the United Nations Framework Convention on Climate Change (UNFCCC) by Zimbabwe is *prima facie* demonstration that we would like to preserve the global climate for the good of the present and future generations. The preparation of the initial National Communication by Zimbabwe not only contributes towards capacity building but also forms the basis for sustainable development. The efforts gone into the preparation of this initial National Communication were beset with a host of impediments such as nascent expertise to tackle various sections of the document as well as scanty data used to estimate the greenhouse gas emissions. This background setting explains why this initial attempt contains some assumptions when arriving at certain conclusions. It should not be expected to be a document with perfect science. After all, climate change as a discipline is still laden with considerable uncertainties resulting in large error margins.

This document goes beyond the simple mechanics of mere compliance with the UNFCCC obligations but also demonstrates that Zimbabwe is concerned with climate change-related inter-generational issues despite its low position in the global geopolitics of climate change.

The experience and lessons which Zimbabwe has gained in the preparation of this initial National Communication on Climate Change will become useful when we prepare our second generation of the same document. For example, in preparing this document, we foundout that our task would have been much easier had we established regularly updated data bases.

The other aspect of the National Communication lies in the fact that these reporting requirements are a useful means of encouraging national involvement by Parties to the Convention when climate change issues are publicly debated at international level. The long term perspectives of National Communication are that it forms the basis for identification of climate change projects and the expected investment so as to realise sustainable development.

Finally, some environmental analysts have observed that the threat of climate change is unique in the sense that it has the potential to bring together the diverse nations of the Earth to a convergence of interests. The continued practice of preparing National Communications by Parties to the Convention should facilitate this process.

Hon SK Moyo M.P.
Minister of Mines, Environment
and Tourism
March 1998

Acronyms

AEEI	Autonomous Energy Efficiency Improvement
AEC	Apparent Energy Consumption
AIJ	Activities Implemented Jointly
AvGas	Aviation Gas
AVHRR	Advanced Very High Resolution Radiometer
CCC	Canadian Climate Centre
CEF	Carbon Emission Factor
CF	Conversion Factor
CIDA	Canadian Internatinal Development Agency
COMESA	Common Market for East and Southern Africa
COP	Conference of the Parties
CSO	Central Statistical Office
CZI	Confederation of Zimbabwe Industries
DANIDA	Danish Internatinal Development Agency
DOC	Degradable Organic Component
DOE	Department of Energy
ESAP	Economic Structural Adjustment Programme
EU	European Union
FAO	Food and Agriculture Organisation
FAR	First Assessment Report
FCO	Fraction of Carbon Oxidised
FINESSE	Financing Energy Services for small scale Energy Users
GCM	General Circulation Models
GDP	Gross Domestic Product
GEF	Global Environment Facility
GFDL	Geophysical Fluid Dynamics Laboratory
GHG	Greenhouse Gas
GISS	Goddard Institute for Space Sciences
GOZ	Government of Zimbabwe

GTZ	Deutsche Gesellschaft Fur Technische Zusammenarbeit
ERSI	Environment and Remote Sensing Institute
IES	Institute of Environmental Studies
INC	Intergovernmental Negotiating Committee
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature and
Natural	Resources (World Conservation Union)
LPG	Liquified Petroleum gas
MOMET	Ministry of Mines, Environment and Tourism
NGO	Non-governmental Organisation
NOAA	National Oceanic and Atmopheric Administration
NRSE	New and Renewable Sources of Energy
ODA	Overseas Development Administration
PF	Power Factor
PV	Photovoltaic
PVP	Photovoltaic pumping
SADC	Southern African Development Community
SOI	Southern Oscillation Index
SCEE	Southern Centre for Energy and Environment
UCCEE	UNEP Collaborating Centre on Energy and Environment
UNDP	United Nations Development Programme
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate
Change	
UNITAR	United Nations Institute of Training and Research
USA	United States of America
WHO	World Health Organisation
WMO	World Meteorological Organisation
WWF	World Wide Fund for Nature
ZIMPREST	Zimbabwe Programme for Economic and Social Transformation

Executive Summary

1. Background

Global climate change is viewed as a serious issue by the Government of Zimbabwe. The Government signed the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 at the Rio Earth Summit and ratified it in November of the same year. The driving forces behind this concern stem not so much from problems of reducing Zimbabwe's emission of greenhouse gases (GHG), but rather the potentially serious impacts that global climate change might have on the country. By including climate change issues in the 1996 review of environmental legislation, Zimbabwe intends to incorporate climate change policies in its national development plans. Zimbabwe, like the rest of Africa, is constrained by its inability to put appropriate measures in place in order to respond to climate change requirements because of the lack of human, institutional and financial resources.

The national circumstances (summarised in Table ES2) of Zimbabwe are significantly influenced by its population distribution which is approximately 30% urban. The remaining 70% live either in rural areas or on commercial farms. The economy is heavily dependent upon renewable and non-renewable natural resources. The most important primary economic sectors are agriculture and mining. Manufacturing, which is the largest economic sector in terms of value added, has strong linkages with agriculture. Tourism-based on natural habitats, scenic areas and wildlife-is emerging as one area for growth in the next century. For the commercial sector, the primary energy sources are coal and hydroelectric power. Wood-fuel forms the main energy source for most rural people. Any future climate change policies in Zimbabwe will have to take into cognisance energy sources and their distribution as well as the differential socio-economic strata of the Zimbabwean population.

2. Greenhouse Gases (GHG) Inventory

Zimbabwe's GHG inventory includes carbon dioxide, (CO_2), methane (CH_4) and nitrous oxide (N_2O), as required by Second Conference of the Parties (COP2) guidelines. In addition, Zimbabwe is also reporting on nitrogen oxides (NO_x) and carbon monoxide (CO). National greenhouse gas emissions in Table ES 2 show that Zimbabwe is a net sink of CO_2 (-45 180.52 Gg).

3. General description of Steps: Programmes, Policies and Measures

Zimbabwe has made some progress in climate change issues. The pre- and post-Rio consultations, the climate change studies and legislative endeavours are some examples of how Zimbabwe has positioned itself in the global debate on climate change.

A number of mitigation options have been assessed for Zimbabwe. Due to resource constraints, however, little work has been done on policy options, the costs and benefits of these, or broader macro-economic interventions. The following possible measures are being considered for implementation:

■ I Industry

a) Introduction of More Efficient Coal-Fired Industrial Boilers:

The present efficiency of coal-fired boilers made in Zimbabwe is about 74%. It is possible to improve this efficiency to 80% through the introduction of soot blowers to clear steam pipe surfaces and thus increase heat transfer.

b) Increase the use of Hydro-Electricity:

This measure would reduce the use of coal- fired thermal stations which supply more than 50% of electrical energy used in Zimbabwe.

■ II Forestry

Introducing Afforestation for Carbon Sequestration:

Measures to control land clearing and thus enhance vegetation and forests as carbon dioxide sinks are part of carbon dioxide mitigation options. It is estimated that 7 million tonnes of carbon dioxide per ha in Zimbabwe per year are sequestrated (IPCC estimates for a growing forest - UNEP Studies, 1993)

■ III Agriculture

Introduction of Minimum Tillage:

This option is a way of abating GHG emissions associated with the use of diesel in commercial agriculture. Commercial farming in Zimbabwe entails ploughing and harrowing using tractors and other mechanised devices. Ploughing requires 31.8 litres of diesel per hectare. Studies have shown that zero tillage can be adopted for most crops without negative effects on crop yields.

■ IV Rural areas

a) Introduction of Biogas Digesters:

Wood burning in rural households is a major contributor to CO_2 emissions. The average consumption rate of wood per household is 12.0 kg per day. Biogas digesters use organic wastes derived from vegetation without the complete destruction of the nutrition in the vegetation. Biogas digesters can be used for lighting, cooking and refrigeration.

b) Photovoltaic Technology:

The Government has embarked on a programme to promote the use of solar panels in rural areas so as to minimise wood cutting for lighting purposes.

4. Energy and emissions projections

Official projections show that energy use will have doubled by the year 2010 and should increase by factors of 3 and 4 by 2030 and 2050 respectively. Between 2030 and 2050 there will be a decrease in per capita energy consumption due to expected energy efficiency improvements. During the same period energy demand will only increase by one-and- half times.

CO_2 emissions are expected to increase by 150% times by the year 2010 and by 250%

Summary Table

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and 300% by year 2030 and 2050 respectively. Methane emissions are expected to increase by 168% by 2010 and by 340% by 2050. This increase is attributed to the current trends in urbanisation and population growth.

5. Impacts

The geographical location of Zimbabwe in the tropics makes it vulnerable to climate change through shifting rainfall and agricultural patterns, water resources, vegetation and forestry. It is also vulnerable to high incidence of malaria cases. Adaptation measures are required to reduce the impact in some of the economic sectors referred to above. Critical areas of potential climate change impacts are related to water supply and food security. The country is already prone to droughts which have become more recurrent over the last two decades.

6. Research and systematic observations

Due to lack of financial and human expertise, Zimbabwe has no basic climate change research programmes. However, research in climate change-related issues is carried out by Government institutions in the areas of agriculture, water resources, energy and forestry, among others. The Southern Centre for Energy and Environment (SCEE), a non-governmental organisation in Zimbabwe, carries out climate change research for possible mitigation options in industry, particularly in energy efficiency.

7. Education, training and public awareness

In Zimbabwe, awareness-raising campaigns are used to involve the general public in issues concerning climate change. With the assistance of the UNDP and other bilateral donors such as the USA, workshops and seminars are being conducted throughout the country for a variety of stakeholders, including policy makers, industrialists, NGOs, academia, media and the public. As a result of these campaigns, the level of climate change awareness is relatively high in Zimbabwe.

8. Outlines of proposals for climate change projects

Chapter 8 contains outlines of climate change project concepts which will require financial and human resources inputs from co-operating partners.

Table ES2: National Circumstances (1994)

Population	10 638 418 (1993)
Area size (sq km)	390 000
Gross Domestic Product (US$ million)	4 971.88
GDP per capita (US$)	467.35
Estimated share of informal sector in GDP	Not known
Employment in informal sector (million)	1.6
Employment in formal sector (million)	1.3
Share of industry in GDP	28%
Share of services in GDP	5%
Share of agriculture in GDP	12%
Land area use for agricultural purpose (ha)	10 738 077
Land area under forest (million ha)	20.5
Urban population as a percentage of total population	31
Livestock population	
cattle	5 154 318
sheep	404 106
pigs	221 130
goats	4 227 256
Population in absolute poverty (%)	46
Life expectancy (yrs)	61
Literacy (%)	80

Introduction

Climate change is a controversial issue. One school of thought argues that the build up of greenhouse gases (GHG) and the subsequent warming of the earth's mean temperature is so serious that immediate global control on the burning of fossil fuels is required.

For thousands of years, the earth's atmosphere has remained fairly stable until recently in the context of geological time. The most significant changes have occurred over the past two centuries in response to increasing greenhouse gases emanating from human activities. According to current COP2 guidelines, non Annex 1 Parties to the Convention are required to prepare GHG Inventory for carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). In addition, data for NO_x and CO are also provided though they are not important greenhouse gases in their own right. These gases trap outgoing long wave infrared radiation, thus contributing to a warming effect, much like in a glasshouse on a sunny day hence the term "greenhouse effect". The higher the concentration of these gases, the greater the potential for trapping heat causing the climate to change.

In 1988, the United Nations General Assembly resolved to protect the global climate and requested the United Nations Environment Programme (UNEP) and the World Meteorological Organisation (WMO) to establish the Intergovernmental Panel on Climate Change (IPCC). The international community then started negotiating a Climate Change Convention. The negotiated United Nations Framework Convention on Climate Change (UNFCCC) was opened for signature at the 1992 Earth Summit in Rio de Janeiro. Zimbabwe was among the first countries to sign it. The Second Assessment Report of the IPCC (1995) asserts that there is discernible evidence that climate change is caused by anthropogenic activities.

While Zimbabwe's contribution to global emissions of GHG is very small, there is growing concern over the potential impacts of climate change on the country in the future. Given the heavy dependence of the country on rain-fed agriculture, absence of natural lakes, frequent occurrence of droughts in the region and a growing population, the potential social and economic impacts from climate change could be devastating.

Article 12.5 of the UNFCCC requires non-Annex 1 Parties (except those least-developed countries) to make their initial national communications "within three years of the entry into force of the Convention for that Party, or of the availability of financial resources...." The preparation of this National Communication is to fulfil Zimbabwe's obligations under this Article.

Following the COP2 guidelines, this National Communication presents the national circumstances, GHG inventory based on 1994 data; mitigation analysis and a range of possible policy options, vulnerability and adaptation assessments as well as programmes for education, training and public awareness.

Finally, conclusions and recommendations are made on the basis of the study. A number of projects concepts are identified for further development and funding.

National Circumstances

2.1 Geography

Zimbabwe is a landlocked country in tropical Southern Africa, falling between latitudes15^0 $35'$ and $22^0 30'$S. The main physical feature of Zimbabwe is the high watershed running from south-west to north-east. The height of the watershed ranges from 1 200m to 1 500m above mean sea level. In the east is a series of mountain ranges with peaks towering to 2 600 m above mean sea level. The major rivers are the Zambezi and the Limpopo with valleys below 500 m above sea level.

The country lies in a region with limited and unreliable rainfall patterns. It is greatly concerned with the effects of climate change on its economy within which both rural and urban economic activities have a strong linkage to agriculture and natural resources. The annual rainfall ranges from 300 mm in the south to over 1 000 mm in the north-east (Fig. 2.1).

fig 2.1: Rainfall pattern of Zimbabwe

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The relatively high elevation of most parts of Zimbabwe, especially the central watershed, has a moderating effect on temperatures. Most parts of the country, therefore, enjoy temperatures which are generally lower than might be expected for their latitudes.

The mean annual temperature varies from 18^0C in the highveld to 23^0C in the lowveld. The highveld experiences some frost in June or July in most years and temperatures rise up to 30^0C around October. In the lowveld region, temperatures rarely fall below 2^0C in winter but can rise to over 40^0C in summer
(Fig. 2.2)

With a population of 10.64 million on a land area of 390 000 square kilometres, Zimbabwe's population density is 27 persons per square kilometre. The population growth rate is 2.9%. Seventy percent of the inhabitants live in rural areas mainly as peasant farmers and the rest live in urban areas. The structure of Zimbabwe's population has a high dependency ratio with about 45% of the population under 15 years.

Limited resources and opportunities in the communal areas have accelerated rural-to-urban migration. In recent years, Zimbabwe's urban population annual growth rate has averaged 5.9% and urban areas now account for 30% of the total population. This rapid urban population growth rate has not only exerted a lot of pressure on urban social services (i.e. electricity, housing, water, waste management) but has also further affected resource management in rural areas by depleting the rural labour force.

Fig. 2.3: Population distribution

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2.2 Political and decision making structure

Zimbabwe is a unitary democratic republic with an elected as well as appointed parliament. The national legislature consists of House of Assembly with 150 members, 120 representing geographical constituencies elected by universal adult suffrage every five years. The remaining 30 include eight provincial governors, 10 customary chiefs and 12 others appointed by the President. The major functions of the Parliament are to enact laws, supervise the Government's administration, allocate taxes as well as address grievances by way of petition. The head of the government is the executive President. The Zimbabwe legal system is based on Roman-Dutch Law and the 1979 Lancaster House Constitution.

The country has nine administrative provinces that are linked to the central government. The provinces are headed by Governors who are politically appointed by the executive President.

■ 2.3 Socio- economic structure

Zimbabwe is classified as a developing country with an income per capita of just under $500 USD in 1994, the base year for this study. The Gross Domestic Product (GDP) in 1994 was Z$56 441 million at factor cost, in constant 1980 dollars. GDP growth rate has remained positive but declined from 14% in 1980 to 4 % in 1994/95. Social statistics have improved since independence in 1980 as the majority of the population have gained better access to health and education services.

Since independence, Zimbabwe's economic development policy has produced commendable results. The country has one of the most balanced economic structures in the region (Fig. 2.4). The country's economy is heavily dependent on natural resources for generating employment, income and foreign exchange. The dominant sectors and their contribution to GDP in 1994 were as follows:

manufacturing, 44 percent;
agriculture and forestry, 9 percent;
mining, 6 percent;
distribution, and hotels and restaurants (tourism), 10 percent.
electricity and water, 6%
education and health, 6%
transport and communications, 5%
others, 14%

The manufacturing sector produces 6 000 different products, and accounts for 17% of the total employed labour force. Activities in this sector are based on processing agricultural products and minerals. Agriculture is the largest employer of labour. The tobacco industry is the leading source of foreign currency followed by mining. Agriculture remains by far the most important sector of the economy due to the fact that it directly supports over 80% of the population, especially in rural areas.

The strong dependence on agriculture for economic development is a concern with potential climatic changes. Because so much of national agricultural production is based on rainfall, the country's output is directly influenced by weather patterns. During periods of severe drought, crop production and livestock herds decline quite significantly. Like livestock, wildlife is also affected and tourist visits to prime attractions can fall significantly. The 1991/92 drought saw GDP decline by about 5%. Despite these limitations, growth in the productive sector, which includes mining, manufacturing, and agriculture has been

fairly strong in the past few years. Overall GDP is expected to grow at 4.6% during the next five years, depending upon weather patterns and the success of government to reduce fiscal deficits and corresponding domestic borrowing.

■ 2.4 Trade

Zimbabwe's trade situation has improved in recent years with an estimated balance on its current account of $624.7 million in 1994. Maintaining this position is of interest to Zimbabwe hence its membership to various regional trading groupings such as Common Market for Eastern and Southern Africa (COMESA) and the Lome Convention. In 1991, Zimbabwe embarked on a major five-year economic reform programme termed the Economic Structural Adjustment Programme (ESAP). A second phase Zimbabwe Programme for Economic and Social Transformation (ZIMPREST) has just been initiated with support from the International Monetary Fund. The ESAP programme, among other things, recognised that trade needed to be liberalised, along with financial market reforms. This aspect of the economic reform programme has been quite successful. Of key concern, however, is the potential for environmental concerns in western markets to become non-tariff barriers to its potential exports. The opening up of Zimbabwe's small economy under the liberalisation programme makes this possibility a practical concern since both local and global climate change response strategies may impact negatively on Zimbabwe's economy.

■ 2.5 Energy

The primary energy sector is dominated byconventional fuels: coal, with total reserves of 10.6 billion tonnes of which half a billion are proven, petroleum of which about 40PJ of finished distillates are imported every year, and hydroelectric power with a total potential of 4 200 MW mainly on the Zambezi river shared system. The liquid fuels supply is augmented by 40 million litres of ethanol which are produced at the Triangle Ethanol Plant annually in years of good rainfall. The ethanol is blended with petrol up to an ethanol content of 13%.

Investment in the power sector includes 1 295 MW thermal power and 666 MW hydro-electric power. Power transmission is supported by 3 595 km of high voltage transmission lines and 56 115 km of distribution lines.

Biomass constitutes a major source of energy particularly for the rural population and for the low-income urban group. Of the country's total land area of 39 million hectares, 20.5 million hectares are under indigenous forest while 140 000 hectares are under commercial forest plantations. For energy purposes, only the indigenous forests in communal land areas can be considered as the major resource. Timber on private land and commercial forests is ordinarily not available for supplying energy to households. Total forest cover in the accessible areas is estimated at 8.4 million hectares. This area also has much lower forest regeneration rates than all the other forest categories with only 0.94 tonnes/ha/year mean annual increase as opposed to 4.1 tonnes/ha/year estimated for forests in private commercial farms. Overally, however, forest regeneration rates exceed depletion rates.

Other forms of renewable energy such as solar and biogas have received notable attention but this has mainly been at research level or under diffusion activities funded on a non-commercial basis. While solar water heaters are becoming more common in high-income urban areas, the cost relative to alternative

Fig.2.4: Historical sectoral contributions to GDP: Zimbabwe

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and more traditional heating appliances still makes these prohibitive for the majority of the people.

■ 2.6 Mining resources

The mining sector, also a major employer and source of industrial raw materials, is basically concentrated on a mineral rich dyke that stretches for over 600 km on a north-east/south-west axis across the country. The dyke contains numerous mineral deposits with the major ones being gold, copper, chrome, iron, platinum and emeralds. Although no studies have been carried out to show clearly the possible effects of climate change on mineral resources and the mining sector, Zimbabwe remains watchful of any possible economic, social and developmental fallout from all aspects of climate change, including the relevant global accords.

■ 2.7 Water resources

Water resources are critical to Zimbabwe's agriculture, as well as its rural and urban populations. The same applies to agro-industries, the manufacturing sector and mining which depend heavily on water for their production processes. The country has no natural lakes and there are a few perennial rivers. Water storage development is dependent on run-off accumulated during the rainy season. In Zimbabwe, there are presently over 8 000 dams and of these only 135 have dam walls higher than 15 metres, thus most dams have little storage capacity. The total storage capacity is approximately 4 900 million cubic metres of which 80% is stored in 100 dams of more than two million cubic metres.

Water available for storage from run-off varies between seasons with an estimated long-term mean of 2 000 million cubic metres per annum, excluding the flow of the Limpopo and Zambezi rivers. The provision of water for urban requirements now assumes proportions of national importance in planning and development of water resources. Acquifers areprincipally associated with sedimentary geological formations. The Nyamandhlovu acquifer found in south western Zimbabwe is one of the major acquifers in the country. Secondary acquifers exist in crystalline formations that comprise two-thirds of the country. The International Union for Conservation of Nature and Natural Resources (World Conservation Union) IUCN estimates show that Zimbabwe's water supply to demand ratio is 0.89 negative with demand outstripping supply by 631 million cubic metres. This situation together with the threat of droughts make it imperative that response mechanisms, including water conservation programmes be put in place. This is true for all sectors, including irrigation, rain-fed agriculture, industrial processes and concentrated human settlements.

With these environmental concerns in mind, Zimbabwe moved quickly to sign and ratify the UNFCCC during the last quarter of 1992, becoming the fifth country in the world to do so. By this act it was hoping to position itself effectively to understand the effects of climate change on the young economy and to fully participate in shaping global response options to climate change while laying out the necessary national mechanisms for such responses. These include studying the extent of its vulnerability to climate change as well as the corresponding mitigation options.

3

Greenhouse Gases Inventory

3.1 Introduction

The ultimate objective of the UNFCCC is to stabilise atmospheric concentration of greenhouse gases and every Party to the Convention has an obligation to submit regularly a national inventory of GHG emissions by sources and removals by sinks. This is part of the global efforts being taken in order to attain certain stabilisation targets. Although developing countries have no particular obligations under the Convention to meet stabilisation targets, it is important that the international community quantify systematically all present day and expected anthropogenic emissions, employing comparable methods to assess the global impacts of such emissions.

Zimbabwe is one of the first signatories to the Convention and has, therefore, undertaken to compile such a study. This will not only allow Zimbabwe to place its inventory of emissions against the global picture of emissions but also assist in guiding Zimbabwe to focus on more climate sensitive developmental goals and formulate informed mitigation policies.

A team of national experts (from each analysed sector) was put together under the National Climate Change Office in the Ministry of Mines, Environment and Tourism to compile the GHG inventories for Zimbabwe.

3.2 Methodology

The science of the greenhouse gas effect is based on the accumulation of greenhouse gases in the atmosphere, which inhibit the earth's radiative effect, effectively trapping heat in the atmosphere and thus causing the earth's temperature to rise. Important greenhouse gases are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Following the new COP2 guidelines, this study mainly focuses on CO_2, CH_4, and N_2O. NO_x and CO are also considered because of data availability. Each of these gases has different contributions to the total greenhouse effect, which can be expressed as the global warming potential shown in Table 3.1 below. This allows the GHG to be expressed as CO_2 equivalent since CO_2 remains the most important gas responsible for up to 70% of total radiative forcing globally.

The Zimbabwean assessment of GHG emissions employs the Intergovernmental Panel on Climate Change (IPCC) Guidelines (1996) and these conform to the international agreement to standardise the methodology for estimating emissions. Although the IPCC method might not fully reflect the situation in Zimba-bwe, it assists in those cases where no scientific methods have been developed for Zimbabwe and it represents the best scientifically

Table 3.1: Global warming potential (GWP) of GHG for 100 years

GHG	GWP
CO_2	1
CH_4	24.5
N_2O	320
NO_x	40
CO	3

Source: IPCC SAR (1995)

derived methodology available to-date. However, uncertainties and discrepancies still exist and, hopefully, these will be dealt with in the not too distant future.

A study by UNDP on "Review of GHG Inventories in Zimbabwe" (1997) revealed a steady improvement in reporting, methodology and data accuracy.

Data is usually available in formats that suit Government planning and inappropriate for IPCC reporting. Some information is not normally recorded or statistics may be outdated. Thus in many sectors, it is vital to ensure the existence of reliable databanks feeding the IPCC/UNFCCC data requirements.

A number of assumptions have to be made in all cases where information is difficult to access. Examples include the neglecting of carbon stored in fuel combustion resulting in over-estimated emissions. Methods of estimating emissions from industrial processes are the least developed. Although information on industry could be collected, there might be difficulties as companies conceal vital information fearing exposure to competitors among other reasons. Information on bunkers has not been established up to now.

Agriculture is one of the sectors with sound statistics but the data is in most cases sampled and not representative of totality and a lot of agricultural output is unrecorded. The farming practices and livestock management regimes vary from place to place and generalisations have to be made.

It is also difficult to estimate amounts of waste produced, with several players being involved in waste disposal. Many dumps exist in rural areas and peri-urban communities which remain unaccounted for. Pit latrines, septic tanks and small centre dumps are among some of these waste sites. It is also clearly difficult to determine the degradable composition of waste from all waste dumps and again generalisations have to be made.

Savanna burning and land-use changes are two sources of GHG that remain undocumented fully. It is hoped that more surveys would be carried out to determine the extent and nature of the activities in these sectors.

Although the Zimbabwean study adopted the IPCC methods, there are instances when localfactors were incorporated into the overall IPCC methodology and these are given in the relevant sections. This is the case where certain processes are well known and local experts have confidence in the science of the process. In most cases, IPCC default emission factors and conversion coefficients are used.

Under the IPCC guidelines, the basic approach for calculating emissions of a particular gas from a particular sector is simple in concept:

Emissions = Activity Level x Emission Factor

It is not a complex matter to identify the sources and sinks of greenhouse gases in a developing country. It is common knowledge that the major sources are in energy production, conversion and use. There are also well documented sources in industrial processes. The difficulty comes from determining the activity level. This is particularly difficult for the land-use change and forestry, savanna burning, waste management and others where data either do not exist and must be derived from related statistics or even from anecdotal evidence. The other difficulty comes in identifying the linkages between economic, social and political activities and the rate of emissions which assists in developing policies to mitigate and adapt to climate change.

The level of confidence of data for the commercial use of energy is over 95% while between 80% and 90% accuracy is valid for agriculture, industrial processes, land-use, forestry and waste management. However, most of Zimbabwe's emissions come from energy. Assessments in this document represent the best available data. For brevity, detailed activity data and computations are provided for in the Annex.

The inventory of GHG have been categorised according to sources and sinks and the following broad categories have been included:

Energy

Industrial processes

Agriculture

Land-Use Change and Forestry

Waste Management.

The specific methods relating to each sector and its associated sub-sectors are discussed in the relevant sections below.

3.3 Energy

GHG emissions from the energy sector in Zimbabwe emanate from combustion of carbon-based fuels as well as fugitive emissions during coal mining and handling processes. CO_2 and CH_4 are the two most important gases from the energy sector. NO_x and CO are also emitted from combustion of carbon-based fuels.

3.3.1 Energy combustion

The Zimbabwean energy mix is dominated by carbon-based fuels. Over 96% of the total supply is from such fuels. The only non-carbon energy source is hydro-electricity and some renewables (which represent a negligible portion of the total energy supply). The electricity supply is mainly from coal-based thermal fuels. Fig. 3.1 shows the distribution of coal usage in Zimbabwe.

Fig. 3.1: Distribution of coal use in Zimbabwe

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In calculating emissions from fuel combustion, the IPCC Detailed Fuel approach was used. The basic procedure involves six fundamental steps:

i) Estimating consumption of fuels by fuel product type.
ii) Converting fuel data to energy units.
iii) Selecting carbon emission factors for each fuel product type and the total carbon potentially released from use of the fuels.
iv) Estimating the amount of carbon stored in products for long periods of time.
v) Accounting for carbon not oxidised during combustion.
vi) Converting emissions as carbon to full molecular weight of CO_2.
vii)

The methodology is silent on equipment efficiency. This is often considered unnecessary because the emission factors are based on the energy content of fuels and not the useful energy gained from the combustion process. The IPCC guidelines state that emissions from use of fossil fuels are independent of technology. This assumption is valid if the energy data is based on the energy supply figures. If the data is based on energy use figures such as in electrical energy consumption then it would be important to include efficiency figures in determining the emissions per unit of energy used. The assumption also makes it more difficult to identify interventions as the emission levels will not readily show the linkage with efficiency.

Estimation of apparent consumption of fuels was done using the following equation:

Apparent consumption (GJ) = Production + Imports - Exports - Stock Changes.

Most of the data used was obtained from National Energy Balances (source : DOE) in the form of energy units. IPCC default emission factors were used for all fuels (details attached to Annex). It was assumed that no carbon is stored after fuel use in the absence of accurate estimates on stored carbon. IPCC defaults were also used for the fraction of carbon oxidised- 0.99 for liquids and 0.98 for solids. The complete methodology can be summarised by the following equation:

CO_2 emissions (Gg) = AEC x CEF x FCO x CF

where:

where:	AEC	=	Apparent Energy Consumption (GJ)
	CEF	=	Carbon emission factor (Gg C/GJ)
	FCO	=	Fraction of carbon oxidised
	CF	=	Conversion factor (44/12)

etailed calculations are given in the Annex. Non-CO_2 emissions were estimated in the same manner as above but employing different emission factors. These emission factors were taken from the UNEP GHG studies in Zimbabwe and are listed in the Annex.

Table 3.2: GHG emissions from fuel combustion/Gg (base year -1994)

Fuel	**CO_2**	**CH_4**	**N_2O**	**NO_x**	**CO**
Coal	14 041.29	57.07	-	-	-
Coke	831.68	-	-	-	-
Diesel	2 179.23	0.22	-	0.06	-
Petrol	894.65	1.28	-	0.67	-
Jet A1	264.82	-	-	-	-
Paraffin	228.92	-	-	-	-
AvGas	11.57	0.002	-	0.01	-
LPG	17.74	0.013	-	-	-
TOTAL	**18 469.90**	**58.59**	**-**	**0.74**	**-**

N.B: The decimal in the totals have been rounded

More than 48% of the emissions emanate from power generation. Industry is another significant contributor to GHG emissions at 14.97%,agriculture (11.34%), transport (11.82%), commercial (9.59%) and the rest, including mining and households contribute 4.18% as shown in Fig. 3.2.

Fig. 3.2: Sectoral distribution of GHG emissions from commercial fuels

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The transport sector consumes about 60% of liquid fuels in Zimbabwe, and grew at about 24% between 1985 and 1990 and at about 37%from 1990 to 1993. Table 3.3 below shows the number of vehicles registered in Zimbabwe between 1985 and 1993.

Table 3.3: Registered number of vehicles by type and year

Type of vehicle	**1985**	**1990**	**1993**
Cars, vans	244 390	293 459	328 304
Lorries			
medium goods	8 412	9 354	10 347
heavy goods	13 642	16 532	20 290

very heavy goods	1 199	1 563	1 917
trailers	35 546	43 259	48 454
Others	31 527	35 027	38 754

Source: CSO (1995)

3.3.2 Fugitive emissions

In Zimbabwe, fugitive emissions result only from coal mining, handling, transportation and storage. Zimbabwe produces about 6 megatons of mainly bituminous coal per annum. The coal is mainly used in industrial boilers with about 60% being consumed by power generation. Fugitive emissions from coal are based on total coal production and the IPCC Global Average method was used.

The following formula was used to calculate the fugitive emissions, taking the different mining methods and stages of emission.

emissions (Gg) = Coal production (tons) x Emission factor(m^3 CH_4 / ton) xConversion factor- Recovered methane

Separate emission factors were used for surface and underground mined coal as well as for mining and post-mining coal handling activities. These were default IPCC factors used in the absence of in-country data and are given in the Annex. Data on coal production was obtained from the Department of Energy (DOE).

Methane emissions from opencast mining amounted to 3.97 Gg and that from underground mining was estimated at 9.27 Gg, giving a total of 13.24 Gg of CH_4 of fugitive emissions from coal mining. IPCC default emission factors were used in this calculation although emission factors should be mine-specific as the methane emissions vary with depth of the coal seams and state of coalification. It would also be important to estimate the storage time for the coal, i.e., if the coal is delivered from mine to furnace immediately, then the methane is burnt before being emitted. The emission factor for storage and transport would then be very small.

3.3.3 Emissions from burning traditional biomass fuels

Biomass fuels are the sole source of energy for over 95% of the rural population. Apart from a few who have access to kerosene, biomass fuels are used for cooking, lighting and heating. This is mainly due to unavailability of alternative sources of energy like electricity.

Although the IPCC methodology assumes zero CO_2 emissions from biomass fuel consumption, this is true as long as there is sustainability of biomass resource i.e. managed forests usage where

CO_2 is reabsorbed during biomass growth. It is therefore assumed that any CO_2 emissions from burning traditional fuels is reabsorbed during plant growth. However, CO_2 emissions from biomass are included in the land-use change and forestry section to assess the directions of the "net flux" of CO_2 emissions, i.e. whether CO_2 is being absorbed by forests or is being emitted into the atmosphere. Non-CO_2 emissions are included since they are not reabsorbed during plant growth (Table 3.4).

Emissions from traditional fuels were estimated using IPCC recommended methods. The method can be summarised by the following formula:

Carbon emissions = Fuel consumed x Carbon content of fuel x fraction of biomass oxidised.

Trace gas emissions are then derived from the carbon emissions using trace gas emission ratios and conversion factors (see Annex). All these factors, coefficients and ratios are IPCC defaults. Data on traditional fuels was obtained from National Energy Balance (DOE).

3.4 Industrial processes

Zimbabwe's industrial sector comprises mainly of mining and agro-based primary extractive operations. Zimbabwe's industries have been classified into the following major categories:

mining industry explosives
metallurgical processes
beer, wine and spirit manufacture
sugar manufacturing
cement production
fertiliser manufacture

Data used in the assessment was obtained from industrial operations identified as major emitters of greenhouse gases and from records of the Central Statistical Office (CSO). The majority of operations did not have specific monitoring results or information on site. Most of the emissions therefore, were determined using balanced chemical equations of the resources transformation processes. The use of these equations, which are not standard IPCC methodology is justified because most of the industrial processes assessed in this communication are not included in the IPCC methodological guidelines. Locally derived methods were therefore, used except for cement which is provided for in the IPCC guidelines. In the case of nitric acid, actual plant monitoring provided reliable measurements for emissions. These are used in this report alongside other industrial process emissions.

Table 3.4: GHG emissions from burning traditional biomass fuels/Gg (1994)

Biomass fuel	Annual consumption (1000 tons)	CO	CH_4	NO_x	N_2O
Fuelwood	9 392	543.37	62.10	10.06	0.43
Dung	-	-	-	-	-
Agricultural residues	-	-	-	-	-
Charcoal Consumption	1	0.11	0.0014	-	-
Charcoal Production	49	0.98	0.59	0.018	0.00017

3.4.1 Mining and mineral processing industry

Mining operations involve ore digging and stockpiling, while mineral processing involves industrial production of mineral-based final products.

Mining operations use explosives containing mainly ammonium nitrate base that produces nitrous oxide (N_2O). There are no IPCC guidelines to estimate emissions from explosives used in mining operations. Emissions were estimated based on balanced chemical equations of the processes. This approach was also used for all other processes for which the IPCC has no methodology. In 1994, 6.05 Gg of N_2O were released from explosives. GHG emissions were also estimated from lime production. These amounted to 23.70 Gg of CO_2.

Metal production involves primary production of ferroalloys and iron-and-steel making. Tier 1b of IPCC guidelines was used in estimating emissions from this sector on known products. Emissions from ferroalloys amounted to 404 Gg of CO_2 and emissions from iron-and-steel production were estimated to be 1440 Gg of CO_2, 0.04 Gg of NO_x and 1.38 Gg of CO.

3.4.2 Sugar manufacturing and beer brewing

In sugar manufacturing, molasses fermentation during the distillation process is an important source of carbon dioxide. GHG emissions are also produced during microbial fermentation process in the production of beer, wines and spirits. However, these two activities are assumed to give zero net CO_2 emissions since the CO_2 emitted is assumed to be reabsorbed during crop growth.

3.4.3 Cement manufacturing

Carbon dioxide is also produced during the production of clinker, an intermediate product from which cement is made. It should be noted that when concrete mixture is cooling, some CO_2 is reabsorbed by the concrete from the atmosphere. This CO_2 reabsorption is, however, believed to be only a small fraction of the CO_2 emission resulting from cement production and is therefore usually ignored in emission calculations.

Because CO_2 is emitted during clinker production (rather than cement production itself) emission estimates should be based on lime content and production of clinker. However, clinker statistics were not readily available in Zimbabwe and, as a result, cement production statistics were used. If information on clinker is not available, emissions are based on cement production instead and IPCC emission factors based on the average CaO content of cement can be used. This does not compromise the accuracy of the emission estimates since there is a direct relationship between cement and clinker produced. The emission factors simply translate this direct proportionality and factors in the cement quantities produced from the clinker. A total of 0.4985 tonnes of (CO_2) are released per tonne of cement produced. This is an IPCC default based on average lime content of cement. Studies in most countries have indicated that the difference in emission estimates using clinker or cement data is very small. The errors in lime content assumption is also very small compared to the assumption in the cement production figures. This translates into 448.65 Gg of CO_2.

3.4.4 Fertiliser manufacturing

Fertiliser manufacturing is another industrial process which emits GHG. Sable Chemicals, a fertiliser manufacturing facility operating two nitric acid plants, advised that 0.165Gg of NO_x was released into the atmosphere in 1994. These emissions were based on actual measurement at the plant.

3.5 Agriculture

As mentioned before, agriculture is one of the most important sectors of the Zimbabwean economy. Zimbabwe produces a wide range of crops and livestock. Crops range from cereals such as maize, wheat, barley, sorghum and millet to tobacco and cotton. Livestock includes cattle, sheep, goats, pigs, poultry, donkeys and to a small extent horses. Emissions of GHG occur from several sources, including burning of crop waste, enteric fermentation, manure management and savanna burning. Using the 1994 crop production, livestock figures and the IPCC Guidelines, the GHG emission levels were estimated.

3.5.1 Emissions from burning crop residue

The residue of most of the major crops is either heavily grazed by livestock, and thus added to the kraal manure, or fed to the animals during winter. The stova that remains (estimated at 20%) is burnt after the above operations have been carried out. The trash that remains after burning is incorporated into the soil during ploughing. However, with the introduction of minimum tillage techniques, burning of stova is being discouraged. The practice of minimum tillage has been taken up so fast that stova burning is on the decline, particularly among large-scale commercial farmers.

Cotton is the only crop where 100% of the crop residue is required by law to be destroyed by burning. This is a measure for controlling a potentially serious crop pest, the pink bollworm. Tobacco stalks are slashed and ploughed into the ground and wheat stova is usually baled and fed to cattle and horses. Any remaining wheat stova is either grazed by cattle or left on the surface to enrich the soil through minimum tillage.

The field burning of crop residues is not treated as a net source of CO_2 because it is assumed that the carbon released to the atmosphere is reabsorbed during the next growing season. However, other non-CO_2 gases are considered. (Table 3.5).

The IPCC methodology was applied in estimating GHG from crop waste burning. Data on amounts of crop yields was obtained from the CSO and Ministry of Lands and Agriculture. IPCC default residue to crop ratios, dry matter content of crops, fraction of biomass oxidised, emission and conversion factors were used.

Trace gas emissions were derived from carbon emission estimations and the following general formula was used to estimate emissions:

Carbon Released = $3_c(PxRxDMxBxCxCE)_C$

where :
- P - crop production (t/yr)
- R - residual/crop ratio
- DM - dry matter content
- B - fraction of residue burned
- C - carbon content (tC/t DM)
- CE - combustion efficiency
- c - crop type

The fraction of crop waste burned in the fields is a local factor obtained from experience of farming methods in Zimbabwe as described before. Details of these are given in the Annex. However, the IPCC methods and other default factors were used despite these revelations.

The overall formula for estimating emissions from livestock is as follows:

CH_4 emissions = Animal production x Emissions factor

Data on livestock populations was obtained from the CSO and Ministry of Lands and Agriculture.

3.5.2 Emissions from livestock

Emissions from livestock originate from enteric fermentation and manure management systems. Methane is produced during normal digestive processes of animals. The amount of methane is dependent upon the particular animal's digestive system, feed intake and the size of the animals. The available methodology relies on knowledge of food intake and daily activity of the animal. Diary cows tend to have higher emissions and draft oxen lower emissions. It is therefore necessary to know the breakdown of the herd by type of animal, daily activity and daily energy intake. This information is not normally available when looking at the national herd. The IPCC guidelines give defaults for emissions for grazing, zero-grazing and dairy cattle by weight and region. Information for other ruminants is also provided in the same format. It was realised in Zimbabwe that the default data did not match the animal weight for the local herd.

Methane is also produced during the anaerobic decomposition of organic matter in livestock manure. The methane produced is directly related to the amount of manure decomposing and how the manure is managed.

Table 3.5: CH_4 emissions from livestock/Gg (1994)

Livestock type	No. of animals ('000s)	Emission factor (Kg/head/yr)	CH_4 from enteric fermentation	Emission factor (Kg/head/yr)	CH_4 from manure management	Total CH_4 emissions
Dairy cattle	110.1	36	3.96	1	0.11	4.08
Non-dairy cattle	4 950.1	32	158.40	1	4.95	163.35
Sheep	393	5	1.97	0.21	0.08	2.05
Goats	2 585	5	12.93	0.22	0.57	13.49
Mules & donkeys	230	10	2.30	1.19	0.27	2.57
Swine	261	1	0.26	2.0	0.52	0.78
Poultry	2 5344	-	-	0.023	0.58	0.58
Total			**179.82**		**7.08**	**186.90**

Table 3.6 summarises methane emissions from livestock.

Table 3.6: Non-CO_2 emissions from burning crop waste (1994)

GHG	Emission **Factor**	Nitrogen	Conversion **Factor**	Emissions **(Gg)**
CH_4	0.005	0.70	16/12	0.93
N_2O	0.007	0.02	44/28	0.03
CO	0.06	8.49	28/12	19.18
NO_x	0.121	0.33	46/14	1.10

3.5.3 Savanna burning

Emissions of trace gases from savanna fires are conventionally estimated as a product of the area of savanna burned annually, the average amount of fuel consumed per unit area, and the emission factor for the gas in question in terms of the mass of gas emitted per unit mass of fuel consumed. This is essentially the method recommended by IPCC, though their method is somewhat more complex. An alternative method, designed to estimate default values for fuel loads in a more dynamic manner, involves modelling the processes of fuel accumulation in relation to vegetation and area-specific patterns of plant production, herbivory, and decay, driven by monthly rainfall data, on a 0.5^0 x 0.5^0 grid square basis. The amount of biomass burned and the corresponding emissions are then calculated by using satellite-derived estimates of the area of each vegetation type burned, measures of the completeness of combustion in relation to fuel bed composition and variable emission factors as functions of combustion efficiency.

There is no information on the number of fires or the area burned in Zimbabwe during 1994. For Africa south of the Equator, Scholes et al. (1996) estimated the area burned in 0.5^0 x 0.50^0 latitude/longitude grid squares during 1989. He correlated the number of 'fire points' detected by the AVHRR sensor (1.1 x 1.1 km resolution) onboard the NOAA weather satellites during once-daily overpasses at 13h00-15h00, with the actual area burned as determined from analysis of a sample of 12 Landsat MSS scenes distributed across Southern Africa.

Emission factors, measuring the amount of gas emitted per unit mass of fuel combusted, vary depending on the combustion efficiency of the fire. Although average emission factors for savanna fires have been published (Delmas et al., 1991; Ward et al., 1996), it is more realistic to use emission factors that reflect the degree of combustion of the fuel. Average emission factors, obtained from the literature, were used for the nitrogen trace gases. The original emission factors in these studies assumed a 50% carbon content in the fuel. The carbon content of different plant materials in African savannas is 40 - 47% (Delmas et al.1991; Scholes and Walker, 1993). The cal-culated emissions were adjusted to accomodate a more realistic 45% carbon content (Table 3.7).

Table 3.7: GHG emissions from savanna burning

	Biomass Burned		**Emissions**			
		CO	**CH_4**	**NO_x**	**N_2O**	**NO**
Land cover type	**(Gg)**	**(Gg)**	**(Gg)**	**(Gg)**	**(Gg)**	**(Gg)**
Sub-humid zone						
Moist Forest	0	0	0	0	0.000	0.00
Plantation	6	1	0	0	0.001	0.003
Woodland	9 501	885	34	34	1.368	4.532
Bushland	414	24	1	1	0.060	0.197
Wooded Grassland	582	36	1	2	0.084	0.278
Grassland	1 008	52	1	4	0.145	0.481
Semi-arid zone						
Plantation	0	0	0	0	0.000	0.000
Woodland	4 103	317	11	14	0.591	1.957
Bushland	546	35	1	2	0.079	0.261
Wooded Grassland	160	10	0	1	0.023	0.076
Grassland	60	3	0	0	0.009	0.029
Totals	**16 380**	**1 363**	**49**	**58**	**2.360**	**7.814**

N.B: The decimal in the totals have been rounded

3.6 Land-use change and forestry

Land and forestry resources are key issues when considering the energy and economic requirements of the majority of Zimbabweans. Wood-fuel accounts for over 90% of the total energy requirements of the rural communities and almost 15% of this amount comes from forest depletion. This depletion is also accelerated by the demand for indigenous building materials, natural forest fires and the resettlement exercise. The single largest cause of woodland depletion, however, is from land clearance for agriculture.

CO_2 emissions from forests and other types of vegetative matter can be zero if there is a balance between depletion and regeneration. Standing forests act as carbon reservoirs and growing forests act as carbon sinks. On the other hand, cleared vegetation might be burnt on or off-site, or usable logs might be carried off and the remains allowed to rot over time. In the absence of a balance, a net flux of GHG into the atmosphere will occur if more biomass is burnt than what grows. Estimation of emissions from this category of sources is divided into forest and grassland conversion and changes in forest and other woody biomass stocks. Emissions from abandonment of managed lands was not estimated due to insufficient data.

Table 3.8 below shows the land-use patterns in Zimbabwe according to ecological zones.

Table 3.8: Land-use patterns in Zimbabwe

	Total area (million ha)	Proportion of total area (%)	Proportion of arable land (%)
Non-agricultural			
National parks	4.70	12.10	-
State forests	0.92	2.30	-
Urban and other	0.22	0.60	-
Sub total	5.84	15.00	-
Agricultural			
Large-scale commercial farms (LSCF)	12.65	32.50	38.3
Small-scale commercial farms (SSCF)	1.42	3.70	4.3
Communal areas	16.35	42.00	49.4
Resettlement areas	2.64	6.80	8.0
Sub total	33.06	85.00	100.0
Total	**38.90**	**100.00**	**100.0**

Source: Moyo et al. (1991)

3.6.1 CO_2 uptake due to managed forests

In Zimbabwe, the changes that occur in forests are the largest in woody biomass stocks. These changes largely determine its GHG sinking capacity. Natural undisturbed forests are carbon resevoirs but commercial plantations, regrowing natural forests and other growing woody biomass constitute a significant carbon sink.

In Zimbabwe, commercial plantations comprising of pine (108 185 ha), eucalyptus (24 505 ha), wattle (231 67 ha) and other plantations (1 204 762 ha) and woodlands (20 797 405 ha), bushland (4 974 130 ha) and closed forest (11 554 ha) constitute the changing woody biomass stocks, their growth rates vary from 0.2 tdm/ha for some commercial plantations to 24.51 tdm/ha for eucalyptus. Woodlands, bushland and closed forest grow at 1.9, 1.5 and 2.7 tdm/ha respectively. State forests and forests under national parks and other protected areas can be considered to be carbon reservoirs. Commercial forests represent mostly exotic tree plantations as discussed above under formal or commercial management regimes. Woodlands comprise of varied densities of inter-locking deciduous trees with or without much grass cover. Bushlands are thickets of bushes varying in density with much more grass cover. Closed forests consist of tall evergreen trees associated with high altitudes and high rainfall areas. All these biomass stocks are assumed to have reasonable proximity to allow estimations to be done on an area basis. Where trees are dispersed, the IPCC recommends that the number of trees be taken into account rather than the area covered by the trees.

This baseline information is derived from Forestry Commission estimates of national woody cover. Using the IPCC carbon content of dry matter of 0.45, total carbon increment is estimated for each woody biomass and converted into carbon dioxide sinking. For 1994, wood biomass is estimated to have sunk 81,003 Gg of CO_2.

3.6.2 Biomass removals

This element represents the emissions from commercial harvesting of wood for timber and other applications. CO_2 emissions due to biomass removals are calculated from amounts of commercial biomass harvested and other wood uses (such as firewood and charcoal). The annual CO_2 released from wood biomass removals is estimated to be 16 234 Gg.

3.6.3 GHG emissions from forest clearing

Deforestation in the broader sense of the word, including reductions in tree density and cover, has been widespread in Zimbabwe. Many areas have experienced more than 3 % decrease in woodland canopy cover per annum during the 1980's (Whitlow, 1980). It is unclear whether this trend is continuing over the whole country, and if so, at what rate. The FAO (1995) estimated an annual loss of 61000 ha of 'natural forest' (which is in fact mostly woodland). This loss was offset by an increase of 1 400 ha in the area of commercial plantations.

At a more local level, two studies have recently estimated the area of natural vegetation cover converted to cropland in northern Zimbabwe over the period 1972/3 - 1993. Research in different parts of Zimbabwe has shown a net conversion of natural vegetation to cultivated land of about 6 290 ha over the period 1972-1993, and 1 699 ha per annum (4.3 % annual rate of change) for the period 1973-1981, and 6 933 ha per annum from 1981 to 1993 (WWF, 1997). In the Dande/Chiswiti area of the Zambezi Valley, the rate of conversion was negative from 1973-1981 (-0.4 % per annum, representing an overall abandonment of 1 070 ha), but positive during the period 1981-1993 when an additional 52 160 ha were settled and cultivated. This represents an annual rate of change of 9.8 % (WWF, 1997).

If the latest figures for the annual rate of clearance are applied to 1994 (only one year after these studies were completed), then, over the three regions involved, an estimated 18 290 ha of land was cleared in 1994, the baseline year for this study. This is the figure that is used in calculating emissions from deforestation.

The amount of biomass burned during the clearance of land for cultivation is not known. The mean above ground biomass density for a number of such woodlands and shrublands in Southern Africa is 24.7 t ha^{-1} (Timberlake, 1995; Frost, 1996). The estimates in this study are based on a rounded value of 25 t ha^{-1} and the assumption that 80% of this (20 t ha^{-1}) is present on site at the time of burning (the remainder is salvaged or left on the boundaries of the cleared area).

3.7 Waste management

Urban waste in Zimbabwe is ordinarily disposed of by landfilling, recycling, incineration and open dumping in the case of solid waste. Liquid waste is disposed of through managed municipal treatment works. In some cases waste stagnates in septic tanks at residential stands but the bulk of it is drained directly into municipal ponds. The most common biodegradables in solid waste include foodstuffs (77%), paper (12%) and textiles (2%). Other constituents include plastics (4%), metal (1%) and glass (4%). This data is typical for the city of Harare.

A number of major urban centres which kept records of their solid waste provided data on annual municipal solid waste landfilled. The municipalities in Zimbabwe are responsible for ensuring that all waste is collected and dumped at landfill sites. Most municipalities do not analyse the composition of waste which they dump. They collect most of the domestic waste and sometimes subcontract private companies to dispose industrial and hazardous waste. At some dumps, there is organised waste picking where members of a cooperative are given a special license to salvage particular types of waste e.g. plastics, cardboards and metals. These cooperatives operate mainly in the large centres.

From the eight major centres in Zimbabwe included in the sample for waste data, the total annual municipal solid waste handled was estimated to be 720.1Gg for 1994.

The centres comprised Harare (365 Gg), Bulawayo (144 Gg), Gweru (76.3 Gg), Kadoma (10.6 Gg), Mutare (80 Gg), Chegutu (6.5 Gg), Masvingo (24.8Gg) and Bindura (12.9 Gg).

The total annual degradable organic component (DOC) landfilled was estimated to be 107.99 Gg. Using the IPCC default of fraction of DOC that actually degrades (0.77), the amount of methane released from landfills was 24.31Gg. No methane is recovered from the landfill sites and hence net CH_4 emissions amount to 24.31Gg.

3.8 Remarks

Table 3.10 shows that Zimbabwe is a net sink of CO_2. As a net sink, Zimbabwe is placed in a position where it is currently absorbing emissions from countries which are net emitters of greenhouse gases. The effect of that is Zimbabwe, together with other Parties to the Convention that are net sinks, is slowing down the pace of climate change. At the present rate of emissions, Zimbabwe will remain a net sink for some time to come (until 2040). The positive effect of this negative flux of greenhouse gases will not be globally felt unless net emitters take serious steps to reduce their emissions.

Most of the sources and sinks of GHG in Zimbabwe (as recommended by the IPCC) were analysed in this study. However, there were some sources which could not be analysed for lack of reasonably accurate or unavailability of data. These include bunker fuels, agricultural soils among others.

An analysis of the energy supply by fuel for the years 1982-1994 indicates very little change in the percentage contribution of each fuel to the total energy supply. This is possibly due to the fuels being sector specific such as liquid fuels for transport and coal for industry. The fuels are, therefore, related closely to economic activity.

Table 3.9 clearly illustrates the dominance of CO_2 in emissions caused by energy consumption. The trend over time for CO_2 is a very gradual decline although emissions were slightly up in 1994 compared to the previous year. The trends in the other energy based emission types are inconclusive. The main concern in Zimbabwe should be with trends for CO_2 particularly from thermal power generation.

Table 3.9: Energy-based emissions in Zimbabwe, 1990-1994 (Gg)

GHG	**1990**	**1991**	**1992**	**1993**	**1994**
CO_2	16 750	15 950	15 727	14 331	14 772
CH_4	97.01	99.15	106.08	102.57	103.67
N_2O	1.12	1.12	1.17	1.18	1.18
NO_X	9.19	9.19	0.41	10.08	10.08
CO	496.07	496.07	519.59	544.48	544.46

3.9 GHG emission projections

3.9.1. Introduction

The previous inventories show that carbon dioxide emissions in 1994 were mainly from energy use. About 63% of the emissions werefrom coal combustion. Projections of greenhouse gas emissions are therefore highly dependent on energy consumption. The consumption of energy can be interpreted as a rough indicator of economic development. In Zimbabwe, industry relies on coal and electricity for energy. The productive sector accounts for about 31% of energy use, the residential sector about 52% and the transport sector about 11% (Fig.3.3).

Fig. 3.3: Percentage energy use by sector, 1994

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table 3.10

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3.9.2 Energy intensity in production

Energy use in production can be related to the GDP contribution of each sector to the economy. Energy efficiency in the activity can therefore, be measured in terms of monetary GDP units produced per unit of energy consumed.

The assumptions used in preparing Table 3.11 are that there is an inherent improvement in productivity as economies modernise. Old equipment is replaced by newer and more efficient fixed equipment, and production methods themselves become more refined. Even though there may be no deliberate effort to improve energy efficiency, there should still be an efficiency improvement due to the advancement of technology. This indirect gain in energy efficiency is termed, "Autonomous Energy Efficiency Improvement (AEEI)". The AEEI figure in each sector is related to technology and can be estimated crudely. This approach does not rule out more drastic changes in production methods due to discovery of new technology but is related to the difference between available technology and that which exists in Zimbabwe. The estimated AEEI for each sector in Zimbabwe are based on UNEP Studies (1993).

Table 3.11: Energy intensity of production

ENERGY INTENSITY	TJ	TJ/ Z$	TJ	TJ/ Z$	TJ	TJ/ Z$	TJ	AEEI %/yr
	1994		2010		2030		2050	
Agriculture	31 606	49.69	58 568	50.54	87 029	50.54	129 321.82	0.00%
Mining	7 663	22.87	10 358	25.52	10 566	21.34	12 838.28	1.00%
Industry	43 373	40.65	50378	40.09	236 045	33.51	348 642.64	1.00%
Transport	28 631	100.11	87 928	118.99	119 843	104.95	154 752.24	0.70%
Services	15 413	35.19	26 131	6.06	63 379	5.54	85 222.18	0.50%
Residential	138 221	-	147 910		215 180		313 044.64	
TOTAL	**264 906**		**481 273**		**732 042**		**1 043 821.81**	

N.B: The decimal in the totals have been rounded

Source: UNEP Country studies phase II, 1993

3.9.3 The energy demand forecast

Given GDP projections, it is possible to project energy demand and CO_2 emissions by each sector for the respective forecast years (Tables 3.12, 3.13, 3.14, Fig. 3.4). The forecast is obtained by multiplying the energy intensity for each sector by the AEEI of that sector. Since each sector includes various forms of energy it is not possible to split the energy used by fuel type for each sector. The goal is, therefore, to find the total energy demand and then split it by fuel using the energy supply figures given in Table 3.11. This computation obviously has an error due to the exclusion of energy switching options in each sector. It is however, assumed that Zimbabwe has limited energy sources such that energy switching is not a major option for most activities. As an example, industry cannot switch from thermal energy based on coal to natural gas as in many North American and European countries, since the latter fuel source is not available on a large-scale commercial basis in Zimbabwe.

Table 3.12: Projection of GDP contribution by sector in 1980 Z$ (million)

	1994	**2010**	**2030**	**2050**
Agriculture	636	1 159	1 722	2 558.80
Mining	335	406	495	735.54
Manufacturing	1 067	3 751	7 043	12 720.44
Total Production	2 038	5 316	9 260	16 014.79
Electricity & Water	126	484	719	1 068.40
Transportation	286	739	1 142	1 696.95
Services	2 211	4 313	11 444	17 005.18
TOTAL	**6 699**	**10 851**	**22 566**	**17 005.32**
Growth rate		**4.6**	**3.8**	**2.90**

N.B: The decimal in the totals have been rounded

Source: UNEP Zimbabwe GHG Country Studies. (1993)

Table 3.13: Energy demand forecast/TJ

	1994	2010	2030		2050
Coal	41.7%	132 436	229 112	348 492	496 916
Ethanol	0.1%	329	1 402	2 133	3 043
Jet A1	1.2%	3 779	6 266	9 531	13 590
Gasoline	3.9%	12 273	16 920	25 738	36 699
Diesel	9.4%	29 976	38 529	58 606	83 566
AvGas	0.05%	54	242	368	25
Wood	43.7%	138 777	188 799	287 173	409 482
Coal	41.7%	132 436	229 112	348 492	496 916
Total		**317 724**	**481 273**	**732 042**	**1 043 822**

N.B: The decimal in the totals have been rounded

The above table can then be used to determine the emission levels by applying the IPCC default factors. Results are the base case emissions assuming no deliberate effort to reduce greenhouse gas emissions.

Table 3.14: CO_2 emission projections for Zimbabwe/'000 Gg

Emissions	**1994**	**2010**	**2030**	**2050**
Coal	14.041	21.77	33.11	47.21
Ethanol	0.00	0.00	0.00	0.00
Jet A1	0.264	0.45	0.69	0.98
Gasoline	0.895	1.24	1.88	2.68
Diesel	2.179	2.85	4.34	6.18
AvGas	0.012	0.018	0.027	0.038
Wood	0.00	0.00	0.00	0.00
Total	**17.391**	**26.32**	**40.04**	**57.09**

N.B: The decimal in the totals have been rounded

Fig. 3.4: CO_2 emission projections from fuel combustion

This figure is not available electronically

3.9.4 Emissions from waste management

Projections of waste generation were based on population growth rate and the urbanisation rate. Such initiatives as responses to global climate change and the environmental awareness campaign in the country will dampen waste generation rates per capita. But due to the high urbanisation rate, high volumes of waste are likely to result. These assumptions were the basis for CH_4 emissions projections shown in Table 3.15.

Table 3.15: Urban population trends and waste generation tendencies

	1994	**2010**	**2050**
Urban Population (m)	3.2	5.4	11
Solid waste (kt)	734	1 244	2 522
Methane Emissions (kt)	25.1	42.2	85

3.9.5 Emission projections for industrial processes

Projecting emissions from industrial processes was rather difficult. This was mainly because there was no information on baseline trends in technologies used in the industries of concern. Nor was it possible to reasonably assume demand for the various product associated with the industrial sources of GHG. Under these circumstances, we assumed that emissions from these sectors will maintain the present linkage factors with GDP. This is a weak assumption given that even trends in GDP will change with technological transitions. But it is the best assumption we have at present. This assumption yields estimates shown in Table 3.16 for industrial process emissions.

3.9.6 Emissions from agriculture and livestock

Agricultural practices are unlikely to change in the first 20 years from the baseline year. Emissions are likely to be pushed more by population demand for food and the expansion of commercial crops than by major technological changes. Expansion for both foodgrain crops and livestock is bonded to population per capita food requirements controlled by historical trends.

Only marginal historical expansion was allowed for commercial crops such as tobacco and cotton. This expansion was limited to the first 20 years of the projection period and leveled off thereafter.

Table 3.16: Projections of emissions from industrial processes /Gg

	1994	2010	2050
CO_2			
Cement production	448.65	759.13	2 503.50
Explosives (use)	23.70	23.70	132.25
Metals and mineral processing	1 844	3 120.11	10 289.7
CH_4			
Metals and mineral processing	19.08	32.28	106.47
N_2O			
Metals and mineral processing	6.05	10.24	33.76
NO_x			
Metals and mineral processing	0.04	0.068	0.22
Fertiliser production	0.17	0.28	0.92
CO			
Metals and mineral processing	1.38	2.34	7.70
Total (in CO_2 equivalent)	**4 732.15**	**8 006.95**	**26 405.74**

N.B: The decimal in the totals have been rounded
Results of these production trends were used to calculate emissions shown in Table 3.17

Table 3.17: GHG emissions projections from agriculture/Gg

GAS	1994	2010	2050
CH_4			
Burning of agricultural waste	0.93	1.58	1.74
Enteric fermentation	179.82	305.05	618.13
Manure management	7.09	12.03	
Savanna burning	49.00	83.13	91.66
N_2O			
Burning of agricultural waste	0.03	0.05	0.06
Savanna burning	2.36	4.00	4.41
NO_x			
Burning of agricultural waste	1.10	1.87	2.06
Savanna burning	65.81	111.64	123.10
CO			
Burning of agricultural waste	19.81	33.61	37.06
Savanna burning	1 362	2 310.50	2 547.67

Total (in CO_2 equivalent)	**13 389.21**	**22 713.84**	**32 220.59**

N.B: The decimal in the totals have been rounded

The same assumption is applied on the population of livestock which is bound to reach a specific ceiling due to constraints on land availability.

3.9.7 Projected emissions from land-use change and forestry

Trends in land-use change are hard to determine. This weakens the basis for projecting emissions from this sector. For analytical purposes, we assume that the present relationship with land-use change will continue for the period up to 2030 when population growth and cost of land will limit abandonment of land and engender more intensive agriculture. Forestry clearing emissions are also assumed to be rationalised by expansion in commercial forests although this has remained stagnant for the past few decades. Concern with the environment and the declining resource base for rural energy will force the introduction of wood lots and alternative energy resulting in only minimum decline in emissions from forestry clearing due to population pressure.

These assumptions result in emissions shown in Table 3.18.

Table 3.18: GHG emission projections from land-use change and forestry/Gg

GAS	1994	2010	2039
CO_2			
Land clearing	2 500.28	16 234.20	158.38
Biomass removals	16 234.20	15 490.00	1 030.00
Managed Forests	-81 003.49	-77 310.00	- 5 130.00
CH_4			
Forest clearing	1.26	1.20	0.079
N_2O			
Forest clearing	0.0087	0.0083	0.0006
NO_x			
Forest clearing	0.204	0.19	0.013
CO			
Forest clearing	18.44	17.60	1.17
Total (CO_2 equivalent)	**- 62 171.90**	**- 59 153.90**	**-3 938.26**

N.B:The decimal in the totals have been rounded

Policies, Programmes and Measures

4.1 Background

The climate change issue is a new concept in Zimbabwe both in terms of its science and policy implications. The understanding of this subject - its scientific basis, institutions, and relevance to Zimbabwe's economy - are mainly restricted to a few institutions and individuals exposed to the subject. It is not possible, therefore, that Zimbabwe would, at this stage, have a stated or fully considered national perspective on policies and measures to respond to climate change.

However, climate change activities in Zimbabwe have been growing since its participation at the Rio Earth Summit in 1992. Since then, various IPCC and COP activities in Zimbabwe, including a number of studies, have encouraged limited national consultations and activities relevant to the UNFCCC. These consultations and activities, while not constituting stated government policy, give indications of Zimbabwe's national thought on issues relating to climate change.

Zimbabwe took the Rio conference seriously. It signed and ratified the Climate Change Convention quite early in the process. This interest in the Convention was serious as the events that follow demonstrate.

4.1.1 Pre-Rio consultation

Realising the importance of the environment, the Zimbabwe Government published the National Conservation Strategy in 1987 which was a blue print for the development of the environment in Zimbabwe. The strategy provided a detailed description of environmental issues in the country which failed to be implemented due to poor integration with national planning processes as well as lack of resources.

In the run-up to the 1992 Rio Earth Summit, Zimbabwe conducted a number of national consultations so as to come up with clear positions on several issues, including climate change. Results of these consultations were contained in a formal document entitled, "Government of Zimbabwe National Report to the United Nations Conference on Environment and Development (UNCED) June 1992". This report outlines Zimbabwe's natural resources base, institutional arrangements for the management of the environment and sustainable development, its social infrastructures and economic standing as well as specific recommendations to UNCED.

4.1.2 Post Rio consultations and national response programme

For Zimbabwe, the positions taken at Rio were in fact, a mandate from the stakeholders that were consulted at that time. It was imperative, therefore, that formal report-back arrangements be put in place. A series of these were held including reporting to specific interest groups such as industry. Following these, a National Response Conference to the Rio Earth Summit was organised by the then Ministry of Environment and Tourism, and funded by UNDP. More than 400 delegates from churches, civic groups, industry associations, farming communities, various government departments, universities, NGOs and international development agencies based in Zimbabwe attended the conference. The conference agenda was aided by results of a national Delphi survey to identify, clarify and rank environmental issues and development objectives (Marongwe and Milne, 1993).

Results of this landmark workshop are documented in the report, "Zimbabwe, Towards National Action for Sustainable Development: The Report on the National Response Conference to the Rio Earth Summit, 2-4 November 1992". In this report specific environmental priorities for Zimbabwe are highlighted.

4.2 Steps taken regarding climate change

4.2.1 Country studies on climate change

Zimbabwe's first climate change studies were conducted as early as 1991. ODA, DANIDA and IDRC supported these studies. In 1993, the UNITAR, in its pilot phase, selected Zimbabwe to be one of the three countries, (the others are Lithuania and Vietnam) to undertake programmes on climate change awareness raising (among others) through a series of workshops for a wide variety of stakeholders. In 1994/95, Zimbabwe conducted a third set of studies under the US Country Studies Programme.

With experience gathered from these studies, Zimbabwe is now in a better position to conduct more comprehensive assessments of inventories, mitigation analyses and vulnerability and adaptation studies. The latest generation of assessments is based on 1994 data and was conducted specifically to form part of the country's Initial National Communication to the UNFCCC. These were completed in 1998 and financed under the GEF enabling activities programme with facilitation from UNEP.

4.2.2 Regional studies

Zimbabwe's economy and resources, to a significant extent, exist contiguously to those of its neighbours - Zambia, Botswana, Mozambique, South Africa and other states in the Southern African Development Community grouping. It would not be practical in terms of policies and measures to ignore the strong interface that exists between these states and Zimbabwe. In this light, the Ministry of Transport and Energy in the Government of Zimbabwe conducted two major studies on the regional aspects of climate change mitigation.

The first study was funded by GEF and carried out jointly by the UNEP Collaborating Centre for Energy And Environment (UCCEE) and Southern Centre for Energy and Environment (SCEE). This study is part of a broader international programme that focuses on methodological approaches to assessing technological options and associated costs of possible regional mitigation interventions. The second study, supported by GTZ, focused on a detailed assessment of greenhouse gas emissions from the power sector in SADC. This landmark project looks at the practical, political, technological and cost aspects of using regional electricity sector groupings such as the SADC's Southern African Power Pool as a vehicle to carry greenhouse gas mitigation options.

These two studies bring in useful regional factors, which are being considered in developing Zimbabwe's national response options to the climate change problem. The most significant of these are the joint operations of hydro-electric power plants in the same hydrological zone, regional power pooling based on cost and CO_2 optimization and data pooling for assessment and adaptation of vulnerability.

4.2.3 Institutions

The Ministry of Mines, Environment and Tourism is the custodian of the UNFCCC in Zimbabwe. Following national consultations, the Ministry established a National Steering Committee on Climate Change, which is a cross-sectoral grouping of stakeholders. The Committee reviews all national climate change positions that the country may take and acts as a deliberating body on new and emerging issues on climate change. To provide consistent facilitation of climate change activities, the Ministry also established a Climate Change Office with a full time Co-ordinator and Secretary. This office and the committee form the institutional core of climate change activities in the country.

Apart from Government initiatives, climate change is being discussed by some organisations in the private sector. Industry associations, particularly the Confederation of Zimbabwe Industries, Environment Sub-committee, the Environment Forum of Zimbabwe, the Zimbabwe Investment Centre, and the Indigenous Business Development Centre have taken climate change issues into the mainstream of their environmental discussions. A number of NGOs provide technical expertise to support these discussions. These discussions have tended to focus on mitigation analysis, inventories, desertification and impacts on water and agricultural production.

More technical and scientific research remains focused on traditional natural resources top ics. In Chapter 6, however, we show how these scientific and technical research institutions can, in fact, expand their programmes to provide data which is also useful to climate change related decisions.

A significant amount of climate change information is also found in the Department of Meteorological Services in the Ministry of Transport and Energy.

4.2.4 Legislation

The 1992 National Response Conference to the Rio Earth Summit strongly recommended that Zimbabwe should make a comprehensive review of its environmental legislation. As part of this process, and with the support of the CIDA-funded Zimbabwe Natural Resources Management Programme, the Ministry of Mines, Environment and Tourism conducted a review of international conventions. In the past two years, a national environmental law workshop was held to solicit input from interested stakeholders. Several background research studies have been completed, including one on economic instruments for environmental management. Many of these incentives could be applied to reducing emissions of GHG. In 1996, the legislative aspects (Zimbabwe context) of the UNFCCC and the Bio-diversity Convention were reviewed under this process. As of now, a draft framework Bill for environmental legislation is being prepared by the Ministry for submission to Cabinet.

Recommendations in the review specific to climate change include the incorporation of climate change policies into Zimbabwe development plans. This process is due to be completed soon and it is expected that specific legislative positions will be outlined. What is significant at this point is that Zimbabwe has included climate change in its national legislative review programme.

4.2.5 Capacity building

Climate change is a new subject in Zimbabwe. Therefore developing a practical national response programme requires skills in many technical and social disciplines. Expertise in research related to climatic change is important. Prior to the eminence of climate change debate, Zimbabwe had developed research capacity mainly in agriculture, mining, and various social disciplines but remains ill-equipped to conduct industrial research with assessment of technologies for industrial mitigation options. The various research institutions in Zimbabwe and their focus in research are discussed in Chapter 6.

Capacity to assess topics on climate change, particularly the main focal areas of inventories, mitigation analysis, vulnerability assessment and adaptation remains rudimentary and restricted to a few institutions. However, Zimbabwe is participating in a regional climate change capacity building programme funded by GEF through the UNDP. This programme seeks to improve capacity among various economic sectors to analyse impacts and response options to climate change. Through this programme, a number of national and provincial workshops on climate change have been conducted. As a result of these workshops, a better understanding of sector-specific climate change implications have been identified. These will have to be studied in detail to allow incorporation into provincial and sectoral economic planning. Climate change programmes will be implemented through various instruments, such as Activities Implemented Jointly, appropriate policies and legislation. It will be imperative that these be properly studied so as to come up with the best implementation mechanisms.

4.2.6 Energy efficiency and industrial energy management

Industrial energy efficiency is one important way to reduce GHG emissions as well as local negative environmental effects. Industrial energy efficiency is, therefore, important to industry with resulting joint benefits for climate change. Zimbabwe's industrial capital stock is quite old. Replacement remains constrained by high interest rates, a constantly depreciating local currency (for imported equipment), and for some items, high import tariffs.

A few studies dealing with energy efficiency in industry can be identified. These include:

4.2.6.1 The Energy Conservation Pilot Project

This project was first developed in 1984 in response to the need to reduce petroleum consumption in SADC industries. The project evolved from two projects that were being considered by SADC at that time. One was
on the potential for energy conservation in industry in general and the other was on assisting Zambia's copper mining industry in improving energy efficiency.

4.2.6.2 The SADC Industrial Energy Management Project

Its objectives are to:

Develop the energy management expertise in SADC.

Motivate and develop capacity within industry to plan and undertake energy management projects.

Develop awareness of energy efficiency opportunities and through this foster the development of a market for energy efficiency services in the region.

4.2.6.3 SADC informal industries energy efficiency improvement

This project focused on improving the efficiency of biomass energy use in small-scale rural industries in SADC. The project originated from a meeting in Maputo in 1991 where SADC biomass energy experts resolved to conduct an assessment of regional bio-energy problems as they relate to small-scale rural industries. The main focus of the project was to reduce deforestation associated with rural industries with special emphasis on brick making and fish smoking. These are important consumers of fuel-wood in rural areas.

Results of the project showed that thermal efficiency in fish smoking can be improved from 8.5% to 20.2% by shifting from drum kilns (using old oil drums as is common in Angola) to the design proposed in this SADC study.

4.2.7 Critique

Small-scale industrialists themselves are not focusing on energy use and sound environmental management as they are pressed to concentrate on survival issues such as financing their operations and meeting loan repay ment obligations. Under this kind of pressure, the benefits of energy efficiency in production systems are not a business priority.
The SADC Energy Sector Framework Action Plan was approved by SADC Energy ministers in Arusha, Tanzania, on June 18th, 1997. The focus of the plan is regional collaboration in such key issues as information and experience exchange, investment and financing of energy sector programmes which are mainly supply side, energy trade and institution and capacity building. While the tone of the plan highlights focus on supply issues and large industrial establishments, there may be scope for addressing the needs of small-scale industries particularly through information and experience exchange.

From the above review, significant work has been done in SADC on energy efficiency in industry. However, this work has focused on larger industries as opposed to new and emerging small-scale industries. Previous studies have also not made serious consideration on the role of policy and support mechanisms, including financing energy efficiency improvements. These issues are important, particularly in relation to the needs of small-scale industries. Generally, in SADC there are very limited energy services support for the private sector. This is the gap the current SADC Industrial Energy Management Programme is attempting to fill by training energy specialists in industry and consulting firms, and creating energy services markets. Naturally, if this project is successful, it will focus on the sectors for which training is being provided and where markets are most likely to develop.

4.3 Promotion of new and renewable sources of energy

Many climate change mitigation technologies can only succeed with strong diffusion support from social institutions. To this end and realising the important joint benefits that may accrue from new and renewable sources of energy (NRSE) technologies, Zimbabwe has conducted a number of promotional activities both on its own and in collaboration with other countries in the region. As current chairman of the World Solar Summit Process, Zimbabwe has opened an office dedicated to supporting the process and developing regional projects to promote NRSE's activities for implementation.

As part of a SADC effort, Zimbabwe conducted assessments of marketing and pricing of NRSE devices, including an assessment of the market and supply base. Results showed that with appropriate pricing and entrepreneurial development activities in place, NRSE could play a significant role in promoting rural development and providing cleaner energy. This information base is being disseminated in six SADC countries, including Zimbabwe through the Renewable Energy Information Network supported by EU. Zimbabwe is working to enhance the availability of NRSE information to consumers, suppliers and policy makers. The SADC programme for Financing Energy Use in Small Scale Enterprises (FINESSE) is developing business plans and support programmes to support entrepreneurship in NRSE-an approach that would ensure effective diffusion of this win-win technology.

The Pilot GEF project on solar devices, which Zimbabwe is currently conducting, has provided useful information on the diffusion of these devices in the Southern African social and economic setting. This information has been helpful in the design of related projects in the region.

Rural areas will suffer from climate change, particularly if this results in reduced rainfall. Alternative water sources such as boreholes to access groundwater have been installed in various parts of the country and trial projects are being conducted with the support of GTZ to utilise solar power for pumping. The trials have focused on both the technical and economic aspects of solar PV water pumping.

4.4 Possible mitigation options

A number of mitigation options have been assessed for Zimbabwe. Present information relates mainly to industrial and energy sector options. Little work has been done on policy options or those associated with macro-economic interventions. The list below is not exhaustive but is a good indication of what is possible.

4.4.1 Industry

a) Introducing more efficient coal-fired industrial boilers

The present efficiency of coal-fired boilers made in Zimbabwe is 74%. In some cases, poor operating practices reduce efficiencies to 50%. It is possible to improve efficiency to 80% by using soot blowers to clear steam pipe surfaces and thus increase heat transfer. Insulation would reduce boiler skin temperature from the present average 40^0C to 30^0C, much closer to ambient temperature in factory settings.

b) Introducing more efficient industrial furnaces

About 31% of electricity consumption in Zimbabwe is accounted for by industry. In the metal industry, most of this energy is consumed in electric furnaces. The total capacity of electric smelters alone is estimated at 230 MW. It is possible to reduce power demand in smelters by replacing electric arc furnaces currently used in the country with coal-fired plasma arc technology. Experience with coal fired plasma arc furnaces is quite limited in Zimbabwe. The only technology so far tried commercially is an Australian design Siro-smelt plant with a capacity of 2 MW. This plant replaced an electric arc furnace in the production of high purity nickel at the Empress Nickel Mine. A 2 MW unit uses 2.5 tonnes of coal/day and has a capital cost of around Z $22 million.

The option assumes that the capacity of the replacement furnace would be the same as that of the current one. It does not adjust for the possible reduction in capacity for the new furnace technology, which may require less installed capacity for the same input of raw materials.

c) Replacing electrolytic ammonia production with ammonia from coal technology

Nitrogenous fertilisers are produced at the Sable Chemicals ammonia plant in Kwekwe. In 1992, the plant used 83 MW of power in the production of ammonia, making Sable Chemicals one of the largest single consumers of power in Zimbabwe. It is possible to reduce the demand for power in this industry by producing ammonia directly from coal using a coal gasification-synthesis process.

4.4.2 Forestry

a) Introducing afforestation for carbon sequestration

This option would enhance the capacity of forests to absorb carbon dioxide. The present capacity is estimated at 624 million tonnes of wood (dry matter) based on 20.5 million ha of existing area under forests. The afforestation option in this study is viewed in the light of parallel deforestation going on mainly in communal land areas. The deforestation rate of 10 000 ha per year increases to about 28 000 ha in 2010. This would have to be at least balanced off with the same rate of afforestation or reforestation to maintain the present CO_2 absorption capacity. The minimum diffusion rate for afforestation in the analysis is, therefore, 10 000 ha a year.

4.4.3 Power generation

a) Increasing the role of hydroelectricity in electricity supply

Zimbabwe has a significant amount of potential hydropower resources. Most of these locations are on the Zambezi river and require international agreements with Zambia to develop. The Southern African region also has large endowments of hydropower as evidenced by such massive potential projects as the Inga Dam scheme proposed in Zaire. This project could harness some 40 000 MW of power for supply to the Southern African region. It is considered possible, therefore, that Zimbabwe could either increase the use of hydro in power generation or use inter-connectors with other regional installations to reduce the use of coal. Coal utilisation in power generation is the largest contributor to CO_2 emissions in the country. Introducing abatement in this sector is, therefore, an attractive option.

4.4.4 Agriculture

a) Introducing minimum tillage in agriculture

Farming in Zimbabwe entails ploughing, in large-scale commercial operations where tractors, roam harrows and other mechanised devices are used. Ploughing requires 31.8 litres of diesel per ha. In small-scale peasant operations single mould-board ploughs and spike harrows are more prevalent. These implements are animal drawn.

International studies as well as the work done at the Institute of Agricultural Engineering and the Agriculture Research Trust in Zimbabwe have shown that zero tillage for most crops can be adopted without negative effects on crop yields but instead with positive gains in soil conservation. On the negative side, additional herbicides for weed control may be required, however, with its own implications on surface and groundwater pollution.

This approach is a way of abating GHG emissions associated with the use of diesel for ploughing in commercial agriculture. Because of the predominant use of animal power in peasant farming and in small-scale commercial farms, which results in low utilisation of diesel in this sector, it is assumed that emissions from the use of diesel in ploughing are nil. Diffusion of this option is therefore restricted to large-scale commercial farming operations.

b) Introducing more efficient coal-fired tobacco barns

Zimbabwe is a major producer of flue-cured tobacco. Production in normal seasons exceeds 185 000 tonnes. Curing of this tobacco is done by using either coal or wood-fired barns. Twenty-five percent of the present stock of coal fired barns requires 5.0 kg of coal to cure one kg of tobacco. A new design of the same barn can reduce consumption by 68% to 1.6 kg of coal per kg of tobacco cured.

This option seeks to replace the stock of inefficient barns with the new design, introducing 320 new barns by 2010 and 660 by 2030. The extra cost for an efficient barn is 16 500 Z$. One new barn takes 20 batches of 3 500 kg of tobacco per year.

4.4.5 Rural areas

a) Introducing domestic biogas digesters

Rural households are a major contributor to CO_2 emissions mainly because wood is the primary source of energy. The average consumption rate of wood per household is approximately 12.0 kg per day.

Since 1982, the Department of Energy has been carrying out a programme to introduce Chinese type biogas digesters in rural households. To date, about 60 biogas digesters have been introduced for domestic purposes. A few are used on a commercial basis. A typical biogas digester has a capacity of 12 cubic metres and supplies energy for lighting, cooking and water heating with a general space heating effect.

A major limiting factor to the diffusion of these devices is the supply of biogas burners for lighting and cooking. Presently, these are imported from China or India. Diffusion of the technology should increase once this distribution problem has been overcome. The rate of diffusion is, however, likely to remain low since the technology will be applied to low-income rural households. Biogas digesters use organic waste derived from vegetation without the complete destruction of the vegetation as in the case of trees cut for firewood. The biogas option, therefore, assumes zero net emissions of $CO_{2.}$

b) Introducing solar PV water pumps to replace diesel pumps

There are about 30 000 boreholes in Zimbabwe. The majority of these supply water to rural communities and commercial farms. The Ministry of Water and Rural Development is compiling a computerised database on characteristics of the borehole population in the country. So far, however, only 3 000 of these boreholes have been analysed. Significant proportions of the boreholes reviewed are head driven; the rest are driven by diesel engines. Therefore introduction of solar PV pumps would reduce CO_2 emissions through reduced diesel usage.

4.4.6 Urban areas

a) Increasing the diffusion of solar hot water systems

Solar hot water geysers have been introduced in Zimbabwe. There are several commercial suppliers in Harare alone. Marketing of these devices has, however, been largely restricted to urban high-income households. While it is likely that this market will expand into the rural areas, the potential exists for greater diffusion into urban middle income and low-income households. In this report it is assumed that a third of the total population of electric geysers will be replaced with solar devices with some electrical back up. In summary, the previous mitigation measures can combine to save energy and thus reduce emissions of GHG (Table 4.1).

4.4.7 Ranking of GHG abatement options

Prioritising GHG abatement options can be achieved on the bases of cost of abatement, volumes of GHG abated as well as non-cost national considerations. The "abatement cost curve" which ranks options according to the unit cost of abating unit weight of CO_2 and amount of CO_2 reduced per year can help in prioritising options on a national basis. The cost curve clearly sequences "no regret options" or negative cost options and non-negative cost options.

However, no regret options have to be implemented in parallel with positive cost options so that cheaper options are not exhausted first. They would also be guided by priorities in affected economic sectors for instance the zero tillage option with very low costs could be implemented in parallel with solar PVP which has very high costs as national programmes for water supply are scheduled independently of other rural programmes. It is also possible that the least cost options may be difficult to organise and would require longer lead times than the costlier options. Alternatively, the more costly options may be forced into sequence by other factors.

Prioritising options even on the basis of cost and volumes of abatement is likely to follow the national agenda for development rather than the cost curve, although the cost curve may be a good indicator for which items could be rearranged within the existing set of national priorities. The ranking would also have to consider other factors such as broader national benefits of options, and the long-term effects of options on social and economic factors. It may also be necessary to consider the country's institutional capacity to implement an option or a set of options even if funding were available. The above argument ind-icates the difficulty of having an abatement strategy as the country attempts to follow its own development strategy.

The introduction of abatement activities would require first a national policy position to support industrial energy conservation and the transfer or development of environmentally sensitive technology. Ensuring the success of such a policy requires specific policy instruments to enable productive sectors to adopt appropriate abatement practices. The introduction of such instruments in turn requires some policy and technical capacity to monitor emissions for purposes of enforcing reduction instruments.

Table 4.1: Summary of possible mitigation options

Sector/Option	**Primary Energy Saved / GJ**	
	2010	**2030**
Industry		
Efficient boilers	45.9	136.1
General savings	0	10.2
Efficient motors	1.1	4.3
Efficient furnaces	10.2	10.2
NH_3 from Coal	6.8	6.8
Agriculture		
Efficient motors	0.1	0.5
Zero tillage	0.3	0.3
Efficient tobacco barns	2.1	4.4
Solar PVP	0.003	0.003
Service		
Efficient motors	0.2	1.0
Residential		
Prepayment meters	0.1	0.1
Geyser timers	0.9	1.4
Biogas digesters	0.6	0.8
Solar geysers	1.3	1.9
Power generation		
Hydro power	0.0	28.4
Power factor correction	1.8	6.5
Central PV power	0.0	3.6
Solid fuels		
Coke oven gas in power generation	0.6	0.6
Direct CO_2		
Afforestation	0.6	0.6
Total	**72.6**	**217.7**

N.B: The decimal in the totals have been rounded

Source: UNEP GHG Abatement Studies (1993)

However, Zimbabwe has indicated a political predisposition to carry out abatement activities through the ratification of the UNFCCC. While no official policy has been enunciated on this subject, the general disposition of the Government is that its supports participation in global efforts to reduce emissions.

The options listed in Table 4.1 were derived from the UNEP study on GHG abatement costing studies. Each option was assessed for its economic cost and volumes of abatement. These were then summarised in an abatement cost curve and sequenced according to their relative abatement cost and volumes of abatement. Some of these costs are negative (for no regret options) and some are positive (for expensive options). Some of the options, especially those that require high initial capital investment, are susceptible to changes in discount rates and can shift from negative to positive cost if discount rates change. Table 4.2 below outlines the likely order of priority of mitigation options studied in Zimbabwe. It also distinguishes the no regret options (-) and the positive cost options (+) according to the UNEP study and outlines the technologies involved for each option.

Table 4.2: Ranking of options and associated technologies

Option	Description of technology
1. Hydropower (+)	Increased generation of electricity from hydropower stations and limiting generation from fossil-fuel based generation stations
2. Solar geysers (+)	Solar water heater geysers/replacement of electric geysers
3. Efficient boilers (-)	Introduction of more efficient coal-fired industrial boilers Technology involves introduction of soot blowers for clearing steam pipes surfaces, boiler jacket insulation
4. Ammonia from Coal (++)	Coal-gasification synthesis
5. Efficient furnances (++)	Replacing electric arc furnance with coal fired plasma technology e.g. Siro-smelt plant
6. Biogas digesters (+)	Chinese "fixed dome" type digester. Indian "floating dome type", Carmatec " fixed dome" type
7. Efficient tobacco barn (-)	Improved efficient coal-fired tobacco barn
8. Afforestation (++)	Planting more trees
9. Solar PVP (++)	Solar Photovoltaic Pumping technology replacing diesel pumps
10. Zero tillage (-)	Use of animal power as opposed to diesel-powered tractors
11. Power factor correction (+)	Capacitors or reactors for power factor correction
12. Central PV power (++)	Solar Photovoltaic technology
13. Geyser timers (+)	Time Switch set to switch electric geyser on/off
14. Efficient motors (+)	Replacement of old and renewed motors with new efficient electricity motors.
15. Prepayment meters (-)	Meters controlled centrally by utility. User can monitor energy being used and adjust consumption accordingly
16. Coke oven gas in	Use of coke oven gas (coke production by-product) power generation (+) in place of diesel for thermal stabilisation etc.

Expected Impacts of Climate Change Vulnerability and Adaptation Assessments

5.1 Introduction

For those economic sectors that were considered, General Circulation Models were used to simulate likely changes in temperature and precipitation as a result of doubling of CO_2. The potential impacts under this scenario were then assessed for the following sectors: forestry, water resources, agriculture and health. In the near future, it is intended to conduct similar vulnerability and adaptation studies for the following vital sectors:- energy, ecosystems and human settlements. The above sectors could not be included in this Initial National Communication due to time and resource constraints. Adaptation measures can be seen against the Business-As-Usual scenario where it is assumed that the doubling of CO_2 will be reached by 2075. The corresponding population projections are based on the figures produced by the Central Statistics Office of Zimbabwe.

5.2 Forestry

5.2.1 Impacts

The Holdridge (1947) classification was used to investigate the impacts on forests. Some key assumptions and limitation of the approach used to determine the effects of climate change on forests are:

The concept of growing-degree days is incorporated indirectly into the biote-mperature values used to compute the different vegetation indices. Growing-degree days consist of the sum of mean daily temperatures above some defined threshold (i.e. base) temperature over a defined time interval (e.g growing season). According to the Holdridge model, the biotemperature values are set at a base temperature of 0^0C: this is much lower than the 18^0C recommended for Zimbabwe. What this means is that the Holdridge classification will tend to exaggerate levels of aridity under climate change scenarios.

As with any classification scheme, the Holdridge model is an abstraction of the actual vegetation pattern; it is not a classification based on the actual distribution of vegetation. It is based, instead, on some climatic factors.

The limited number of categories of life zones results in a coarse resolution of vegetative description. In reality, the patterns of vegetation (i.e hysiognomic structure, species composition, biomass) vary within any one life zone. Adding to this limitation is also the coarse spatial resolution of the global climatic databases used (i.e. 0.5^0 latitude x 0.5^0 longitude) which tend to mask out all meaningful details at national level, more so in small countries.

The approach also wrongly assumes that the vegetation or life zone moves as a fixed entity in time and space. The model is thus too simplistic because it is based on a limited set of variables. Additional factors that are important in determining the actual patterns of vegetation are left out (e.g. soils).

The approach represents an equilibrium solution for both climate (i.e. 2 X CO_2) and vegetation dynamics. In reality the vegetation would most likely be unable to track the true transient climate dynamics: the response of vegetation and soils to climate change may take place at time scales that are significantly different from those at which climate changes.

In areas where biomass values decrease because of moisture stress, the changes may occur quickly as the environmental conditions worsen (e.g. the shift from woodland to grassland). In contrast, increases in biomass may require much longer periods of time. In particular, major shifts from less productive forest types to more productive categories will depend on the movement of species across the landscape and the ability of new species to invade existent communities. Such changes in forest type would operate on time scales related to the life-cycle or longevity of the component species.

The Goddard Institute for Space Sciences (GISS) model of 1982 was used to evaluate changes in forest cover due to climate change. The GISS predicts a global temperature rise of 4.2^{O}C at 2XCO_2 and an increase in precipitation of 11% at current precipitation levels. Under this scenario, the changes that take place according to the Holdridge classification (1947) are:

Subtropical dry forest could become tropical dry forest.

Subtropical thorn woodland could be come tropical dry forest.

The warm temperate moist forest in the Nyanga is replaced by subtropical moist forest due to increased potential evapo-transpiration.

Subtropical moist forest loses 3 220 km^2 to tropical dry forest. The southern most portion of Zimbabwe degenerates into tropical thorn woodland.

These changes are shown in (Fig. 5.1 and 5.2).

5.2.2 Human adaptation options

Adaptations options are the following:

(a) Changing land use practices

Maintaining forest diversity and extensiveness, through altering land-use, harvest and planting practice to allow forests to adapt to climate change; conserving large tracts of natural forest (for example, the demarcated forest reserves; nature reserves and national parks) and expanding as well as connecting protected areas with conservation corridors for wildlife.

(b) Protecting areas under stress

Protecting critical habitat and potential areas of expansion of species and forest communities likely to come under stress due to altered climate regimes.

(c) Introducing new species

Introduction of both native and exotic species, as a means of facilitating shifts in forest range (for example, planting native or exotic species that may already be favourably adapted to future climate at the latitudinal or altitudinal ecozones of present community ranges). Such species may include drought- or heat-resistant species for regions predicted to become drier.

(d) Improved forest management

Managing and planning land uses around forested areas, to identify and manage areas of potential forest migration or decline, especially corridors or buffer zones along water bodies.

Fig. 5.1: Current forest types

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Fig. 5.2: Forest types under 2xCO_2 scenario

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5.3 Water resources

Of the three Global Climate Models (GISS, GFDL and CCC), the CCC reasonably simulates current temperatures particularly in the Gwayi, Odzi and Sebakwe catchments. Therefore, this model was used to develop both temperature and precipitation scenarios for the doubling of CO_2 case. Estimating water demand to year 2075 was based on population projections and average growth rates in water usage from 1950 to 1995.

Rainfall-runoff simulation for the doubling of CO_2 scenario showed that a 15%-19% decrease in rainfall and a 7.5%-13% increase in potential evapotranspiration will result in a 50% decrease in runoff. The difference in climate change impact on runoff among the three representative catchments considered was a 50% decrease. Therefore, a 50% decrease was assumed a reasonable estimate for the whole country.

5.3.1 Impacts

5.3.1.1 Water supply

Fig 5.3 shows the existing hydrological zones of Zimbabwe (A-F).

A doubling of CO_2 would cause the rivers in the Eastern Highlands of Zimbabwe that are today well watered and perennial to develop flow regimes similar to those currently experienced in the dry regions i.e seasonal rivers. (Table 5.1).

Fig. 5.3: Hydrological Zones

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Table 5.1: Baseline and 2xCO_2 mean annual runoff of the hydrological zones (A to F)

ZONE	AREA	BASELINE		2XC0_2	
	km^2	10^6M^3	MM	10^6M^3	MM
A	102 557	1 743	17	872	9
B	62 541	1 188	19	594	10
C	90 523	5 612	62	2 806	31
D	36 711	4 148	113	2 074	57
E	84 550	5 919	70	2 959	35
F	7 290	1 268	174	634	87
National	384 172	19 879	52	9 940	26

5.3.1.2 Water demand

The water demand is made up of water used for domestic purposes, irrigation, livestock, industry and energy generation. The impact of climate change on water consumption for some of these water uses are not yet clearly known. It is projected however, that climate change will increase irrigation water requirements due to increased potential evapotranspiration for the doubling of CO_2 scenario.

5.3.1.3 Water supply-demand relationship

The water demand in each of the three studied river basins was projected to the year 2075. This water demand was compared to the mean annual flow with and without climate change impacts (Table 5.2). The table clearly shows that although the catchments will be water scarce as a result of increase in demand due to population growth and allied uses, climatic change will make conditions twice as severe.

Table 5.2: Water demand as a percentage of mean annual flow

Catchment Area	1995 Existing demand	2075 without Climate change	2075 with Climate change
Sebakwe	21	106	202
Odzi	19	102	204
Gwayi	24	121	240

5.3.1.4 Impact on conservation reliability

The major form of water conservation in Zimbabwe is through the construction of dams. All urban centres and large-scale irrigation schemes depend on dams for water supply. The impact of climate change on future water supply from dams is a major indicator of the vulnerability of Zimbabwe to climate change. The amount of water that can be supplied by these dams with a reliability of 96% was estimated for the baseline and doubling of CO_2 scenarios. The costs of constructing reservoirs with such storage capacities were estimated using current construction costs of about Z$500 per 1 000 cubic metres of water stored (Table 5.3). The analysis further shows that the yield of dams will decrease by about 30%-40%. If the same level of supply and reliability is desired, then there will be a need to either increase the storage of these dams or construct new ones. Increase in storage is not possible since all major dams are designed for their maximum yield.

5.3.2 Adaptation measures

The amount of water stored as groundwater is still unknown in Zimbabwe. Improvement in the knowledge of groundwater storage may indicate that groundwater is a feasible source of water that can be developed to cushion the impact of climate change.

It is estimated that agriculture currently uses about 80% of the surface water resources. Irrigation efficiencies vary from 40-60%. The improvement in water-use efficiency is one form of adaptation that has minimal costs.

Table 5.3: The cost of the amount of water that can be stored

	Storage ($10^6 M^3$)	Construction costs (Z$millions)
Sebakwe	109	54
Odzi	166	83
Gwayi	235	118

Table 5.4 below shows the potential water storage and the water stored in existing storages in each of the hydrological zones. Currently, only 18% of the potential storage has been developed which shows that water conservation in dams is a feasible adaptation measure for climate change impacts. The information below shows that there is still some scope for further water conservation through using dams.

Table 5.4: Comparison of potential yield with existing water storage

HYDROLOGICAL ZONES	EXISTING STORAGE 10^6 m^3	STORAGE YIELD $10^6 m^3$	POTENTIAL STORAGE $10^6 m^3$	STORAGE YIELD $10^6 m^3$
A	254	138	3 512	816
B	1 202	309	2 314	529
C	2 292	1 104	11 276	3 083
D	323	395	8 206	2 436
E	3 245	1 510	11 908	3 451
F	36	103	2 544	945
Total	**7 350**	**3 560**	**39 820**	**11 260**

5.4 Agriculture

5.4.1 Methodology

Studies have been carried out to investigate the effects of climate change on agriculture in Zimbabwe. Matarira et. al., (1995) used the CERES-MODEL (IBSNAT 1989) to simulate maize responses to climate change at four sites in four of the country's five natural regions.Maize was considered for the simulation because it constitutes the staple food crop of over 95% of the country's population.

Simulations were discrete, with the default initial soil water moisture set at the field capacity of the soils. Nitrogen stress and pests were not simulated. The cultivar simulated was R201, a short-season maize cultivar common in communal farming regions in the country. Various planting dates were tested. Two equilibrium climate scenarios were used, representing much larger changes in climate than are presumed to occur after 2050. This model was validated by means of local experiment crop data. Experimental data included types of cultivars, planting date, growth analysis, fertiliser application, harvesting date and final yield. Using Global Climate Models, the observed climate data were modified to create climate change scenarios. The CCCM in (Houghton, 1990) and the GFDL (Boer et. al., 1992) were used to establish the climate change scenarios for the vulnerability assessment. Subsequent sections of this chapter describe the impacts as shown by the models.

5.4.2 Impacts

Maize production at all sites shows a considerable amount of variation under climate change conditions. Maize planted late will not give good yields, thus making maize production a less viable activity under climate change conditions (Table 5.5).

Table 5.5: Average maize yields over 40 seasons under different planting dates

Planting Date/ Climate Scenario	Average Maize Yield over 40 Seasons (kg/ha)			
	Beitbridge	**Masvingo**	**Gweru**	**Karoi**
October 15				
Normal	738	3 006	3 006	3 727
CCCM(2XCO_2)	514	3 493	5 011	2 634
GFDL(2XCO_2)	1 640	3 097	5 446	2 940
November 1				
Normal	1 136	2 779	2 567	3 654
CCCM(2XCO_2)	838	2 725	3 444	4 641
GFDL (2XCO_2)	1 740	2 402	2 815	4 640
November 15				
Normal	514	2 592	2 507	3 531
CCCM(2XCO_2)	1 092	58	3 444	3 512
GFDL (2XCO_2)	1 422	47	2 815	3 507
December 1				
Normal	1 203	2 417	2 047	3 225
CCCM(2XCO_2)	1 304	47	3 063	2 956
GFDL (2XCO_2)	1 453	45	2 640	2 940
December 15				
Normal	1 213	2 339	1 121	3 143
CCCM(2XCO_2)	713	43	770	41
GFDL(2XCO_2)	725	40	735	41

Source: Matarira et al (1995)

The simulated changes in crop yields are driven by two factors: CO_2 enrichment and changes in climate. In the low-lying areas of southern Zimbabwe, for example, it is probable that climate change will turn the region into a non-maize-producing area, as exemplified by reduced maize production in Masvingo. If climate change becomes a reality, this area, which represents 42% of the communal area, will become even more marginal for maize production. Based on site results, seasons could be 25% shorter than now (Table 5.6).

Table 5.6: Impact of climate change on length of growing seasons

	Average Season Length (days)			
Planting Date	**Beitbridge**	**Masvingo**	**Gweru**	**Karoi**
Normal				
October 15	83	121	121	127
November 1	85	121	122	129
November 15	88	121	121	103
December 1	85	124	121	132
December 15	84	127	113	135
CCCM(2XCO_2)				
October 15	77	101	110	105
November 1	79	101	107	108
November 15	78	101	103	208
December 1	78	102	104	109
December 15	83	102	112	109
GFDL(2XCO_2)				
October 15	87	104	111	107
November 1	84	103	106	110
November 15	81	103	103	111
December 1	82	104	105	111
December 15	84	105	113	112

Source: Matarira et al (1995)

5.4.3 Adaptations

5.4.3.1 Land-use changes

Studies have shown that Southern Africa is one of the most vulnerable regions to climate change. In Zimbabwe, the agriculture sector is quite vulnerable with marginally productive areas probably shifting to non-agricultural use. For areas where crop production becomes non-viable, livestock and dairy production may be developed as major agricultural activities. Some farmers could switch to different crops or change to more drought tolerant and disease resistant crops.

In areas of high temperatures and high evapotranspiration rates, introduction of irrigation systems would help to sustain agricultural production. Switching from monoculture to diversified agriculture is one of the more popular adaptive measures. This is already being encouraged through various awareness raising campaigns. However, it can only be expected that local farmers, mainly subsistence, are conservative and would gradually accept growing other crops. Cash crops such as tobacco need much more skill, specialised equipment and capital to grow. Use of supplementary feeds and livestock breeds adaptable to drought will enable farmers to cope with some adverse climate change impacts. This again requires cash injections and the more vulnerable groups are usually uncredit worthy, sceptical of borrowing and possess no formal training on agricultural practices.

5.4.3.2 Management changes

Changes in agriculture management practices can also offset negative impacts of climate change. The timing of farming operations (for example, planting dates; application of fertilisers, insecticides, and herbicides) becomes imperative if farmers must reduce their vulnerability to climate change. Changing plant densities and application rates of fertilisers and agrochemicals would also help farmers to cope with the impacts of climate change.

5.4.3.3 Anticipatory adaptive measures

At the national level, adaptive measures are anticipatory. Through its policies on infrastructure development, research and development, education, water resources management and product pricing, the government can plan and implement anticipatory adaptive measures.

a) Infrastructure development

The Government has an ongoing investment programme to construct medium to large dams throughout the country. Increases in dam capacities and numbers will enhance the availability of water in future. Construction of these dams allows policy makers to establish irrigation projects, which facilitate a shift from subsistence agriculture to a cash-crop economy and higher rural incomes. Technology of irrigation has to improve as well in order to minimise water costs.

b) Research and development

The Government policy and support for research and development considerably influences the agricultural production sector. Strategic research planning and a well-directed research programme are needed to study crops, and livestock that are more drought tolerant and disease resistant. Sustained research on short-season, high-yield crop varieties and livestock breeds is of paramount importance to adaptation.

5.5 Human health

Both the IPCC and the World Health Organisation (WHO) have raised concern about potential adverse effects of climate change on human health. In Zimbabwe, investigations into the possible implications of climate change on human health have been rather limited. Reviews that have been conducted reveal the complex nature of the problem, where demographic changes, increase of malaria incidences, water-related health effects as well as changes in heat stress associated with temperature increases have been observed. Incidences of malaria usually reach a peak during the rainy season when temperatures are high and bodies of stagnant water are abundant. It is estimated that about one in every three people live in malaria risk areas (Fig. 5.3).

In 1996, the incidence of malaria was very high after heavy rains and high temperatures throughout the country. About 1.4 million clinical cases were reported. The estimated deaths of 6 000 represented a major cause of national mortality. In general, the risk is highest during the wet season and in low lying and warmer regions of the country. These increasing malarial trends are likely to become more pronounced as the climate changes due to increase of greenhouse gases. Other climate change associated diseases are cholera, dengue fever, yellow fever and general morbidity.

Fig. 5.4: Malaria risk areas

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Research and Systematic Observations

Zimbabwe, as a developing country, has not yet put in place institutions that are specifically mandated to undertake climate change studies. However, a number of existing institutions carry out research on the interface between climate change and the respective economic sector. These are described below.

6.1. Department of Research and Specialist Services

Current research studies at the Department of Research and Specialist Services are aimed at investigating productivity and quality of crop yields, livestock herd, minimum tillage, soil protection and control of diseases.

Climate change may significantly alter patterns in the normal rainfall precipitation and temperature. The changes are likely to result in the decrease of the length of growing season and reduction of the amount of precipitation available for crop growth due to late start and early cessation of the rainy seasons. Therefore, research into drought-tolerant crops and development of water resources becomes imperative. During recent years, droughts have resulted in severe losses of cattle, crops and vegetation, leading to shortages of food and water for both human and animal consumption, depletion of forests and wood fuel as well as changes in land-use practices.

Changes in climate require that further studies be conducted on the response and tolerance of main staple food crops especially maize yields during short rainy seasons and dry weather conditions. Studies have also been carried out on other dryland tolerant crops covering varieties of sorghum, millet and cotton. Estimation of greenhouse gases emissions from livestock, a major source of methane, has been difficult because of the lack of national data on the breakdown of the national herd by type of animal, daily activity and daily energy intake.

6.2 Tobacco Research Board

The Tobacco Research Board has conducted extensive studies on cost-effective substitutes in seedbed fumigation, including the use of methyl bromide (a chemical considered to have properties that deplete the ozone layer), as well as improving tobacco crop yields and control of diseases. The institute has conducted studies on alternative technology to using methyl bromide as a fumigant in agricultural applications. For curing tobacco, coal or wood-fired barns are used on farms and the process generates significant amounts of carbon dioxide. Current research into fuel efficiency of curing tobacco includes investigations into the use of pinewood as an alternative to burning coal. To obtain comparative ratios of coal and wood, the research is focusing on the use of wood as a fuel for curing tobacco in large barns. Quantitative data on greenhouse gas emissions related to coal and fuelwood burning needs to be estimated from commercial and resettlement agriculture. The use of solar energy available from a simple hot air collector is being tested and considered as an alternative air heating method which does not emit greenhouse gases during tobacco curing.

6.3 Department of Energy

The Department of Energy carries out research on sustainable energy sources such as biogas, solar radiation, wind power, hydroelectric forms of energy, sectoral energy consumption, energy pricing and taxes as well as energy efficiency. These studies can all provide valuable information to promote alternative energy sources and help reduce the emission of greenhouse gases into the atmosphere.

6.4 Forestry Commission

The Forestry Commission is concerned with the conservation of existing natural forest resources and the planting of new forests (through reforestation and afforestation) to compensate for woodlands cleared for agriculture, building materials, resettlement, construction, energy and from forest fires. Deforestation and fuelwood burning contribute significantly to climate change.

The Research Division conducts research into forest protection, mapping and inventories, methods of managing indigenous forests sustainably and genetics to improve the yield and quality of timber in the country. One objective of the research programme is to improve the vegetation cover by planting drought tolerant indigenous trees.

6.5 Institute of Environment and Remote Sensing (ERSI)

ERSI conducts studies aimed at improving the management of natural resources and protection of the environment for sustainable development. Research programmes provide temporal data for the detection of environmental change, crop yields forecasts, early warning and drought monitoring as well as development and utilisation of clean production technologies.

Using remote sensing techniques, the institute has conducted studies into developing methodologies for monitoring vegetation changes and establishing forest inventories, land-use mapping, and delineation of geological structures related to the occurrence of underground water. A study on greenhouse gases emissions from land-use practices in agriculture and forestry has also been carried out.

Facilities and expertise available at the institute are used to acquire, process, interpret and make maps of satellite data necessary to assess environmental change and impacts. The institute has capacity to apply remote sensing techniques for the exploration and detection of renewable and non-renewable environmental resources.

6.6 Institute of Environmental Studies

The Institute of Environmental Studies facilitates multi-institutional, interdisciplinary and policy-directed research on environmental issues. It has in-house technical expertise to co-ordinate and monitor research studies. The institute's current research programme deals mostly with ecologically sustainable management of trees, soils, grazing and the potential contribution of non-wood forest products to sustainable forest management. If donor funds were secured, the institute could co-ordinate a quantitative research programme into sectoral greenhouse gas emissions.

6.7 Department of Meteorological Services

The Department of Meteorological Services monitors climatic conditions and maintains records of meteorological data. The meteorological activities carried out by the department include weather forecasting, measurement of wind speed and direction, temperature and humidity in the atmosphere by radar and radiosonde and reception of weather satellite pictures. The department also mantains a network of meteorological observatories, meteorological stations and rainfall stations throughout the country. The Regional Drought Monotoring Centre is also hosted by the department. The Centre issues drought forecasts in collaboration with the SADC Early Warning System for Food Security. These forecasts are based on various factors, the most notable of which are the El Nino phenomenon and the Southern Oscillation Index (SOI).

6.8 The Southern Centre for Energy and Environment

The Southern Centre for Energy and Environment is an NGO that specialises in research on the interface between energy and environment. With financial support from various co-operating institutions, the Centre has conducted research on country studies (inventories, mitigation and vulnerability and adaptation), energy efficiency as well as new and renewable sources of energy.

7

Education, Training and Public Participation

7.1 Background

In 1987 the Government of Zimbabwe produced a policy document which was a blue- print for the conservation of the environment: "National Conservation Strategy". This document paved the way for most environmental programmes in Zimbabwe, including the signing and ratification of the UNFCCC by Zimbabwe in Rio de Janeiro. Climate change activities which followed the issuing of this document were part of environmental programmes based on this historic policy document.

Article 6 of the UNFCCC requires Parties to the Convention to promote and facilitate the development and implementation of educational and public awareness programmes on climate change and its impact. In an attempt to meet this obligation, Zimbabwe has mounted climate change awareness workshops targeted at the grassroots community, industry, schools and universities, professional groups and policy makers. These climate change workshops were co-funded by both the Government of Zimbabwe and donors. This chapter covers some of the climate change activities which Zimbabwe has carried out:

7.2 National Communication

As a way of building capacity towards the preparation of the National Communication, the Climate Change Office has been holding workshops on how to conduct the country studies: (greenhouse gas inventories, mitigation, vulnerability and adaptation). Further- more, Zimbabwe also benefited from the GEF Enabling Activity funding on the preparation of the National Communication itself.

7.3 UNDP Capacity Building Project

Currently, Zimbabwe has benefited from the Regional UNDP Capacity Building Project under GEF funding.

The objectives of the project are to:

Improve capacity in participating countries to comply with the requirements of the UN Framework Convention on Climate Change.
Contribute to the emergence of African regional approaches and responses to the Convention.

Strengthen the capacity in Africa to develop climate change projects that also advance long-term development objectives and to generate private sector funding support.

Hold climate change awareness workshops in all provinces throughout Zimbabwe so as to enhance national awareness.

7.4 CC: Train (UNITAR)

In 1993 and 1994, CC:Train (UNITAR) sponsored the following activities:

Workshops on preparing a national GHG inventory.

Workshops on identifying and analys ing mitigation options.

Workshops on assessing vulnerability to climate change impacts and adaptation options.

The workshops were based on materials developed by other organisations such as the IPCC, UNEP, and the US Country Studies Programme. They were being conducted primarily for designated experts from a variety of economic sectors.

7.5 United States Country Studies

In 1994, Zimbabwe benefitted from the United States Country Studies programme whereby country studies (greenhouse gas inventories, mitigation and vulnerability and adaptation) were carried out by national consultants. This programme has been successfully concluded with the publication and distribution of the findings.

7.6 Activities Implemented Jointly (AIJ)

Article 4.2 (a) of the UNFCCC, urges developed parties to jointly implement policies that will contribute towards the reduction of greenhouse gases. In July 1997, the Ministry of Mines, Environment and Tourism held a national workshop on Activities Implemented Jointly (AIJ) to explain the concept to various stakeholders in Zimbabwe. The stakeholders included government ministries, private sector, municipal authorities and other interested parties. The deliberations at this workshop came up with a national position:

(i) It was agreed that Zimbabwe should cautiously get into AIJ making sure that it adopts a set of conditions that make AIJ favourable for Zimbabwe. These conditions are to be met by the investor community.

(ii) The Permanent Secretary of the Ministry of Mines, Environment and Tourism was designated as the focal point for AIJ activities.

(iii) To hold an Activities Implemented Jointly workshop targeted at industrialists so as to highlight the role played by industry in the climate change area.

7.7 Photovoltaic Project

The Global Environment Facility (GEF) is currently funding a project on the use and diffusion of solar-photovoltaic panels for lighting in the rural areas. The project holds workshops on the popularisation of this technology among the rural folk.

7.8 General Remarks

The level of awareness of climate change phenomenon and its effects is relatively high in Zimbabwe. The country has been active in the climate change debate since the inception of the IPCC in 1988. The First and Second Assessment reports of 1990 and 1995 respectively provided policy makers with the best available knowledge on the science, impacts and responses to climate change. Unfortunately, the high level of climate change awareness is not matched with the same level of financial resources to support meaningful climate change research to switch from inefficient technologies to cleaner ones within a reasonable time scale. In the light of this, Zimbabwe will continue to require assistance to implement climate change projects in accordance with its obligations under the UNFCCC.

8 Concepts for Proposed Climate Change Projects

Climate change activities in Zimbabwe do provide indications of possible areas where further work ought to be done. Such areas include extension of classical country studies (inventories, mitigation options, impacts etc), institutional building so as to support decision-making framework by policy makers, enhancement of private sector participation in mitigation approaches, targeted research and the building of greenhouse gas databases for future National Communication uses. The project concepts treated in this chapter need further development and financing in order to be implemented. For clarity, these project concepts may be considered under two sections - enabling activities and mitigation options.

8.1 Enabling Activities

Enhancing capacity in present research institutions to provide information on climate change

This project will provide technical and financial support to institutions listed in this communication under chapter 6 (Research and Systematic Observations) to enable them to extend their present research programmes to include information relevant to climate change. For example, climate change studies in Zimbabwe have been rather weak in the area of vulnerability adaptation. Such studies are useful in assisting decision makers to make informed decisions in the face of climate change. Critical areas for such studies include population at risk, severity of impact, economic losses, and ecosystems damage, among others.

Training and capacity building for climate change decision making in industry

Present capacity building projects focus on awareness creation and building a national consultation mechanism on climate change. By and large, this has been reasonably achieved. This project will focus on decision-support capacity building among individual enterprises. Its objective is to enhance their ability to introduce the various climate change mitigation or emission reduction techniques some of which are listed in Chapter 4 of this communication (Programmes, Policies and Measures). It is acknowledged that mitigation options studied to-date are in a generic format which cannot be readily adopted by individual enterprises.

Reviewing, updating and systematic dissemination of climate change data

The present set of data needs to be continuously updated and disseminated in a systematic manner than presently experienced. This project will conduct such reviews and updates through broad-based national consultations, information packaging and user feedback mechanisms. This will build onto the national climate change web-site developed for Zimbabwe under the CC: INFO programme. If successful, this project should enhance internal climate change communications within the country - a must for successful implementation of any mitigation and adaptation options.

Enhancing policy analysis capacity to enhance climate change activities

Climate change concerns bring in a new shift in policy objectives and therefore, policy analysis. This project will conduct a series of training and consultations among various public sector institutions including sector and central planning ministries on new perspectives on policy making under climate change. One typical area to be included is energy pricing and related analysis and the use of incentives, standards and regulations as tools for achieving desired effects in climate change mitigation.

This will also include new perspectives on national disaster preparedness and long range strategic planning for the agricultural and other natural resource-based sectors.

Curriculum development for climate change

Present educational curricula, naturally, are not designed with the climate change paradigm in mind as this has not been the operational environment hitherto. The advent of climate change and the new socio-economic thrust that must emerge from demands of climate change requires that a systematic review of educational curricula be conducted to ensure that young citizens build climate change into their knowledge systems. This project will be an assessment of possible options for curricula improvement for the purpose of generating appropriate recommendations.

Studies on energy efficiency improvements in small-scale industries and in the informal sector

Zimbabwe expects a significant share of new employment and industrial expansion to come from the small-scale sector. This sector is expected to continue to grow. Traditionally no formal policy or programmes have focused on this sector. The emphasis has been on formal and larger scale industries. This project will study the policy and practical needs of small-scale and informal sectors regarding energy efficiency and management. This will include equipment and appropriate technology choices, procurement options as well as general energy management technical support such as energy audits and staff orientation.

Investigate systematic options for including solar energy in the Rural Electrification Master Plan

Zimbabwe has just completed drafting its Rural Electrification Master Plan with the support of the African Development Bank. It is also currently concluding the GEF photo-voltaic project on the dissemination of solar PV devices in low income rural households. From these two experiences it has been learnt that rural electrification can make intermediate use of solar PVs in areas where the grid is too expensive as an electrical energy delivery mode. It is not clear, however, how the incorporation of PVs could be successfully introduced. Assessments will be conducted taking into account experiences of the GEF PV project and the thrust of the Master Plan.

Alternative energy initiatives

Zimbabwe intends to further develop current initiatives in alternative energy development in the following appropriate technologies: improved woodstoves; low mass stoves; coal stoves and biogas digesters.

■ 8.2 Mitigation activities

The majority of mitigation options are in the energy sector. Projects for emissions reduction will therefore, focus on implementing recommendations listed in Chapter 4 of this document (Programmes, Policies and Measures). The incremental cost and emission reduction potential of these projects are fully documented in the two climate change mitigation studies carried out with the support of UNEP and the US Country Studies Programme referred to earlier. In addition to the national options, regional response options in the power sector are being studied under a programme supported by GTZ. Results from the first phase of these studies which focused on producing an inventory of emissions from the SADC power sector are provided in the report, "Zimbabwe's Options for Greenhouse Gas Mitigation Under Power Pooling in Southern Africa." In addition the following projects will also be conducted:

Investing in demand side management in the electricity sector. This will include auxiliary consumption reduction and reducing losses in transmission.

Investment in small-scale hydroelectric power stations to supply rural and peri-urban consumers.

Install solar mini-grid utilities to serve rural centres not connected to the grid.

Accelerated promotion of biogas technology in rural low income households.

■ 8.3 Constraints: financial and technical needs

All projects listed as enabling activities are intended for grant financing. The exact costs will be developed and discussed with interested international collaborating partners or relevant UNFCCC financing mechanisms.

Projects listed as mitigation activities will need initial external support for project development. In essence, however, these are investment projects which seek international investment partners and low cost financing.

9 Conclusions and Recommendations

The weight of scientific evidence regarding climate change appears to indicate that the threat from global warming due to a build up of greenhouse gases is real. The 1992 Framework Convention on Climate Change is a reflection of this issue. The challenge at the global level is to develop options to reduce the level of greenhouse gas emissions, particularly from the industrialised nations. The options must be cost-effective, equitable and balanced against political and socio-economic realities. It is important that techniques to address the problem be economically efficient in terms of costs imposed on an economy versus the potential benefits gained.

Zimbabwe, like most developing countries, makes only a minor contribution to global emissions of greenhouse gases. A balance is, however, required between Zimbabwe achieving the goal of reducing its small level of emissions under the terms and conditions of the Convention, and striving for continued economic growth and social development. Reducing emissions will impose costs on low-income countries like Zimbabwe, both in terms of new technology required, and perhaps a reduction in national income, at least in the short-term. The national economy is heavily dependent on agriculture, mining, secondary manufacturing of primary commodities and most recently, tourism.

Regardless of whether or not Zimbabwe makes a major reduction in its own emissions, the global problem will remain. What is more important for Zimbabwe however, is developing policies and programmes to address the impact of climate change. As this report has shown, an increase in global mean temperatures could have significant and serious impacts on countries in the Southern African region. Zimbabwe is land-locked, has no natural lakes, and suffers from periodic droughts. A shift to a warmer climate could have severe implications on the economy, especially with agriculture, manufacturing based on agriculture and tourism.

The majority of the population are still engaged in subsistence agriculture and depend on rain (and catchment dams) for crop production. A warmer regional climate poses threats from reduced water supplies and expanding boundaries where the staple crop, maize, may become more difficult to grow.

Tourism depends on sustained biodiversity, both in terms of favoured wildlife species such as elephants, and a healthy, supportive ecosystem. A warmer climate could result in changes to the ecosystem, the food chain, and the wildlife that tourists come to see. Most of the tourism in Zimbabwe is particularly susceptible to droughts. If water levels are low in the Zambezi river, this would cut back on recreational activity in the Kariba Dam and the Victoria Falls. The 1991/92 drought resulted in the deaths of wildlife in major national parks, especially elephants. The major national parks of Hwange and Gonarezhou are located in semi-arid ecological zones in the country. Other tourism centres are also dependent on good rains to maintain beautiful scenary and sustain flora and fauna.

Another threat from global warming is changes to human health. One particular threat is the potential spread of malaria to a wider geographical area of the country. Presently, malaria tends to be a year-round problem only in low-lying areas such as the Zambezi valley. A warmer climate could cause the vector mosquito to migrate into higher
elevated areas where malaria is presently not a serious problem.

These types of threats should be taken seriously by government and affected stakeholders. However, the impacts are long-term and there is time to effectively develop policies and programmes to address potential problems within the framework of the Climate Change Convention.

Solutions to potential agricultural problems relate to developing new plant varieties that are more drought tolerant, and investing in water catchment and distribution systems including irrigation technology.

With tourism, water management within national parks may have to be explored to keep wildlife within the parks and reduce migration to external areas.

Health impacts, such as from malaria, will require investments in education and prevention techniques such as netting, repellents, and low-cost anti-malarial drugs.

An underlying requirement is sustained research, development and technology transfer related to climate change. It is imperative that local researchers shift their focus of study to encompass climate change. There are several institutions that have some capacity to undertake climate change research. This implies better co-ordination to reduce dissipation of scarce resources. Investments in global communication, for example through Internet, will allow scientists here (who may have limited travel funds) to keep abreast with international research, and build collaborative networks. Research must continue to provide policy-makers with good information on projected shifts in temperature and the biophysical responses.

One area of research that should be stepped up in Zimbabwe is studies to determine the socio-economic realities for potential solutions to mitigating GHGs in Zimbabwe, such as, introducing minimum tillage in agriculture, new and renewable sources of energy such as photovoltaics, biomass technologies and hydro- power among others. The costs and benefits of various ameliorative actions as well as the distributional issues must be addressed through scientific research. As an example, projecting the impacts from climate change on maize production is one step; policy-makers then need to know the costs of options to address the problem. Trade-offs can be evaluated and the most efficient solutions can then be implemented. Studies carried in Zimbabwe on mitigating GHGs analysed a number of possible intervention measures. A number of these were discovered to be negative cost options and included minimum tillage in agriculture and improving efficiency in industrial and agricultural equipment. Some low cost options also exist such as hydro electricity, renewable energy and afforestation. High cost options include central PV and PV water pumping.

Climate change is a complex global issue. While Zimbabwe has been an insignificant contributor to the problem, the impacts of a warmer climate in this region are significant. Control and adaptation costs, including indirect effects on the economy, and direct compliance expenditures to reduce domestic emissions, could be high for a developing country like Zimbabwe. The country has made good progress in raising awareness of the issue and focusing attention on potential issues. Sustained effort is now required to begin exploring and planning for mitigation measures to reduce the long-term costs of climate change on the country.

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LIST OF CHEMICAL SYMBOLS, UNITS AND CURRENCY

CHEMICAL SYMBOLS

CO_2	Carbon Dioxide
CH_4	Methane
NO_x	Nitrogen Oxides
CO	Carbon Monoxide
H_2O	Water Vapour
N_2O	Nitrous Oxide
O_3	Ozone
NMVOCs	Non-methane Volatile Organic Compounds
CFCs	Chlorofluorocarbons

UNITS

kg	Kilogrammes
km	Kilometres
mm	millimetre
ha	Hectares
t	Tonnes
dm	Dry matter
KW	Kilowatts
MW	Megawatts
m3	Cubic metres
Gg	Gigagrams
PJ	PetaJoule

CURRENCY **Z$** **Zimbabwe Dollars**

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