Climate Change Mitigation in Southern Africa.

Methodological Development, Regional Implementation Aspects, National Mitigation Analysis and Institutional Capacity Building in Botswana, Tanzania, Zambia and Zimbabwe

Phase 1

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METHODOLOGICAL DEVELOPMENT, REGIONAL IMPLEMENTATION ASPECTS, NATIONAL MITIGATION ANALYSIS AND INSTITUTIONAL CAPACITY BUILDING IN BOTSWANA, TANZANIA, ZAMBIA AND ZIMBABWE

PHASE 1

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Foreword

This report presents the result of the work in Phase I of the project: "Climate Change Mitigation in Southern Africa, National studies and regional collaboration" with the subtitle: "Methodological Development, Regional Implementation Aspects, National Mitigation Analysis and Institutional Capacity Building in Botswana, Tanzania, Zambia and Zimbabwe."

The project has been sponsored by the Danish Ministry of Foreign Affairs (Danida) and the authors wish to thank Danida for their contribution to the capacity building and policy making process in the involved countries.

The project represents the first attempt to combine national and sub-regional aspect of Climate Change Mitigation analysis. The preliminary finding of this limited Phase I confirms the need to look beyond the national boundaries to realize the full mitigation potential. At the same time the collaboration between the four national teams show the benefits of inter regional collaboration. The direct collaboration, sharing of information and experiences, etc. clearly has contributed to the capacity building process and to increased understanding of the common challenge the countries are facing.

The work was initiated at a start up workshop in Harare 6-7 October 1994 where project teams from all the involved institutions participated and agreed on a work programme. All project teams produced their draft reports for the Regional Seminar which was held in Harare 17-19 November 1994, here the preliminary results of phase I of the project were discussed and presented for participants from the involved ministries in the four countries.

It is the hope that it will be possible to continue the project work in the envisaged Phase II, and all the participating governments and institutions have expressed their strong interest in such a continuation.

Finally I would like to thank the team members listed on the next page for their contribution to the successful completion of this Phase I report. A special thanks goes to the Southern Centre for hosting me during the period September to December 1994.

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1. Background

Scientific studies conducted in recent years, particularly under the Intergovernmental Panel on Climate Change (IPCC), have investigated the link between greenhouse gases and global climate change. A consensus has emerged, recommending that such emissions need to be reduced significantly worldwide to combat the threat of rapid and serious climatic changes. Most recently the adoption of the Framework Convention on Climate Change (FCCC) established that emissions of greenhouse gases should be limited or reduced through a coordinated and concerted international effort. The FCCC entered into force on 21 April 1994.

The climate convention requires the signatory countries to report on GHG emissions and reduction plans, assessment of costs and financial requirements especially for the developing countries. The developing countries have been given a period of 3 years from when they ratify the convention to establish their first national reporting. In order to meet this commitment it is important to strengthen the local institutional capacity in order to secure that the reporting and the national strategy development becomes truly founded in local priorities.

Several international activities and bilateral support programs have been established to support the implementation of the climate convention and in that context a number of national studies in different areas (emission inventory, impact assessment, mitigation and/or adaptation strategies) of the climate problem are being undertaken.

The Global Environment Facility (GEF) have supported a number of country studies, and the US, German and Dutch governments have established specific bilateral country study support programs.

All these activities have basically been initiated within the last one to two years and the need for coordination and common methodological approaches is evident.

On the coordination aspect the Climate Change Secretariat in Geneva has recently established the CC:INFO program with the specific mandate of coordination of country study activities.

On the methodological aspects several activities are in progress to establish common approaches in the different areas mentioned above.

1.1 The UNEP Greenhouse Gas Abatement Costing Study

The UNEP Collaborating Centre on Energy and Environment (UCCEE) at Risø National Laboratory is through a UNEP project on GHG abatement costing in the process of developing a set of common guidelines for national mitigation analysis. This work is divided into three phases:

1. Overview of key issues and methodological approaches
2. Development of a common methodological framework for GHG abatement costing esp. for energy sector options and CO_2
3. Establishment of the methodological basis for inter-sectoral comparisons and for assessment of reduction options and sinks for different GHGs.

The Phase II was finalized in the middle of 1994 and the smaller Phase III will end mid-1995. The whole project activity has been undertaken in close collaboration with national teams in a number of developed and developing countries. The methodological development has therefore been an iterative process in which practical applicability has been a key priority.

The methodological guidelines developed by the UNEP Centre are at present the only common approach available internationally for national mitigation analysis, and the Centre is working with several groups under the IPCC to secure that the results and experiences are represented in the next assessment report to the INC.

The methodological work has under the UNEP activity focused on national level assessments based on detailed sectoral analysis. The present Danida funded project for Southern Africa is building on the experiences obtained in the National UNEP studies and has three general objectives:

- Develop a new methodological framework for regional abatement analysis building on the UNEP Centre's methods for the national level analysis
- Establish national capacity and emission limitation strategies in three countries not included in previous programmes and undertake the first international study on the sub-regional level
- To establish or improve the national capacity to comply with the requirements of the Framework Convention on Climate Change.

Zimbabwe has been one of the countries participating in all three phases of the UNEP project, and the local capacity to undertake national mitigation analysis has been well developed. This is also one of the reasons for Zimbabwe being selected for a pilot awareness building project (now named CC:TRAIN) implemented by UNITAR in support of the climate convention.

The organizational set-up for the collaboration between the UNEP Centre and the Zimbabwean institutions has been very successful and is used as a model for the other countries participating in this project. The official collaboration in Zimbabwe has been between the Zimbabwean Ministry for Transport and Energy and the UNEP Centre. The Ministry has then used the local Southern Centre for Energy and Environment, as the implementing organization seconded by staff from the Ministry. The present project is therefore not having a Zimbabwean national component, in fact it is the experience from Zimbabwe that is being used in support of work in the three other countries in the region. The same type of institutional set-up is used in this project in the other three participating countries.

1.2 Coordination with other activities

It is crucial to avoid duplication of efforts in order to use both institutional and manpower resources efficiently.

The UCCEE has through its existing activities in the area of national climate studies and support to UNEP's activities in GEF established close contacts with all programmes providing support to country study activities. For the present project for Southern Africa close coordination with the following activities have been maintained.

First the US country study program, with a mitigation county study activity in Botswana and Zimbabwe.

Second the German bilateral programme to support national climate change studies with ongoing projects in Tanzania and Zambia.

The third main activity to coordinate with has been a GEF project implemented by UNEP focusing on large scale testing and application of the OECD/IPCC inventory methodology. Tanzania has been participating and the results has provided input to the present report.

The last is a GEF financed project to be implemented by UNDP on a regional project including 4 African countries where the aim is to undertake country studies including impacts, emissions, mitigation and adaptation in four countries (Ghana, Kenya, Mali and Zimbabwe). This programme was approved more than a year ago, but is still under preparation.

At the time of the present Phase I of this regional project the US study in Botswana is only starting and the study coordinator has been participating in the regional workshop. The GTZ activities is fully integrated, as they are implemented by the same national institutions and supported by the UNEP and the Southern Centres.

For the coming Phase II of this regional project coordination is mainly an issue for work in Botswana where a new GEF capacity building project is under preparation. The GTZ project in Tanzania and Zambia will be finished and Phase II will build directly on their results.

1.3 Outputs of the project

In accordance with the project description the outputs of the total project (Phase I+II) will be:

a) Methodological guidelines for regional mitigation analysis

b) Strengthened national institutions within each of the participating countries with the possibility of serving as focal points for climate change activities

c) National and regional phase I reports with emission inventories, energy balances and reviews of other sectors

d) National and regional phase II reports including sectoral baseline scenarios, identification of abatement options and costs

e) National and regional final reports including frameworks for abatement strategies based on integrated sectoral analysis of abatement options, evaluation of macroeconomic implications and linkages with general social and economic development plans. The reports will also present an assessment of national policy implications and barriers for the implementation

f) Project proposal input for key identified options prepared for GEF or other multi/bilateral funding agencies

g) Report on comparative assessment of national mitigation strategies, regional mitigation options, and political and financial constraints on implementation

The present small Phase I covers outputs under point c) and contributes to the processes under a) and b).

1.4 Regional aspects of GHG emission limitations analysis and implementation

From the background description it is evident that the international methodological work as well as actual analytical activities have focused almost entirely on the national level. This is a logical consequence of the fact that it is the national governments that sign and have commitments under the climate convention. It is, however, evident from the national studies undertaken so far that a number of mitigation aspects touch on inter-country or sub-regional collaboration issues.

The present project therefore seeks not only to establish the national mitigation strategies, but also examine the sub-regional interaction and possible joint mitigation activities.

The regional analysis considers the regional implications of major abatement options implemented either in individual countries or in all countries of the region. These may include technical options implemented in the emitting sectors (energy, forestry, agriculture, industry or transport) or policy instruments like taxes, financial schemes and investment grants.

The regional analysis assesses the regional and national economic consequences of implementing alternative abatement options. Two types of main regional effects may be expected to appear:

- Effects related to larger regional investments in power-supply and transmission systems and in the transportation sector. The same could be the case for fuel transmission pipelines, refineries and possibly coal mining.
- Effects at a more general economic level that may have implications on the relative comparative strengths of production sectors and countries, as a consequence of implementing abatement options and regulation policies.

In order to evaluate such effects an initial survey of main economic relations and energy sector and transportation links between the countries must be made. This survey must include information on customs regulations and foreign exchange systems between the countries. Following that, some general development paths for regional economic and energy collaboration in the region should be discussed for the scenario period (serving as a baseline scenario).

This should again serve as reference point for the assessment of positive effects of regional collaboration on larger technical systems, and negative effects of implementing abatement options in individual countries, which implies loss of regional competitiveness for the country in question.

With the recent political changes in South Africa perspectives are that the country will become an even more important and in many areas dominant economic factor for the development in the region. It is therefore crucial to work closely with on-going studies examining the future role of South Africa in the broader regional economic development and in particular in the energy scene.

1.5 Introduction to the report

This report covers the work contained in Phase I. At the Regional Seminar in Harare 17-19 November, here the preliminary results of Phase I of the project were presented.

The experience from Zimbabwe were presented and the other three country teams presented their preliminary national phase 1 reports covering the following areas:

- Country background
- Overview of the institutional setup for national planning
- Overview of existing national climate change activities
- Review of existing studies and plans on climate change and related issues in energy, land-use, forestry, environment and economic development planning
- Description of the energy sector (supply, demand, projections)
- Greenhouse gas emission inventory
- Opportunities for GHG mitigation

The report contains the final phase 1 reports from Botswana, Tanzania and Zambia written by the reseachers from the respective countries mentioned above. Additionally the report contains a chapter covering the region, not only the four participating countries but the whole SADC region, including South Africa. This chapter was written by the researchers Southern Centre for Energy and Environment, Harare with support from Risø.

2. Regional report

2.1 Regional overview

At the moment Southern Africa is undergoing a massive transformation. The republic of South Africa now has a democratically elected government. In August 1994 it joined the SADC (Southern African Development Community) which was formerly established in 1980 as SADCC (Southern African Development Coordination Conference) by the countries surrounding South Africa as an organization dedicated to promoting development at the national level through coordination at the regional level. When Namibia achieved independence in 1990 it also joined the SADC.

To provide an analytical background to assessing possible emissions of GHGs and to assess abatement options meaningfully, we provide below a brief analysis of the regional economy to assess possible expansion patterns. Key factors assessed are population, energy and the various sectors of the economies of the eleven countries that make up SADC. Assessments for the four countries included in this study are done in the context of the total SADC region.

Population, household energy and expected expansions.:

Population and population distribution particularly the urban-rural divide is the primary driver for economic trends and energy consumption patterns and therefore CO_2 emissions.

Table 2.1. Population, area and expected population trends in SADC

	1990	2010	2030	1990-2010	2010-2030	Urban	Area
		million		% growth p.a.		%	1000 km^2
Angola	10.1	17.1	26.5	2.7	2.2	35	1247
Botswana	1.3	2.4	4.2	3.2	2.7	43	582
Lesotho	1.8	3.2	5.3	3.0	2.5	13	30
Malawi	9.0	16.3	26.8	3.0	2.5	11	119
Mozambique	15.7	25.2	36.7	2.4	1.9	19	799
Namibia	1.3	2.3	3.6	2.8	2.3	18	823
South Africa	35.2	52.3	70.4	2.0	1.5	59	1221
Swaziland	0.8	1.6	3.0	3.6	3.1	16	17
Tanzania	24.3	41.2	62.5	2.6	2.1	15	945
Zambia	7.8	16.1	30.3	3.7	3.2	42	753
Zimbabwe	9.4	15.7	23.8	2.6	2.1	33	391
Total	117.5	193.7	293.3				6927

Source: (SADC,1992)

The total population in SADC was 117 million in 1990 (see table 2.1) and is growing at the fast rate of 3.1 % pa. varying little among the countries, however the percent living in urban areas vary from 11% in Malawi to 42% in Zambia. At present and based on figures in table 2.1, a total of 78 million people in SADC live in the rural areas mainly as peasants. This population in the rural areas depends on wood for primary energy supply. The average individual consumption of fuelwood in fuelwood dependent household in SADC is ranging from 938 kg a year in Zimbabwe to 1385 kg a year in Botswana (Mosimanyane, May 1994). About half the countries of SADC, Angola, Malawi, Mozambique, Tanzania and Zambia, use charcoal as the base fuel for urban households. The practice of using charcoal is less commonplace in the other halve which includes Zimbabwe, Botswana, South Africa and Namibia where direct wood utilization in more the practice.

Households use a total of 600000 tonnes of charcoal a year in Zambia and only 100 tonnes a year in Zimbabwe. Following the SADC 1990 statistics the total charcoal consumption in Angola was at the same level as Zambia while the consumptions in Malawi, Mozambique and Tanzania were about half this level. Charcoal conversion efficiency in these countries (a key factor in the relationship between forest depletion and household energy) are around 10% as opposed to 25% which has been achieved in some commercial charcoal technologies.

Household electrification is very low in the region with only 7% of the population having access to household electricity. Table 2.2 shows that Zimbabwe has the highest rate of 16% higher than the South African of 10% since some 25 million people in South Africa have no access to household electricity. In Zambia the percentage is 8%. The lowest level of household electrification is in Tanzania, Malawi and Lesotho with only 3%.

Table 2.2. SADC household electrification levels

1993	Connected households	% of population electrified
Angola	n.a.	n.a.
Botswana	30232	12
Lesotho	9580	3
Malawi	47167	3
Mozambique	114000	4
Namibia	n.a.	n.a.
South Africa	715219	10
Swaziland	17980	11
Tanzania	172246	3
Zambia	132303	8
Zimbabwe	294246	16
SADC		7

Source: (ESKOM,1993)

Compared to Europe SADC has a total land area (see table 2.1) which is 50% greater than Europe, while the population is only 24% of the population in Europe.

<u>The SADC economy and expected trends</u>

The SADC economy is made up of 11 different independent economies each at different level of development and with varying expansion perspectives. The economies are run independently but are agreed on basic protocols for cooperation. Prior to the present Southern African Development Community was SADCC the development coordination conference with loose alliances bent of a specific development with freedom from apartheid South Africa as a primary goal. A key operational protocol under SADC and one that is likely to remain key under the new SADC was equity in gains from economic cooperation including a perception of equality in the distribution of projects for regional cooperation. In describing the SADC economy and particularly in developing regional projects, these concepts are important. Particularly important is the interpretation of equity in gains derived from cooperation. It has come to pass that this has been defined to mean equal distribution of development projects. This interpretation or sentiment derives from the continued presence of nationalism among member states. Its significance lies in that it perceives gains as investment projects -- which would mean equal distribution of projects as rather than gains from the optimum distribution or location of projects in member states.

The worry among states with the distribution of projects and not gains from optimum distribution is somewhat justified because it will more than likely occur that the optimum location of projects (resulting in greater benefits for all) will favor those countries with a better infrastructure to support the projects.

During the 80's SADCC disparities in the economies of member countries were significant (see table 2.3) with Zimbabwe having the most advanced infrastructure but Botswana having the highest per capita income and the highest economic grow rate of 9.8% as opposed to say, Mozambique's rate of -1.3% in 1990. The development in GDP in the period 1980-90 for Zambia and Namibia was close to zero, for the remaining countries the growth were in the range 3-4%. The GDP/capita for the countries in the region was in the range of 95-2208 US$/cap. in 1990.

Table 2.3. Development in GDP in the SADC countries

GDP 1990 US$	1980 mill.	1990 mill.	Annual % growth 1980-90	GDP/cap 1990
Angola	5309	7135	3.0	710
Botswana	1124	2871	9.8	2208
Lesotho	326	445	3.2	249
Malawi	1465	1861	2.4	206
Mozambique	1704	1494	-1.3	95
Namibia	1825	1882	0.3	1415
South Africa	n.a	n.a.	n.a.	n.a.
Swaziland	443	657	4.0	832
Tanzania	2064	2642	2.5	107
Zambia	2888	3038	0.5	389
Zimbabwe	3670	5322	3.8	567

Source:(SADC, 1992)

In 1990 the average economic growth rate for the region was 3.1% for the 10 member states excluding South Africa. Assuming this average growth rate, the SADC economy is projected to grow to US$ 50177 million by 2010 and US$ 92401 million by 2030. The distribution of this growth is difficult to determine particularly for those countries with negative growth rates. We have attempted a distribution shown below in table 2.4 for all the 11 countries based on official expansion projection.

The importance of this distribution is that it has a bearing on the final energy consumption in the region and on the carbon intensity of the energy consumed. Higher economic growth rates in high energy countries would imply higher total energy growth in the region and without effective energy trade, this would also imply the dominance of certain fuels in the final energy supply for the region particularly electricity supply. i.e. Without full scale energy trade and in the event of greater economic expansion in South Africa, it should be expected that the total energy or electricity supply will be heavily dependent on coal since 91.2% of South African power supplies are derived from coal fired stations. The reverse would be true if greater economic expansion was expected in Angola or Zambia which are wholly dependent on hydropower for generating electricity. Further, expanded regional trade in the energy sector would have a depressive effect in coal based generating stations in South Africa since a significant amount of power supplies outside South Africa are hydro based.

2.2 Overview of the regional energy sector and expected trends

This overview provides some perspectives on the historical and expected future structure of the energy sector in SADC. The overview focuses primarily on identifying the regional energy balance in order to provide a background over which to assess emissions and abatement options. Because a significant share of abatement options of a regional nature fall within the electricity sector, this overview dwells notably on the electricity sector primarily to identify the electrical capacity balance. This balance would indicate the distribution of excess capacity and supply shortfalls among countries of the region.

2.2.1 Regional electricity supply and demand

Electricity supply in SADC is based mainly on coal, thermal and hydro power stations with very little energy derived from oil thermal stations. See table 2.4 which provides the regional fuel-base distribution of generating stations in the region. According to this table, only 0.1% of the total electricity consumed in the region is derived from oil fired stations. Nuclear energy, installed only in South Africa supplies a significant 7255 GWh or 4% of consumed electricity. An important feature of the regional power system is its dependence on coal for 87% of its electricity consumption (in 1993). Ordinarily this would supply all the base load and all the additional capacity from nuclear, oil and hydro power could theoretically be defined as reserve margin. Electricity in the region is therefore, practically coal based.

Looking into specific countries, however, shows that some countries are wholly hydro based or they have a strong share of hydro in their systems and that the bias in favour of coal comes in through South Africa which consumes 86% of total supplied electricity and as indicated earlier derives over 90% of its electricity from coal.

Table 2.4. Electricity supply in the region in 1993

1993	Electricity supply					Total	Own	Losses
GWh	Hydro	Coal	Oil	Nuclear	Imports	Supply	consump.	
Angola	772		163			935		105
Botswana		1015			226	1241	120	91
Lesotho	1				289	290		47
Malawi	780		2			782		127
Mozambique	356	15	31		518	920		50
Namibia	967	27			627	1621		195
South Africa	1491	145514	0	7255	-2488	151772	1898	8663
Swaziland	82		3		556	641		85
Tanzania	1879					1879		383
Zambia	6412		10		478	6900		420
Zimbabwe	2062	5406			1213	8681		951
Total	14802	151977	209	7255	1419	175662	2018	11117

Source:(ESKOM,1993)

Table 2.4 shows how the electricity was produced in 1993 in the region. South Africa, Botswana produce most of their electricity from coal. The electricity supply in Zimbabwe in 1993 (from ZESA) was about 1500 GWh lower than normal, the large decrease was due to the depressed economic climate and the electricity saving campaign necessitated by the shortage of power after the drought 1992/93. Normally about half of the electricity in Zimbabwe is produced from coal. Angola, Mozambique, Namibia, Tanzania and Zambia are hydro based. Lesotho and Swaziland import most of their electricity.

Table 2.5. Electricity consumption in the region in 1993

1993	Electricity GWh	Electricity Consumption kWh/cap.	Fossil GJ/cap
Angola	830	83	5.1
Botswana	1030	792	25.3
Lesotho	243	136	3.3
Malawi	655	72	0.8
Mozambique	870	55	1.0
Namibia	1426	1072	14.1
South Africa	141211	4012	95.9
Swaziland	556	704	15.2
Tanzania	1496	61	1.5
Zambia	6480	831	4.6
Zimbabwe	7730	823	20.8

Source:(ESKOM,1993)

The electricity consumption in table 2.5 is the production minus own consumption & losses from table 2.4. The second column in table 2.5 is this electricity consumption divided by the population of the country. The table shows that the per capita electricity consumption in South Africa is four times higher than the highest in the other SADC countries. Four countries have a very low consumption, less than 200 kWh/cap and five countries lie in the range 700-1100 kWh/cap. The same trend is seen in the per capita consumption of fossil fuel, except that Zambia here also is in the very low end caused by the high electricity consumption by the copper production, 71% as shown in table 2.6, which also shows that the industry in general consumes a high percentages of the electricity.

Table 2.6. Electricity consumption by sector in the SADC countries

1990 %	Electricity consumption by sector Agriculture	Mining	Industry	Transport	Households	Service
Angola	4		33		35	28
Botswana			75		10	15
Lesotho			18		33	49
Malawi	20		22	2	19	37
Mozambique	10		47		33	11
Namibia	1	54	0		40	5
South Africa						
Swaziland	17	6	56		14	7
Tanzania	5		25		28	42
Zambia	3	71	15	0	8	2
Zimbabwe	9	17	45	0	17	11

Source:(ESKOM,1993)

2.2.2 Regional power generation and transmission systems

In the region, the current installed capacity is around 40000 MW, far more than the required peak load of 27000 MW (see table 2.7). However, there is significant national and local problems. Many rely on fossil fuel generation, while inexpensive hydropower is available in neighbouring countries. The excess investment in the power sector is a result primarily of independent development of national systems and derives from a general urge for each country to ensure security of supply during the turbulent period of national wars of liberation.

By far the largest fraction of the capacity is coal based (75%). Hydro accounts for 18%, but the additional hydro potential of 44000 MW could replace a large part of the coal based power if the regional collaboration and interconnections were improved.

In addition there is a surplus capacity of 1305 MW (for 25 % reserve margin) in Zaire, where the installed nominal capacity is 2180 MW and the system peak is 700 MW. The ultimate potential capacity of the Inga Falls is almost 100,000 MW. Feasibility studies for harnessing 39,000 MW is underway.

Table 2.7. Present installed nominal capacity in the SADC countries

Interconnected MW	Coal-fired	Oil-fired	Hydro	Nuclear	Total	Peak load	Hydro potential
Angola	0	196	323		519	n.a.	16000
Botswana	214	6	0		220	191	0
Lesotho	0	2	3		5	66	450
Malawi	0	25	164		189	100	960
Mozambique	55	134	2180		2369	102	12500
Namibia	120	24	240		384	255	1500
South Africa	29647	368	601	1930	32546	23169	3500
Swaziland	0	10	41		50	112	330
Tanzania	0	192	326		518	209	5590
Zambia	0	0	1608		1608	919	4000
Zimbabwe	1020	0	666		1686	1478	2000
Total	31056	957	6152		40094	26604	46840

Sources: (SADC,1992),(ESKOM,1993),(ZESA,1993),(Maya,1993),(ESMAP,1993) and chapter 3-5.

Botswana has a peak load of 191 MW and a generating capacity (exclusively coal-fired) of 132 MW at Morupule and 62 MW at Selebi-Phikwe (see chapter 3). The power lines to Zimbabwe (132 kV) and to South Africa (220 kV) enable Botswana to import hydro power from Zimbabwe or coal-fired power from South Africa under droughts but are too weak for any exchange of power between South Africa and Zimbabwe. To improve this automatic generation control (AGC) units have to be built in Zimbabwe and South Africa. However the problem will be solved by the 400 kV Bulawayo - Matimba interconnector to be finished end of 1995. It will be capable of transferring 500 MW between South Africa and Zimbabwe. It will be connected to the Botswana system at the Selebi - Phikwe power plant.

Lesotho buys most of their power from ESKOM. This supplements nominal hydro and diesel capacities of 3 MW and 2 MW respectively. The peak load is 66 MW (ESKOM,1993).

Malawi has a peak load of 100 MW and a installed hydro capacity of 164 MW concentrated at the Shire river which flows out of lake Malawi and joins the Zambezi river in Mozambique, consisting of the Tedzani (40 MW), Nkula A (24 MW), Nkula B (80 MW) and Nkula C (20 MW) Plants. The grid connected fossil capacity is 25 MW. With the completion of the Tedzani III project 50 MW hydro is added. By the year 1999, the installed hydro capacity would expand to 282.5 MW with the completion of Kapichira Phase I (64 MW) and the Wovwe Minihydro (4.5 MW) (ESKOM,1993).

The total estimated hydro potential of Shire is 660 MW. Several small rivers in the northern and the central region have an additional potential of 300 MW adding up to the total hydro potential of 960 MW for Malawi in table 2.7.

A 132 kV line connects Lilongwe with Blantyre in the southern part of the country. There is no interconnections with the surrounding countries.

Mozambique has a peak demand of 102 MW. Most of the peak demand is in the Maputo area (96 MW) which is connected to South Africa by a 275 kV line. There is no connection between Maputo and the local grid around Cabora Bassa using only 20 MW of the installed 2075 MW. Cabora Bassa was commissioned in 1975 and until 1981, it supplied power to South Africa. From 1982 the supply was discontinued because of repeated sabotage along the 1500 km DC line liking Cabora Bassa to Johannesburg (also supplying Maputo). In 1995 the North/Central network interconnection is expected to be completed (ESKOM,1993).

Namibia has a maximum demand of 255 MW, which is growing at 2% per annum. The generation capacity consist of a coal-fired station near Windhoek (120 MW), a hydro station (Ruanka) on the Cunene River on the border with Angola, which can produce 240 MW, but unfortunately the plant must at present be operated as a run-of-river station because the Gove Dam, which is upstream in Angola has been damaged. Diesel units rated at 25 MW are situated at Walvis Bay (ESMAP,1993).

Namibia is interconnected with South Africa via a long double circuit 220 kV line of 860 km. During the first part of the year Ruacana can normally meet all of Namibia's power needs. During the second half of the year most of the electricity is imported from South Africa where the price is slightly cheaper than on the Windhoek station.

SWAWEK has identified a promising site for a 500 MW plant in the vicinity of the Epupa falls. A pre-feasibility study is currently being undertaken with NORAD's support.

In **South Africa** about 90% of the power is generated from coal-fired stations and tied collieries in an area east and south of Johannesburg. The remaining 10% is generated by the two peaking hydro stations situated half-way between Johannesburg and Cape Town (1000 MW near Durban and 400 MW near Cape Town respectively) and one nuclear power station (1800 MW) near Cape Town. This uneven distribution of generation capacity has led to an extensive transmission system linking the major load centres in the country. Table 2.7 shows that the total nominal capacity in the country is 10000 MW larger than the peak demand of 23169 MW. This excess is reduced to 8000 MW when looking at the total nominal capacity, caused by the auxiliary power consumption and reduced capacity caused by age of plant and/or low coal quality. With a reserve margin of 25% the excess capacity is 6000 MW ESKOM,1993).

The reason for this large excess capacity was the sudden drop in the growth in electricity consumption in 1982 from about 8% to about 2.5% p.a. in 1982 where five 3600 MW coal-fired stations were in order. The possibilities of cancelling the contracts was excluded because the costs were to high. Instead five old coal-fired power stations (680 MW each) were shut down and another seven and a half (6050 MW) were mothballed. If the capacity of these mothballed stations were added the excess capacity would be even greater.

In case of drought the high merit coal-fired stations lacks cooling water and some of the load has to be dispatched to less efficient stations where water is still available. If stronger interconnections with the other SADC countries existed this could be avoided.

Swaziland has a total installed capacity of 50 MW of which most is hydro power (40.5 MW). The rest is supplied by diesel generators. The import from South Africa is of the same size (50 MW). The 132 kV ESKOM link has an import capacity of 96 MW. The system peak is 112 MW (Maya,1993),(ESKOM,1993).

Tanzania has a peak load of 209 MW. The installed capacity in 518 MW of which 326 MW is hydro power: At the Pangani river 423 MW is installed. At the Rufiji river another 284 MW is installed (Kidatu 104 MW and Mtera 80 MW) out of a potential on the river of 2100 MW.

The least cost expansion plan for the hydro resources is: Redevelopment of Pangani system (60 MW), Downstream Kihansi (162 MW), Upstream Kihansi (45 MW), Masigira (80 MW), Rumakali (204 MW) and Mpanga (160 MW) (ESKOM,1993).

Tanzania is not exporting nor importing electricity.

Zambia has a peak demand of 919 MW. The installed capacity in 1608 MW: 900 MW at Kafue Gorge, 600 MW at Kariba North plus 108 MW at Victoria Falls. Beside the two above mentioned 330 kW lines to Zimbabwe Zambia is also connected to Zaire by a 220 kV line. See chapter 5 and (ESKOM,1993).

In Zambia the National Energy Policy (Min. of Energy and Water Development, 1994) gives first priority to the construction of the Kafue Gorge Lower Power Station (450 MW). Adding other potential projects including Luapula (884 MW) and Gorge (884 MW) the total hydro potential in these project is thus around 4000 MW.

Zambia is interconnected to Zaire via a 220 kV line. Zaire has a low peak demand (<700 MW). The size of this line plus the need to rehabilitate several generating units at Inga (1730 MW installed) and in the Shaba province (450 MW installed) limits the export capacity to about 180 MW. An extra benefit of an improved Zaire-Zambia interconnector is that it connects two areas with different rainfall patterns.

Zimbabwe has a peak demand of 1478 MW. The total installed capacity is 1686 MW with the main power stations Kariba South (666 MW) and Hwange (920 MW). In the last few years ZESA has imported from Zambia via the two 330 kV interconnectors at Kariba. This import will diminished as the load in Zambia increases and instead Zimbabwe will import 400 MW from ESKOM through the Matimba interconnector when it starts operating by mid 1995 (this import will be reduced to 150 MW in 2003) and 500 MW via a new 400 kV line from Harare to Cabora Bassa from mid 1996 until 2003 where all electricity must return to ESKOM.

ZESA has just updated (10 March 1994) its 2010 development plan from to accommodate recent developments such as the power crises which occurred after the 1992/93 drought. Two 220 MW coal fired units are projected to be in service at Hwange in 1997/98. Five 220 MW coal-fired stations at Sengwa have also been considered. ZESA's expansion plans include the Batoka Gorge (800 MW) and Kariba upgrading (84 MW projected into service in 1997/98). Other potential projects on the Zambezi river, Devils Gorge (620 MW) and Mupata Gorge (500 MW) are at the bottom of the priority list because they are more expensive. However the total potential in these projects is about 2000 MW (ZESA,1993), (Risø & Southern Centre,1993)

2.2.3 Regional electricity expansion trends

Only a small fraction of the population in the region have access to electricity. In South Africa about 25 million people have no electricity in their homes. Therefore a significant increase in the domestic electricity consumption is foreseen. Table 2.8 shows a very simple projection of the future electricity peak load in the area. It is assumed that the present load factors will remain the same in the future in all countries. The annual growth in the demand is assumed to be constant for simplicity reasons. The growth factors for Botswana, Malawi, Mozambique, Zambia and Zimbabwe is from SADC energy project AAA 3.8 (Engineering & Power Development,1992). The others are from national reports

Table 2.8. Projection of regional electricity peak load

	Peak load in MW			Annual
	1993	2000	2010	% growth
Angola	n.a.	n.a.	n.a.	n.a.
Botswana	194	273	445	5
Lesotho	66a	81	109	3
Malawi	100	161	316	7
Mozambique	102	144	234	5
Namibia	255	314	421	3
South Africa	23169	30489	45131	4
Swaziland	112	138	185	3
Tanzania	209	257	345	3
Zambia	919	1056	1287	2
Zimbabwe	1478	1818	2443	3
Total	26604	34729	50916	

2.2.4 Regional coal consumption

Coal consumption is greatest in South Africa where it is used in electricity generating plants, industrial boilers and in coal synthesis to light liquids and chemicals at Sasol. Table 2.9 shows that the second largest consumer is Zimbabwe with only 4% of total regional consumption as opposed to South Africa's 95%. The rest of the SADC countries consume less than 1% of total coal consumed in the region.

Coal demand analysis by sector shows electricity taking 58% of total demand, transport 21% and industry 17%. Households consume a small amount of only 1.4%. The high demand for coal in the transport sector relates to the use of coal in producing transport fuels at Sasol in South Africa. This takes 22% of total coal consumption in South Africa and just over 20% of total coal consumption in SADC.

These demand levels will provide information for the baseline definition of coal demand and possible future demand trends. It is expected that households will increase their demand levels as fuelwood becomes less available and incomes improve. Transport sector demand should decline significantly perhaps to zero in the very short term unless the gasification synthesis at Sasol continues or expands. It is quite likely that the Sasol process for light liquids will be discontinued. This is mainly because the process is quite expensive and having an energy conversion efficiency from coal to gasoline of only 28%. Industrial demand will increase with an increase in the industrial share of GDP.

Table 2.9. Coal consumption by sector in the SADC countries in 1990

TJ	Power plants	Coke ovens	Agri-culture	Mining	Industry	Transport	Service	House-holds	Total
Angola									0
Botswana	11861			3795	360		456	41	16513
Lesotho					272		93	958	1323
Malawi			12		1178	2	63		1255
Mozambique	1597		293		586	586		29	3091
Namibia	1934				553			336	2823
South Africa	1914394		754	11321	536010	711416	33591	45118	3252605
Swaziland	366			1158	2744	529	694	826	6317
Tanzania			357		461				818
Zambia				4179	4906				9085
Zimbabwe	70335	22090	11820	2610	20930	5700	8460		141945
SADC	2000487	22090	13236	23063	568000	718233	43357	47308	3435775

Source: (SADC,1992)

2.2.5 Regional oil consumption

Oil consumption in terajoules is only 26% of coal consumed in the region (see tables 2.9-2.10). The greatest demand is in South Africa with 77% of total regional demand. Second in volumes consumed is Tanzania with 4% of total regional demand and Tanzania with just under 4%. The biggest application is transportation consuming 61% of total sectoral demand. Demand in industry which is the second largest user of coal (if we excluded transport) is 28% of total sectoral demand. It is important to note that the household sector which is virtually devoid of electricity consumes only 5% of total liquid fuels (in the form of paraffin). This sector also consumes only 1.4% of total coal consumed by all sectors of the SADC economy indicating that conventional fuels are not yet a meaningful feature of the SADC household energy base.

Table 2.10. Oil consumption by sector in the SADC countries in 1990

TJ	Power plants	Agriculture	Mining	Industry	Transport	Service	House-holds	Total
Angola	4249	1070		10602	11958	19967	3055	50901
Botswana	544	514	1337	848	8306	897	890	13336
Lesotho	13	255		170	2664	57	1386	4545
Malawi	44	731	65	222	3799	881	424	6166
Mozambique	975	1408		2718	6749	961	508	13319
Namibia		1439	1993	484	7573	1675	1943	15107
South Africa				221907	445946		23673	691525
Swaziland				933	4397	100	277	5707
Tanzania	1735	3684		8621	14043	1341	7446	36870
Zambia	103	660	5784	2340	13546	3085	734	26252
Zimbabwe	1232	2985	2156		29132	1250	1601	38356
SADC	8895	12746	11335	248845	548113	30214	41937	902084

Source:(SADC,1992)

With the growing shortage of wood and perhaps an increase in household incomes, it should be expected that the use of paraffin and coal will increase in the short term but be overtaken by electricity in the long run. The route via paraffin and coal in the household energy sector remains necessary due to the high and prohibitive cost of household appliances associated with the use of electricity in households.

2.2.6 SADC energy balance

Table 2.11 shows the total energy balance for 1990 for all the SADC countries. The Source is the 1990 Energy Statistics Yearbook from the SADC Energy Sector Technical and Administrative Unit (TAU) in Luanda, Angola. Following initiatives of this unit, a number of countries in the SADC grouping now make their own energy balances which are regularly published and are only a few years out of date. Most of this support has been built with the support of GTZ, a German program assisting a number of regional countries with energy sector management.

The data, like any other data base still has gaps in some areas particularly in the household energy segment and more so the biomass energy section. The 1990 balance is provided here simply to provide a composite picture of the energy sector of the countries in the region and to provide a springboard for the assessment of future trends.

A unique feature of the balance is the existence of such novel technologies as ethanol, nuclear and coal synthetics in the balance. This may serve to demonstrate the readiness of the countries in the region to adopt new and even novel technologies when the situation demands. This is contrary to the technological inertia that characterises some countries including those in the North. A major challenge to the region as shown in the balance is the transition from fuelwood to conventional fuels in the household sector. In Europe, this transition took a long period, but this delay was due to a lack of technological drive which is not the case in today's SADC, which is constrained more by economic factors than by technological deficiency. The former hurdle should be easier to overcome. But if we consider that industrialisation started as early as the 1800s for such countries as South Africa and in the mid 40s for countries like Zimbabwe, it is clear that the transition is taking quite long even in the light of such an enabling environment where electricity and fuel supply networks are reasonably in place. Whether this becomes an indication of trends of the future depends primarily on how aggressive government policies on rural electrification will be. So far this appears to be quite conservative with a general acceptance that rural electrification in an expensive and untenable proposition. But even if the rural areas remained unelectrified but all urban households were electrified, the gains would be quite significant.

To date the electrification of urban areas also remains at slow pace with Zimbabwe only managing 5000 households per year, South Africa doing 250000 and Zambia 19000. Tanzania electrifies 19000 households per year, Botswana 5000 and Mozambique 2000. These are very low figures considering the expansion of the populations of these countries and the growing rate of urbanisation in some of them.

Table 2.11. Primary energy consumption for 1990 in the region (after refineries)

TJ	Coal	Fueloil	Diesel oil	Kero-sene	Jetfuel	LPG	Gaso-line	Total fossil	Etha-nol	Wood	Char-coal	Dung	Hydro power	Total
Angola		7727	15985	821	19163	2556	4650	50902		42955	20522		1760	116139
Botswana	19954	144	6400	482	428	365	5169	32942		22367				55309
Lesotho	1324		1623	1275		118	1516	5856		15071		5207	12	26146
Malawi	1459		3229	424	488		2025	7625	187	86365	10241		2538	106956
Mozambique	3091	186	8806	475	1774	228	1848	16408		194825	10393		889	222515
Namibia	3408	393	7024	161	926	279	6541	18732		19601			4140	42473
South Africa	2671582	221907	37098		32007		413943	3e+06		239000			10274	3625811
Swaziland	6317	540	2440	259	164	118	2187	12025		20102	275		612	33014
Tanzania	818	6496	16892	8428			5055	37689		391704	11519		5134	446046
Zambia	9085	5141	11470	1534	2605	131	5700	35666		133391	19033		27450	215540
Zimbabwe	156885		22294	2052	3893	248	10355	195727	849	124950			12894	334420

2.2.7 Energy resources in the region

The region is well endowed with primary energy resources but has very limited petroleum reserves compared with other parts of the world. See table 2.12.

Discoveries of ***natural gas*** are quite recent in the region. Natural gas resources have been established in Angola, Mozambique, Namibia, South Africa and Tanzania.

In South Africa the gas fields off the south coast at Mossel Bay started in 1992 to pipe natural gas to the Mossgas gas refinery, where it is converted to petrol.

In Tanzania, about half of the reserves of 29 billion cubic meters have been committed to an ammonia/urea fertilizer plant, due to have begun operation in 1990. As for the remainder, a pipeline to Dar es Salaam for power generation is being considered (Songo Songo gas). Another discovery at Mnazi Bay is yet to be delineated.

The Kudu field offshore Namibia could supply 1 billion cubic feet per day for at least 15 years. However the main question for the development of the Kudu field is the market. The Namibian market is far too small to absorb a meaningful quantity of gas. The most promising market appear to be to supply electricity to the regional grid from a 1300 MW combined cycle generating plant on the Namibian coast. However with the current excess capacity in South Africa of more than 7000 MW, S.A. will not need additional power before year 2002, but from a regional greenhouse gas abatement viewpoint this fuel could make the plant interesting. Investigation are currently under way on the potential of gas trade with South Africa.

In Mozambique a gas field (Panda) containing 65 billion cubic meters has been found. Investigation are currently under way on the potential of gas trade with South Africa. With these new discoveries, gas which was not a common fuel in SADC could gain greater diffusion and be used in a number of applications hitherto not in use or replace some fuels presently in use.

Natural gas finds have triggered suggestion of the use of this resource for conversion to fertilizer to supplement imports of ammonium nitrate and to replace expensive processes such as the electrolytic plant in Zimbabwe which produces about half a million tonnes of ammonium nitrate a year.

Coal is by far the most important fossil fuel in the region with deposits distributed throughout all member states and extraction taking place in all countries with coal deposits. The levels of extraction and the quality of coal, however, vary quite notably and these factors and the cost of transportation hinder regional coal trade and export to the international markets. Only Angola, Namibia and Lesotho are without coal resources. Table 2.12 shows that besides South Africa, Zimbabwe is the main coal user in the region. Botswana has large reserves but a low production. However current production is only a small fraction of the reserve figure of 3340 million tonnes. So the potential for a large increase in CO_2 emission from coal combustion in the region is present. Coal is viewed as a critical vehicle to industrialisation and to the development of hinterlands and all efforts are being made in the region to develop this resource.

Table 2.12. Fossil fuel reserves and production in the region

Source:(SADC,1992),(Raskin,1991)	Coal		Crude oil		Natural gas	
	Million tonnes		Million tonnes		Billion cubic meters	
	Reserves	Production	Reserves	Production	Reserves	Production
Angola			273	23.6	9	
Botswana	3340	0.794				
Lesotho						
Malawi	3	0.044				
Mozambique	240	0.082			65	
Namibia					283	
South Africa	55000	179.000			28	
Swaziland	208	0.150				
Tanzania	304	0.007			29	
Zambia	69	0.375				
Zimbabwe	1187	4.738				
Total	60351	185.190	273	23.6	414	0

Angola is the only ***oil*** producing country in the region. Angola and Tanzania each have one refinery and South Africa have four plus the Sasol synthetic fuel plants. Zambia and Zimbabwe import distillates through pipelines from Dar Es Salaam and Beira respectively. Botswana, Lesotho and Swaziland get their petroleum products from South Africa.

Only Malawi and Zimbabwe produces ***ethanol*** to mix with petrol. The ethanol is produced from molasses from the sugar production. The Zimbabwean plant in Triangle has a capacity of 40 million litres annually. When added to the gasoline a blend is produced with an ethanol content up to 13%. In Malawi the plant situated at Dwangwa sugar estate in Nkhotakota district in the central region produces around 18 million litres annually, the blend has an ethanol content of 15%.

Geothermal energy exists in the region along the rift system. The Olkaia geothermal development in the Kenyan part of the rift system has increased the possibility of this occurrence in Tanzania adjacent to it.

2.2.8 Solar energy

The solar energy potential is quite significant in the region. Solar energy and new and renewable sources of energy have been promoted as alternatives to fossil fuels and electricity in rural households and institutions. The initial purpose for the promotion was to provide inexpensive and also sustainable energy to households where grid extension was prohibitive in cost. Of late NRSEs particularly solar PVs have been pushed as options for reducing the emission of greenhouse gases.

With respect to solar energy, Southern African countries have the advantage of long hours of sunshine since most of the countries lie between latitudes 8 and 30 south and receive an average of between 4 and 6 kWh/m^2 per day. Table 2.13 below shows the monthly and annual solar radiation on a horizontal surface in four SADC countries as a preliminary assessment of the solar energy resource base.

Table 2.13. Monthly and annual solar radiation on a horizontal surface in four SADC member states ($MJ/m^2/day$)

	Malawi	Botswana	Angola	Lesotho
January	20.5	23.0	19.4	25.0
February	20.1	22.0	19.4	22.0
March	19.5	21.0	18.8	20.0
April	20.6	19.0	18.4	17.0
May	18.7	17.5	18.7	14.0
June	17.5	15.0	17.0	12.0
July	18.0	16.5	15.6	12.5
August	21.5	19.0	16.2	15.0
September	24.4	22.0	17.8	20.5
October	26.1	23.5	18.9	22.0
November	24.9	24.5	19.2	25.0
December	21.1	25.0	19.7	26.0
Year	21.1	20.5	18.3	19.5

According to a study carried out by the Energy Department in Zimbabwe in 1992 2500 PV systems have been installed since 1984 giving a total capacity of only 250 kW in Zimbabwe but a number of projects have since then been put into operation to disseminate PV technology. Of notable importance is the GEF PV project which aims to disseminate and install some 9000 PV units in low income rural households.

Prior to the GEF project PV consumers consisted mainly of institutions (which include the government, national army, post and telecommunications, railways, agricultural bodies, national parks, hospitals and clinics and the education ministry), private domestic and business users.

All SADC countries import their PV technology as fully assembled modules with the exception of Zimbabwe, Botswana and South Africa which assemble part of their PV technology and manufacture the balance of systems such as batteries, panels, control electronics, light fittings and mounting frames.

The diffusion of NRSEs is influenced by a number of factors some of which are affordability (price), taxes and duties and supply capacity. Some of these factors are discussed below with the review to indicating the extent to which their rectification could result in a practical abatement intervention for emissions abatement.

The ***pricing structure of the PV systems and Solar water heaters*** was assessed by a study carried out by the SADC TAU unit in 1992. All prices were normalised so as to be compared on a per unit energy output basis. Comparisons were also made between absolute prices and price build-ups for each unit. The build up include such items as dealer mark-ups, taxes, duties, freight and insurance, etc. Each component which makes up the PV systems was priced separately and added to the other components to arrive at the total cost of each system.

We provide below a typical component breakdowns and price build-ups for some of the NRSE systems studied in the SADC region.

a) PV Panels or Modules

The PV panel typically represents 45% of the total cost of a supplied unit. The sizes of these panels range from 8 to 60 peak watts although the most common size is from 45 to 55 peak Watts. The typical price breakdown for a complete system in US$ per peak watt in 1991 prices is as follows:

	US$ per peak Watt
PV cells cost	4.65
PV module support frame and backing	
materials cost	0.65
Tempered glass cost	0.40
Electrical components cost	0.15
Other materials cost	0.45
Labour costs	0.15
Total cost	**6.45**

Table 2.14 shows the prices of PV panels imported into the SADC region.

Table 2.14. Pricing of 45-60 Watt PV panels (US$/Watt)

	FOB[1] Price	Freight[2] & Insurance	CIF[3] Price	Import Duties %	Import Price
Botswana	4.25	0.85	5.10	5	5.35
Malawi	6.90	1.25	8.15	30	10.60
Namibia	4.90	0.55	5.50	20	6.55
Tanzania	4.90	0.55	5.45	0	5.45
Zambia	5.45	1.00	6.45	15	7.40
Zimbabwe	4.80	1.00	15.00	15	6.50

b) PV Light systems

These consist of one or more 45 or 55 watts panels, with a battery, light fittings and lamps and a panel support designed to power small-time and household needs.

c) Portable Light systems or Lanterns

These consist of a PV panel (ranging from 8 to 15 watts), a fluorescent lamp (ranging from 7 to 9 watts) and a battery to be placed outside during the day for the "self contained" type or used as a conventional kerosene lamp for the "plugged in" version.

d) Household AC/DC systems

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[1]FOB- Free On Board - the price of a product at its point of origin outside of SADC

[2]The cost of shipping and insuring a product from outside the SADC

[3]CIF- the "landed" price of the imported system or components, including FOB, freight and insurance

These are bigger systems ranging from 500 to 700 watts used for larger institutions. One AC/DC system consists of about 10 to 15 panels, a regulator, batteries and an AC inverter.

e) Water pumping systems

Water pumping systems consist of PV panels, a DC pump, simple monitoring and power conditioning equipment, a water pipe and electrical wires.

f) PV Vaccine refrigerators

Typical portable refrigerators range from 40 to 100 litres and are powered by 12 or 24 Volts DC from six 50 peak watt panels and 600 ampere.hrs. battery. These refrigerators are heavily insulated.

g) PV Telecommunications systems

Telecommunications systems use up to ten 50 watt panels and a large battery for remote radio repeaters, signalling equipment, etc.

h) Solar water heaters (SWH)

SWHs are either manufactured locally using locally manufactured solar collectors and water storage tanks or imported as complete modules. Their sizes range from 200 litre storage with one collector to 300 litre with 2 collectors. The most common type is the "thermosyphon" using copper or plastic solar collectors and an attached insulated hot water storage tank. Table 2.15 below shows the price breakdown for 200 litre copper and plastic collector SWHs.

Table 2.15: Typical manufactured price breakdown for a 200 litre solar water heater produced in the SADC region.

	Copper collector		Plastic collector	
	Price in US$	% of total price	Price in US$	% of total price
Collector				
Absorber	120	27		
Glazing	20	5		
Other	70	15		
Total	210	47	360	46
Hot water storage	140	31	300	38
Labour	100	22	130	16
Total	450	100	790	100

Trade to trade in solar PV devices

PV technology markets are more well developed in some SADC countries than others, with Zimbabwe, Zambia and Malawi being the major users. One of the most important reason behind the slow rate in PV technology dissemination is the problem of high tariff and tax barriers which prevent both local and regional distribution of locally produced PV systems. This unfavourable financial environment discourages potential PV buyers from purchasing and using the technology. Import duties, surcharges and sales tax are heavier compared to other technologies. Other energy systems like electricity and petroleum products receive subsidies which are not enjoyed by PV technology. Credit facilities for purchasing PV systems is almost non-existent or where it exists, the interest rates are prohibitive.

SADC countries can be grouped into five categories based on their "favourability" to PV technologies as determined by taxes, duties, fuel prices and LRMC costs as shown below.

Group 1: Tanzania, Botswana and Lesotho - countries that have low taxes and duties, moderate oil prices and standard rural electrification conditions.

Group 2: Zambia, Mozambique, Namibia and Swaziland - countries that have combined taxes and duties in the range of 30-40%, moderate to low oil prices and standard rural electrification conditions.

Group 3: Angola - moderate duties and taxes, high oil prices and standard electrification costs.

Group 4: Malawi - high duties and taxes, high oil prices and low LRMC of electrification.

Group 5: high duties and taxes, low oil prices, and low rural electrification costs.

It can be seen from above that PV systems are most unviable in Zimbabwe where there are high taxes and low petroleum products costs. The strategies which are being adopted to ease the dissemination of PV technology therefore includes among other things the rationalisation of taxes and duties on PV equipment. Also tariff barriers between member states have to be reduced to reasonable levels.

2.3 Establishment of preliminary regional GHG emissions.

The total emissions of CO_2 from energy combustion in 1990 in the SADC countries is shown in table 2.16. The total emission were 341 million tonnes of CO_2 of which 90 % originates from South Africa. Coal is the major emitter, giving rise to 80% of the emissions

Table 2.16. CO_2 emissions from the SADC countries in 1990

1000 tonnes	Coal	Fuel oil	Diesel oil	Kero-sene	Jet fuel	LPG	Gaso-line	Total
Angola	0	603	1183	59	1380	166	339	3730
Botswana	1896	11	474	35	31	24	377	2847
Lesotho	126	0	120	92	0	8	111	456
Malawi	139	0	239	31	35	0	148	591
Mozambique	294	15	652	34	128	15	135	1271
Namibia	324	31	520	12	67	18	477	1448
South Africa	253800	17309	2745	0	2305	0	30218	306377
Swaziland	600	42	181	19	12	8	160	1021
Tanzania	78	507	1250	607	0	0	369	2810
Zambia	863	401	849	110	188	9	416	2835
Zimbabwe	14904	0	1650	148	280	16	756	17754
Total	273023	18918	9861	1146	4424	263	33506	341140
CO_2 emission factors kg/GJ	95	78	74	72	72	65	73	

The assessment of regional power systems in chapter 2.2 showed that the individual country systems are based on energy sources with very different levels of CO_2 emissions The countries with a high share of hydro power will have a low CO_2 emission per produced unit of electricity. This can be seen in table 2.17.

The information on individual country systems shows the following country specific balances (i.e. peak demand vs. installed capacity.

Table 2.17.Carbon intensity of electricity supply

	CO_2 /TJ electricity
Angola	14.20
Botswana	24.86
Lesotho	10.50
Malawi	0.35
Mozambique	17.56
Namibia	0.00
Swaziland	9.66
Tanzania	5.10
Zambia	0.08
Zimbabwe	21.78
SADC	42.41

Energy intensity in SADC:

The emission of GHGs in SADC will depend on the levels of activity in the productive and service sectors and in the unit usage of energy in these sectors. Below in table 2.18 we have assessed the current energy intensity of production in each of these countries. This is measured in terms of TJ per unit of GDP produced in the country and is expected to increase or decline over the years depending on the mix of the economy and on the structure of the technology in use. With increasing industrialisation, the intensity of energy in production as measured against total GDP will increase even if energy efficiency may improve.

Intensities will also rise in agriculture with increases in agricultural mechanisation as labour become more expensive and less available due to competition from other sectors.

Table 2.18. Energy intensity in the SADC countries in 1990.

1990	TJ	TJ/GDP
Angola	116139	16.3
Botswana	55309	19.3
Lesotho	26146	58.8
Malawi	106956	57.5
Mozambique	222515	148.9
Namibia	42473	22.6
South Africa	3625811	42.2
Swaziland	33014	50.2
Tanzania	446046	175.5
Zambia	215540	70.9
Zimbabwe	334420	62.8

The average efficiency in energy use will be influenced by a number of factors but the most interesting one at the regional level would be increased regional trade leading to greater competition and therefore a quest for competitive efficiency. Although energy is barely the most significant production cost (accounting in most cases for only 10% of production costs in manufacturing) it is generally targeted for cost cutting measures as opposed to labour which is more difficult to deal with in the face of tough official legislation and pressure from trade unions.

2.4 Review of existing regional studies

In the following a number of existing studies on relevant energy, environment and economic issues covering the SADC region are reviewed. The studies cover the areas liquid fuels, electricity and energy end use.

Liquid Fuels

Synthetic Liquid Fuels Production From natural Gas in Mozambique

Mozambique has significant reserves of natural gas. The SADC region uses a large quantity of liquid fuels annually in the transport sector. The project was conceived for the purpose of reducing the fuel import bill for the SADC region and also creating an end use for the gas reserves in Mozambique. The project was estimated to cost about US$ 50 million. The project would produce synthetic gasoline and diesel and alcohol fuels such as methanol. The market was estimated as 1.8 million tonnes of diesel, 584.000 tonnes of gasoline and 960.000 tonnes of blending alcohol's by the year 2000.

Economic analysis carried out in the late 1980's indicated no viability. This could have been due to the options analysed especially with the fuel mix and the technology that was proposed. International oil prices have not moved in favour of the project and innovative solutions would be required to make project viable.

The project would be a major regional option as it creates opportunities for Mozambique and Tanzania which have natural gas reserves. Experiences by South Africa which can now be shared could change the project performance.

Electricity

Refurbishment of Victoria Falls Power station.

The Victoria Falls Power station is owned and operated by ZESCO in Zambia. The power station was constructed in 1938 with a capacity of 8 MW. The first installation which is now called stage A had two 1 MW machines and two 3 MW machines. The second stage was commissioned in 1968 with six 10 MW machines and is called stage B. The third stage called stage C was commissioned in 1972 with four 10 MW machines. The station has a total installed capacity of 108 MW but a nominal capacity of 98 MW. The station is run-of-the-river and has a potential production of 775 GWh per year. Machine age and vibration in stage C limits the energy production to 700 GWh per year. Machine age and vibration in stage C limits the energy production to 700 GWh or less.

The station is linked by transmission line to Zambia, Botswana, Namibia and Zimbabwe. It also has a strategic ability of being able to start without external power. For this reason the station is an emergency supply for Hwange Power station in Zimbabwe. Increased demand is projected for Namibia, Botswana and Zambia. Apart from the station being a source of electricity the strategic location upstream from the Carabao allows for conjunctive operation that would assist in increasing storage at the Carabao.

Regional Grid - Southern Africa Grid

The concept of the regional grid has been discussed at various fora. Apart form individual projects such as the interconnectors between Mozambique and Zimbabwe, Zaire and Zambia, South Africa and Zimbabwe there has not been a commissioned project to study the concept as a SADC or regional project. The utilities have carried out some exploratory analysis based on theoretical models without in-depth analysis of the economic and technical options.

The regional grid would facilitate the sharing of regional resources with improved economic and environmental dispatch of the various power stations. The major resources such as coal in South Africa, Hydro in Zaire and the hydro stations on the Zambezi would play a major role in determining the structure of the grid. To date the interconnector between Zimbabwe and South Africa is under construction. The project will facilitate the emergency support of the Zimbabwe system from South Africa through the transfer of 400 to 500 MW from South Africa when needed. The project will also

serve to transfer Batoka power to South Africa when Zimbabwe has excess capacity. The project links a hydro system to a thermal system thereby providing the opportunities for environmental dispatch.
The interconnector between Zimbabwe and Mozambique is also in an advanced stage of project commencement. The project will be a 400 kV line operated at 330 kV with a transfer capacity of 500 MW. The tariff will be based on a 400 MW take or pay basis with Mozambique guaranteeing a 100% load factor. The line will provide access for Zimbabwe to the resources at Cabora Bassa and provide potential for cooperation with South Africa since the power being supplied to Zimbabwe is originally a South African entitlement. With the interconnector to South Africa complete and the DC line between Cabora Bassa and South Africa restored the regional grid will be a step closer to reality. There will still be a need to link Zaire and Zimbabwe before the grid can be said to be partially complete.

The SADC energy project AAA 3.8 on regional power generation & transmission capacities.

This is one of the studies with most relevance for this project. The study assessed the scope for coordinated capacity expansion and utilisation of regional generation and transmission facilities. The potential for inter-country transmission interconnections were examined as a means to foster least-cost investment strategies. The study only covers Botswana, Malawi, Mozambique, Zambia and Zimbabwe. The study compares an independent versus an integrated regional power development plan until 2010 and concludes by going regional the net present value of the savings is 1.3 billion US$.

Energy End use

Industrial Energy Conservation Pilot Project

The Industrial Energy Conservation Pilot Project was designed to carry out some energy audits in SADC industry as well as to develop local capacity for energy audits. The project was also aimed at setting up and promoting demonstration projects for energy conservation in industry. The demonstration projects would pave the way for popularising investment in energy efficiency. The project was carried out in 9 countries namely Angola, Botswana, Lesotho, Malawi, Mozambique, Swaziland, Tanzania, Zambia and Zimbabwe. The project completed a total of 20 audits in Zimbabwe, 9 in Malawi, 2 in Botswana, 1 in Zambia and 1 in Mozambique and presented the reports to government and industry. The response in terms of implementation of the recommendations was not as enthusiastic as would have been expected but some companies implemented up to 100% of the recommendations. A second phase is now in the preparatory stage to promote further study and implementation of some additional options. The project was funded by the Canadian Government through CID.

Improvement of Woodfuel End Use Efficiency in Industries of the SADC Region

The project was funded by the Dutch Government and was aimed at improving energy efficiency in the small scale rural industries. The project had to evaluate the potential for improvement of energy use efficiency in the rural industries. The project also had to identify design improvements for local technologies that could be promoted through local users with particular attention to the role of women. The results of the project would then be disseminated to SADC member states and Africa through TAU. The study concentrated on Fish, Smoking and Brick Firing since these were felt not to have received sufficient attention in other studies. The project attempted to derive algorithms for determining field efficiency performance and to allow the use of computers in efficiency studies. In addition to computer software the project was to deliver some manuals on energy efficiency improvement in the rural industry.

2.5 Regional mitigation aspects including a preliminary list of possible options

Introducing regional mitigation options provides added advantages to nationally restricted options. These advantages include increasing economies of scale for mitigation options. National options have smaller scale and therefore may have higher unit costs. Scale economies can also be derived from an expanded market for a regional project. The increased interaction from such markets may increase competition among other national producers and in this manner increase efficiency in production. Locally limited options fail to take advantage of regional resources such as hydropower in shared river systems and interior large scale hydro power systems such as the Inga dam project.

Regional mitigation options, however, would tend to be much more complex abatement than the national ones. This is because of the inherent economic and political arrangements that must be put in place before carrying out a regional project. There may also be simple technical issues which may make it necessary to delay the installation of a regional mitigation option even if in the regional stand point and perhaps from the stand point of one the parties affected by such an installation it may be opportune to immediately carry out an installation.

A case in point is the Batoka Gorge hydroelectric project, which from the stand point of Zimbabwe should be carried out immediately and in the interest of GHG mitigation would be an ideal displacement for a new thermal power plant. From the Zambian stand point this project is not an immediate need even if it may generate an export product if Zambia does not need the electricity. In Zambia's view the investment would mope up limited investment funds resulting in a high opportunity cost for other investment and employment options.

Zambia, therefore opted for an unspecified delay in the project leaving Zimbabwe with an option to go it alone if it so wished. This investment for Zimbabwe even if gone alone would still be a jointly owned investment for Zambia and Zimbabwe in a situation where Zambia would reserve the right to claim its share of the electricity at a specified latter date without having taken the risk of investment and without having suffered any opportunity costs from the investment.

Under this condition, Zimbabwe may be forced to go for an less desirable generation option on the expansion schedule. This may be coal or it may be hydro. Whatever it is, this would tie down Zimbabwe to this installed capacity perhaps through the time Zambia may find itself needing the Batoka installation. By this time Zimbabwe may not be in sync. with Zambia's needs. Of course there are ways out of such complications - but the point is simply that regional projects or abatement options are much less obvious than national options even if their benefits are clear and agreed..

In this section we provide a preliminary listing of possible regional mitigation options.

The following set of regional mitigation options has been identified. Below it are descriptions of the each option and discussions on their chances for successful implementation or descriptions of the necessary conditions for their success.

Power sector:

The power sector provides by far the greatest opportunities for regional abatement options. These include:

- Regional power pooling to take advantage of the most efficient plant
- Regional hydro base loading or coal peaking to reduce carbon intensity
- Regional cross border supplies for rural consumers to reduce the cost of transmission to remote rural locations.

Household and rural energy sector:

- Increased trade / removal of trade barriers on NRSE for rural applications to reduce dependence on wood or kerosene.
- Increased trade in efficient household energy end-use devices.
- Establishment of sufficient scale windmill manufacturing plant to replace diesel water pumping in rural areas.
- Increased transfer of experience with pilot projects on NRSEs in different countries in the region.

Transport sector:

- Improved railway passenger services (high speed trains) to replace buses on crossborder routes.

- Improving railway goods service to reduce the use of cross border truck haulage.

Macroeconomic sector

- Enhancing formal trade practices to discourage cross-border vending.
- Increasing trade in finished goods (removing captive markets) to encourage production efficiency.

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3. Botswana report

3.1 Botswana overview

3.1.1 Physical Features

Botswana is a large landlocked country (582,000 km^2) located in Southern Africa and over 80% of land surface to west and south of the country is semi-arid to arid forming part of the Kalahari desert. This part of Botswana is not a typical desert but consists of shrub/Kalahari savannah vegetation. The areas around Bokspits and Makgadikgadi Pan can be qualified as having mature desert conditions as depicted by sand dunes. The rest (20%) of the country to the east, NE and SE has good loamy soils supporting relatively thick tree vegetation and crops and is the most inhabited part of the country (80% of population).

Much of the country is flat with thick Kalahari sand cover except to the east along the railway corridor where the basement is outcropping. The altitude generally varies between 900-1200m above sea level but falls to 500m in the extreme east where Botswana shares a border with both Zimbabwe and South Africa (see map at the end of chapter 3).

Botswana has a few rivers draining through it namely the Okavango river which drains inland from the North forming the Okavango Delta. The Delta is an important tourist resort in northern Botswana. Emanating from the Okavango is the Boteti river draining to south and water disappears below ground near the Orapa Diamond Mine. The Notwane river flows along the SE border (along which three of the 5 major dams in the country are situated) and together with the Shashi river in the eastern periphery of the country join the Limpopo river. The Molopo river also flows along the border with the western part of South Africa.

Botswana thus largely depends on groundwater for its water requirements except in the towns of Gaborone and Francistown. Water resources will however be boosted by the North-South Carrier when it is complete 5 years from now. This carrier will allow distribution of water to either north or south towns along the railway corridor from available surface and groundwater wellfields within the corridor.

The daily mean temperature generally varies between 22°C in July (Winter) and 33°C in January (Summer) with extremes from less than 5°C in Winter and up to 43°C in summer (NDP7, 1991). Night temperatures fall significantly even in summer to below 15°C.

The climate being mainly semi-arid registers low and variable rainfall which like in the rest of Southern Africa is often exacerbated by recurrence of drought which has become frequent in recent years. Periods 1981/82, 1986/87 and 1991/1992 were critical drought seasons in the past decade and had bad effect on vegetation growth, animal survival and hydro power generation in the region. The mean annual rainfall (see map at the end of chapter 3).is generally low (475 mm) (compared to Zimbabwe (800mm) and a world average of 857 mm) and thus can mainly support grasslands (78% of area). The country vegetation consists of dry deciduous forests in the north, mainly tree savannah in many parts of the country and shrub savannah in the greater part of the country to the west. The limited vegetation has implications on availability of woodfuel resources and CO_2 sinks for emissions generated in anthropogenic activities.

Botswana generally registers over 8-10 hours of sunshine daily presenting a great potential for solar power utilisation. Wind speeds are on the low side and windpower can only be implemented for water lifting in Botswana.

3.1.2 Demographic Setting

83% of the population is confined along the railway corridor between Francistown (NE) and Lobatse (in the south) (see map at the end of chapter 3). Although the total population of Botswana is low in absolute terms (1.3 million), its concentration in 20% of the country creates a localised high population density of about 10 people per km^2 compared to national density of 2 people per Km^2) thus putting stress on the natural resources in that region, particularly water, fuelwood and agricultural land. Over 75% of total farm land (traditional and commercial) is situated along this railway corridor. Districts close to Gaborone are the most densely populated and 50% of the entire population is estimated to live within 100 km of Gaborone.

Botswana's population has more than doubled in the past two decades (1971-1991). The population increased from 574,000 in 1971 to 1,327,000 in 1991. During this period there have been significant changes both demographically and socioeconomically. Towns and villages have mushroomed in many places where they did not exist before.

Botswana's population centres are categorised as city, town, large village, medium village, and small village. The village classification is based on both population and the level of infrastructural development. Within the broad rural sector are other two levels of settlements associated with Botswana's agricultural activities namely cattle posts and lands area/*masimu*. The cattle posts are traditional ranching farms. The women and children also spend the greater part of the rainy season (5-6 months) at *masimu or lands area* ploughing, planting and reaping food crops. The growing season starts from about November to March/April. This situation of each family having three homes has implications on increased energy consumption.

The greater part of the population of Botswana however live in the towns and large villages. Urban and large villages account for 43% of Botswana's population.

The growth in the population of Botswana in the last two decades and the proportions of urban and rural population are reflected in Table 3.1.

Table 3.1 De facto population as per the last three census results (10-year periods)

	1971	1981	1991
Urban**	54,416	150,021	606,239
Rural	519,678	791,006	720,557
Total	574,094	941,027	1,326,796
Female/male ratio	-	1.124	1.091

*Source: CSO, 1993; ** Any settlement of 5000 or more persons with at least 75% of labour force being non-agricultural is <u>urban</u> for census purposes.*

The sizes of populations in major population centres of Botswana are shown in Table 3.2

Table 3.2 Households sizes in the major centres of Botswana

Town/Centre	Population	No.of households	Average household sizes
Gaborone	133,468	36,639	3.52
Francistown	65,244	16,789	3.82
Serowe/Palapye	128,471	24,093	5.30
Selebi Pikwe	39,772	10,595	3.69
Mahalapye	95,433	17,881	5.30
Tutume	100,049	18,688	5.27
Kanye	31,354	6,227	5.04
Orapa	8,827	1,805	4.43
Jwaneng	11,188	2,961	3.48
Shoshong	5,592	1,051	5.32

Source: CSO, 1994- Pers. Comm.

Population projections (NDP7) show that urban population will be greater than rural population in the next 20 years. The high population growth rate (3.5%- Midterm Review NDP7, 1994) and the rapid urbanisation process influence a high energy demand in the domestic sector and the dynamics of the social structures in both the urban and rural areas. These factors will have environmental consequences due to use of cheap energy sources and increased utilisation of energy derived from fossil fuels and fuelwood.

Rapid economic growth will therefore be required to keep pace with the growing population. More job creation initiatives and agricultural land are required to sustain the growing population. The country is already experiencing a growing shortage of good agricultural land, good grazing land, firewood and water (NDP7, 1994).

About 47% of the total households are headed by women (CSO, 1993) and 48% of the people are under the age of 15 years aggravating food and energy insecurity.

3.1.3 Economic and Social Policy Framework

At independence, Botswana was one of the poorest countries in Africa but the 25 years since independence (1966) have seen a remarkable economic transformation with regard to infrastructural development and economic growth.

Table 3.3 and Fig 3.1 below shows the growth of Botswana's economy and its changing structure in the period 1966 to 1992.

Table 3.3 shows that the economy of Botswana was dominated by agriculture and services at independence. The rapid expansion of the cattle herd in response to the high export prices in Europe contributed to the economic boom of the late 1970s and early 1980s. During 1980-1982 export earnings from the cattle and meat products averaged 14.1% but dropped to about 5% in 1991/92. Apart from the lucrative export earnings beef contributed to the economy, cattle are a major source of rural incomes and a symbol of status. The rural population also depend on cattle as the major source of food in form of meat and milk especially for the children.

Frequent droughts in recent years have caused periodic declines in cattle numbers and thus the agricultural sector has slowed down in growth.

Mining contribution to GDP increased from 0% at independence to over 50% of GDP in 1988/89 and is the current largest single contributor to GDP (Table 3.3). Presently (1991/92) diamond mining has become the mainstay of Botswana's economy accounting for 39.3% of GDP and for 78 % of total export trade in 1992 (CSO, 1993).

The growth of mining industry was accompanied by further development of infrastructure and social services

It is estimated that the annual increase in GDP (in real terms) has averaged 13% since 1980. Per capita GDP has grown by nearly 8 times in the same period increasing at 8% since independence.

The diamond resource is not renewable and the government is looking for ways of diversifying the economy but solutions are not in sight (Midterm Review NDP7, 1994) thus Botswana will continue to depend on diamonds for a while into the future. The mining sector is a small employer (4% of cash earners) and depending on mining will not create the much needed employment in the country. Unemployment rate for 1993 was 13.7% (CSO, 1993).

Botswana, however has large foreign reserves (10.781 billion in 1993/94) which is 33% higher than the real GDP in the same period (NDP7, 1994). These reserves could be deployed to increase the industrial base. This healthy economic situation and the rising per capita income is expected to influence a high demand for energy and shift to cleaner energy sources especially in the Household sector.

Table 3.3 Growth (GDP) of Botswana's economy 1966-1991/92 at Constant 1985/86 prices

Million Pula	1966	1977/78	1982/83*	1988/89*π	1991/1992*π
Agriculture	124/ 39.6	309/ 19.9	141.3/ 7.5	202.6/ 5.9	219.0/ 5.2
Mining	- -	241/ 15.5	919.7/48.8	1474.2/42.9	1550.0/ 36.8
manufacturing	25/ 7.9	106/ 6.8	115.5/ 6.1	200.4/ 5.8	238.2/ 5.7
Utilities-water & electricity	3/ 0.8	44/ 2.8	28.9 / 1.5	82.4/ 2.4	96.5/ 2.3
Construction	18/ 5.7	73/ 4.7	68.3 /3.6	171.4/ 5.0	211.2/ 5.0
Trade, hotels	58/ 18.6	311/ 20.0	233.4/12.4	453.9/ 13.2	642.5/15.3
Transport	13/ 4.1	65/ 4.2	34.5 / 1.8	110/ 3.2	150.1/ 3.6
Finance	21/ 6.6	129/ 8.3	85.5/ 4.5	172.4/ 5 0	217.8/ 5.2
Government	52/ 6.7	253/ 16.3	238.1/12.6	538.6/ 15.7	839.1/19.9
Social services	- -	65/ 4.2	47.8/ 2.5	101.2/ 2.9	116.4/ 2.8
Dummy sector	- -	-42/ -2.7	-28.7/-1.5	70/ -2.0	(72.1)/ (1.7)
Total GDP	313/ 100	1554/ 100	1884.1 100	34373/ 100	4209.6/ 100
GDP/capita (P)	579	1982	1905	2799	3095

1966-1979/80 source NDP7 - 1988/89 constant prices

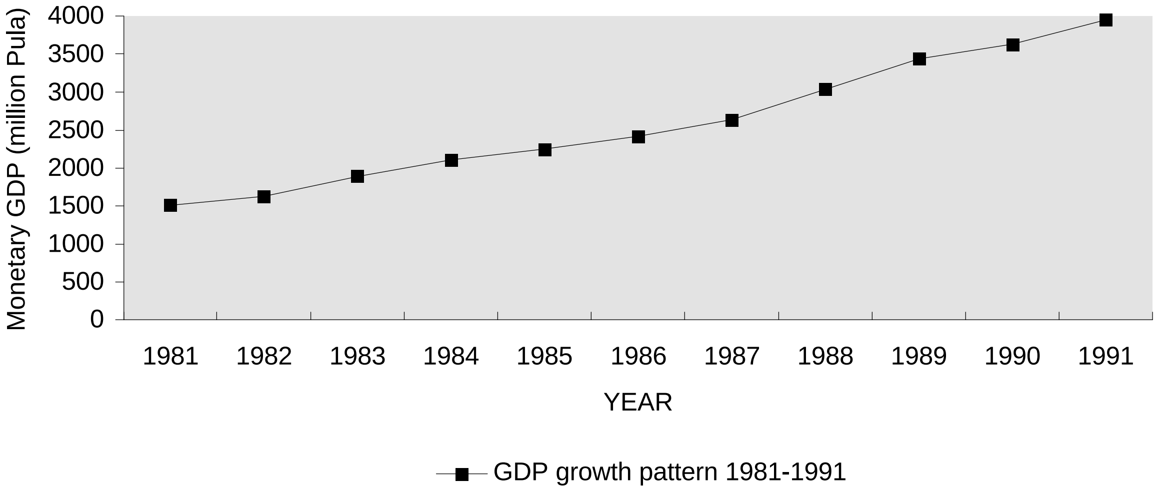
** Source CSO Sept. 1993*

p Provisional figures

The current rate of inflation in Botswana is averaging 10%. Inflation in Botswana is affected by inflationary changes in South Africa from which 80% of Botswana's imports come. The economic policy which may change in South Africa and the structural adjustments in neighbouring Zimbabwe and Zambia makes it difficult to predict the future economic situation of Botswana. Botswana has the challenge of penetrating the regional markets and boost its trade.

The real interest rates presently fluctuated between -5% and 5% from 1980 to 1992 (NDP7, 1994). The low interest rates effectively block relaxation of foreign exchange controls on capital account and tend to inhibit foreign investment in Botswana. The other factors which block foreign investment are the high real wage level, low labour-productivity and high exchange rates which make the cost of production in Botswana higher than in other regional countries (Midterm Review NDP7, 1994).

Fig 3.1 Historical GDP growth 1981-1991- Botswana- (1985/86 Constant prices in million Pula)



3.1.4 Transport systems

a) Regional perspective

Botswana is linked to its neighbours, namely Zimbabwe to N.E., South Africa to south and Namibia to west and north, by road, rail and air routes. The initial thrust in the transport infrastructure was to minimise dependence on South Africa including Namibia when it was not independent which explains why routes to Namibia have not been well developed but are being upgraded.

Botswana transport systems face competition from other transport systems in neighbouring countries.

The rail route through Beitbridge poses a serious threat to operations of Botswana Railways (BR) especially for transit traffic. BR was banned by the government of Bophuthatswana from entering that country until after South Africa's independence.

Botswana road users face difficulties in obtaining permits from South Africa due to strict traffic rules in that country in spite of the memorandum of understanding signed by SACU member countries to share equitably the cross border traffic.

The transport system of Botswana has been affected by regional policies within the Southern African Transport and Communications Commission (SATCC- also associated with PTA) and Southern African Customs Union (SACU). Recovery of road fees for regional road users has been slow due to bureaucratic delays within SATCC and SACU. Charged fees under SATCC and SACU do not include adjustment for inflation hence real fees have been falling by 15% per annum.

Regional cooperation in transport systems among Southern African countries is however surfacing. Both Air Botswana and Botswana Railways have established cooperation with their Zimbabwean counterparts in the regional routes. BR and ZR operate one train between Lobatse and Bulawayo. Their airlines share carriers and human resources particularly for passenger transportation. This shows that opportunities can exist for regional cooperation for implementation of GHG mitigation options in this sector.

b) Country Perspective.

Internally the BR competes with other modes of transport especially the road transport. Domestic air transport is also available and services both settlements along the railway corridor and the remote centres like Maun and Ghanzi.

i) Rail

Policy:- It is government's intention to provide the necessary infrastructure in order for BR to operate a safe, efficient and cost-effective rail system for conveyance of passengers, freight and parcels.

Status:-The whole of Botswana is serviced by one main railway line (640 km) from NE to S with branches to Sua Pan-soda ash mine (175 km) to N and Selibe Pikwe-copper-nickel mine which is located 59km south of Francistown. There is also a 15 km of rail branching to the Morupule Colliery to the NW of Palapye (see map at the end of chapter 3). The Railway line carries freight destined for Botswana and in transit to neighbouring countries.

Areas distant from the railway line however depend on road transport only.

Modal shift to rail passenger transportation has been introduced in Botswana. BR operates a rail bus between Gaborone and Lobatse, and Gaborone - Mochudi. There is however a need to expand the capacity and improve services. BR might also consider electrifying the rail portions with the rail bus to save on imported diesel and GHG emissions.

The freight and passenger transportation provided by the rail compared to total freight are presented in Table 3.4

Table 3.4 Rail Freight and passenger traffic and revenue in Botswana 1988-1993

	1988/89	1989/90	1990/91	1991/92	1992/93
Freight (x1000 tonnes)	2.033	2.264	2.223	2.365	2.852
Freight revenue (p million)	42.4	50.1	57.6	75.8	90.0
Passenger (x1000)	425.3	444.8	394.4	431.1	355.1
Revenue (p million)	6.6	6.7	6.3	7.4	6.5

Source: MWT&C, 1994; CSO, 1993

The disadvantage of the rail systems is that it is capital intensive and has low traffic. The slowness of the train makes it less competitive compared to road transport systems especially for passengers. Although speed of trains could be improved by good signalling and communications system, the installations will be cost-intensive and the current cost estimate is P60 million.

Use of rail system has an advantage in that it has minimal damage to the route unlike the road system which requires huge maintenance costs.

ii) Road

Policy:- The government is to maintain roads to proper standards and the Roads Department will introduce maintenance management system and pavement management system. In order to ensure that gross vehicle weights comply with certain standards of axle loading. Legislation is also being reviewed to enable enforcement of standards and reduction of road damage.

Status:-The road network improved greatly since independence but is far from being satisfactory. There are 18 327 km of road network consisting of 9 566 km (52%) District council roads and 8 761 km (48%) national roads (see map at the end of chapter 3). Of this network, only 3 666 km (20%) are paved, 3 641 km (20%) are gravel, 6 268 km (34%) are earth and 4752 km (26%) are sand roads (MWTC, 1993, pers comm.). Only 3km of the District council (DC) roads are paved and over 92% (50% of total) of DC roads are earth and sand making it necessary to use heavy engine 4x4 vehicles. About 25% (12% of total) of national roads are earth and sand. Culturally, most Batswana visit their cattle posts on weekends in the remote parts of the country where access is mostly by 4x4 wheel vehicles. The earth/sand roads are passable only by 4x4 wheel drive vehicles and even gravel roads have demanded use of light duty vehicles (LDV) making LDVs the largest fleet of cars in Botswana.

As a result, 42% of registered vehicles in 1992 were light duty vehicles, 28% were cars, 12% lorries, 6% trailers,3% buses and 5% other vehicles. The general population of vehicles has been steeply increasing at an average rate of 5100 vehicles per year or about 5%/year responding to the increasing per capita GDP which increased by over 205% between 1979/80 and 1991/92 at 1985/86 constant prices. The largest increase in vehicles was over 10 000 in 1989 which was the peak of economic boom for Botswana in recent years.

The large bus transport has improved but most travelling is still by individual owned vehicles and mini buses. Use of large buses between Gaborone and large villages like Molepolole could reduce traffic on roads.

iii) Air

Botswana is linked by air traffic to regional and overseas destinations. In 1991 the air traffic carried a total of more than 306 242 passengers and over 500 tonnes in cargo and mail. Its cargo carrying capacity is limited because the aircraft used are small so most of imports and exports are freighted mainly by rail.

In a big country like Botswana with decentralised settlements, air transport could reduce road travel significantly saving on travel time and reducing road maintenance and fuel consumption. Domestic air travel has been successfully implemented in countries with similar decentralised population like Australia. There are 5 airports which meet ICE standards, connected to over 120 government and private airfields in Botswana making it possible to operate air travel. For air travel to be effective, air fares have to be affordable to allow a significant proportion of the population to shift to the mode of transport.

iv) Telecommunications

There is international telecommunication links through an earth station at Gaborone as well as via South African stations. Microwave links via South Africa (SA or RSA) and Zimbabwe complement the earth station. Internally telecommunications are good in the urban areas but are being upgraded in the rural areas. Public telephone systems are however vandalised from time to time thus slowing the development process in this aspect.

An upgrade and efficient telecommunication system could save a lot of travelling between points thereby reducing on fuel consumption and hence GHG emissions.

3.1.5 Ecological and Land-Use Setting

There are three main land tenure systems in Botswana namely the communal/tribal land, state and freehold lands.

70% of the Tribal land is divided into grazing and arable zones. Grazing areas are communally owned and fuelwood is collected free of charge. Traditional farming is the major activity in the Tribal land containing over 99% of farmland and 82% of Botswana's cattle herd in 1990 (CSO- Agri Stats, 1990).

Some of the ploughed lands are abandoned after 10-50 years after soil exhaustion and rampant weed infestation resulting in large tracts of land being cleared continually.

Freehold land (5% of the country) is for exclusive commercial farming. Although the proportion of this land is small, it produces over 50% of the national main crops and 18% of the cattle herd (CSO Agri-Stats, 1990).

State land accounts for 25% of the total land and is used as game reserves, national parks, forest reserves and urban development. In some parts of state land, people have free and open access to wood resources (including fuelwood) and pasture land resulting in overuse of these resources and consequently land degradation. Part of the Tribal and State land has also been allocated to people on 50 year leases under the Tribal Grazing Land Policy (TGLP) for commercial farming mainly cattle ranching.

The land categories in Botswana by end-use are presented in Table 3.5

Table 3.5 Land use categories.- Botswana

Landuse	% of Land	Remarks
Arable	2.1	75% in east and NE
Grazing-fenced	5.0	
Cattle posts	30.0	Contributes significantly to range degradation
Forests	0.5	
Swamp and Water	2.5	Okavango delta
Natural Parks & Game Reserve	17.5	
Urban and Industry	0.1	
Tribal/communal	42.0	
Other	0.3	

Source: Min. of Agriculture- Basic Ecology, 1978

3.1.6 Environmental Legislation on Land Use

Environmental legislation mainly pertains to air pollution and wood resources depletion and their impacts on land, water, air and humans. So far the legislation does not include restrictions on emissions of GHGs.

Botswana does not have ground level emission standards but it is government's objective that the emissions do not exceed certain stipulated levels. Emissions are monitored at mines, power stations and urban areas (industrial/institutional emissions). The Department of Mines has been given the mandate to monitor and enforce legislation for the control of atmospheric pollution. The current Atmospheric Pollution Prevention Act will in the near future be reviewed to cover all potential polluters such as vehicles and waste disposal sites (Midterm NDP7 Review, 1994).

Environmental legislation on Land use and related wood resources depletion is mainly based on the Tribal, the Town and Country Planning and the Forest Acts.

Under Tribal Act, the Land Board/chief have the power to prevent people from carrying out activities resulting in environmental damage e.g. cutting trees of food (fruit) and medicinal values. Failure to comply with the Boards' legislation can result in the cancellation of the rights to use the land.

Under the Town and Country Planning ACT, the Minister can make preservation of any trees/woodland as he sees fit. Under the same framework, no one is allowed to source fuelwood and or cut trees in Wild life areas.

The Forest Act prohibits felling of trees (including possession of cutting implement), residing, setting fire, graze livestock in Forest Reserve area unless they have a licence to do so. On State land trees are not to be cut within 10 metres of a river bank especially for construction of housing.

Contravening of these Acts carry a fine or imprisonment or both.

The setback in the current environmental legislation is lack of policing, and it is likely that offences are being committed without anybody being prosecuted.

Large tracts of land are exposed to veldt fires resulting in forest destruction and loss of soil fertility/moisture. In 1989 an estimated 800 km^2 of Botswana woodland was subjected to veldt fires (Otsyina and Walker, 1990).

The commonality aspect related to use of wood resources on tribal lands results in uncontrolled forest depletion.

3.1.7 International Relations

Botswana is a member of the United Nations under which it participates in the activities of various UN agencies (e.g. WHO, WMO, UNEP. UNDP, UNESCO, UNCTAD, UNIDO, ICSU). The Climate change issue which is the subject of this study has its institutional framework within the World Climate Programme consisting of WMO, UNEP, UNESCO and ICSU and its three IPCC subgroups. Botswana is now a signatory to and has ratified the United Nations Framework Convention on Climate Change (UNFCCC) to which it bears responsibility to monitor, report on its GHG emissions and come up with GHG mitigation strategy.

Botswana also belongs to a number of political, economic and financial institutions. Politically, Botswana is a member of the Non-Aligned Movement, the Organisation of African Unity (AU) giving Botswana leverage to partake in international politics.

Botswana is a member of the African, Caribbean and Pacific group of countries covered under the Lome Convention which has trade arrangements with the European Economic Community. Botswana's viable beef industry benefits from EEC markets under this convention. Botswana is still pondering about being a member of the Eastern and Southern African Preferential Trade Area (PTA). The Southern African Transport and Communications Commission (SATCC) to which Botswana belongs within the SADC framework however incorporates PTA objectives since the other members of SADC are also members of PTA.

Regionally, the country belongs to the Southern African Development Community in which it is the permanent chairman and participates in the developing strategies in the various sectors of the economy being allocated to the member countries. Botswana is a member of the South African Customs Union (together with South Africa, Swaziland, Lesotho and Namibia) which gives member states privilege when trading among themselves.

The country is a member of the World Bank, International Monetary Fund and the African Development Bank. Since the above financial institutions will be crucial in funding of UNFCCC environmentally-benign projects and technologies, Botswana is better placed to benefit from them.

3.2 Overview of institutional set-up for national planning

3.2.1 National Management Institutional Framework

The important institutions within Central Government which are crucial to energy and climate change issues are shown in Fig.3.2.

Those Government institutions which will be important in decision- making related to UNFCCC, issues of investments, programme/project implementation, energy and environment aspects and land use activities are discussed below.

a) Ministry of Finance and Development Planning (MFDP) is responsible for drawing the overall national development plan in consultation with other ministries, approval of development plans for funding and collection of population and environmental statistics through the Department of Central Statistics. The Ministry sources funding, either internally or externally, for various programmes/projects to be implemented by the various ministries.

The Department of Development Planning within MFDP is crucial in deciding which projects will qualify for approval and hence funding.

The Botswana Technology Centre (BTC) which falls under the MFDP is a parastatal body charged with research in *inter alia* energy technologies. Under management agreement with MMRWA, BTC is in charge of ECUP during the pilot commercialisation phase.

b) Ministry of Local Government Lands and Housing (MLGL) is responsible for land-use planning (including urban development), Land Boards and Local Authorities, Food Resources and is the parent Ministry for the National Conservation Strategy (NCS). Currently the responsibility for environmental protection is fragmented among different central and local government institutions but is to be coordinated by the National Conservation Strategy (NCS) Agency which has been in existence since 1990.

Land Boards are responsible for allocation and administration of tribal land and are charged with implementing sections of the Tribal Act.

The Botswana Housing Corporation which is responsible for construction of urban housing also falls under this ministry. The BHC becomes important when considering GHG mitigation options associated with the urban household sub-sector.

c) Ministry of Agriculture (MoA) is responsible for crop production, forestry and veldt products and conservation of forest resources. It is also involved in the review of the forestry legislation and strengthening the Agricultural Resources Board in order to promote improved management of forest resources, rangelands and other natural resources. The ministry also formulated new agricultural policy which reflects many requirements of the NCS. Within the energy institutional framework, MoA is in charge of biomass management involving afforestation programmes and natural wood resources management (still under study) and monitoring wood resources depletion. For research and implementation in these areas, the MoA is assisted by the Forestry Association of Botswana (FAB-NGO) and The National Institute of Research (NIR-University of Botswana) although the latter falls under the Ministry of Education.

d) Ministry of Mineral Resources and Water Affairs (MMRWA) is responsible for mineral prospecting and mining, water and energy resource management.

The Department of Mines handles environmental issues related to safe mining and monitoring of air pollution and liquid discharge practices. This Department is charged with implementation of the Atmospheric Pollution Prevention ACT. The Department of Mines is the coordinating agency for the coming US Climate Change country Study in Botswana.

The Department of Water Affairs (DWA) are the custodians of water quality standards. DWA has the responsibility for policy related to assessment of available water resources and providing the Botswana population with portable water. DWA is thus concerned by recurrence of drought/climatic variability in the region which is affecting water recharges and hence portable water supplies to the population of Botswana.

The Energy Affairs Division (EAD) within the MMRWA is responsible for coordinating the national energy policies formulated in ten various institutions within the energy framework (Fig. 3.3). Suggestions have been made to upgrade it to a department in order to give it full responsibility to formulate, implement and evaluate energy policies covering the various facets of the sector. Existence of ten institutions in the energy sector imply duplication of roles.

The Department of Geological Survey within the mineral exploration framework will affect policy on extraction of energy fuels like coal and assessing potential for presence of oil/natural gas in Botswana.

The Botswana Power Corporation (BPC) is a parastatal within MMRWA and is in charge of electricity generation, transmission and distribution in Botswana.

e) Ministry of Commerce and Industry (MCI) is responsible for supply, strategic storage and pricing of petroleum products and the related policy formulation and implementation. However LPG is outside the control of the ministry and is still supplied and priced by vendors.

Subsidiaries of the international oil companies complement the institutional framework by being responsible for petroleum supply and distribution. There is a price review committee in which all the oil companies and government are represented. The Government has the chairmanship and BP. Botswana Ltd is the secretary.

MCI issues licences to new companies if they approve of their industrial/commercial operations. This is an opportunity available to MCI to screen projects based on their environmental pollution/emission implication at the onset and to set standards of industrial operations.

The Rural Industries Promotion to which the Rural Industries Innovation Centre reports to the MCI and carries out R & D , and implementation in agricultural and renewable energy technologies particularly wind and solar energy.

f) Ministry of Works, Transport and Communications (MWTC). Consists of the Department of Meteorology, Central Transport Organisation (COT), Department of Electrical and Mechanical Services (DEEMS) and the Department of Architecture and Building Services (DABS).

The Department of Meteorology is the collaborating Agency on Climate Change issues and together with The Department of Mines are responsible for the US Country Study on climate change in Botswana. Two members of Staff in the Meteorology Department attend the INC meetings.

The Central Transport Organisation is responsible for all government transport especially road vehicles and has a large fleet of vehicles. This Department becomes important when considering fuel savings in the transport sector in the mitigation analysis.

DEMS *inter alia* is responsible for rural power generation and is presently in charge of three stand-alone diesel generators at Tsabong, Ghanzi and Tutume. The fourth diesel generator at Maun also fell under DEMS but is now being operated by a private company for BPC. Maun will be connected to the national electricity grid in 1995. There are also plans (Energy Affairs pers. Comm.) to connect Tsabong to the South African grid and the northern part of Botswana (Shakawe) to the Namibian grid. The Ghanzi diesel generator will be run by a private company.

DABS being responsible for designs and supervising construction of government buildings can make policies in favour of passive solar designs for domestic and commercial buildings in Botswana which can also be a GHG reduction measure.

g) Ministry of Health is responsible for public health, including occupational health. Currently the ministry is spearheading the drafting of the Waste Management Policy. This policy is relevant to CC studies through landfill GHG sources.

h) Ministry of Education is responsible for formal and non-formal environmental education. It has also introduced environmental education in their curriculum (Cantrell and Nganunu, 1992). This ministry can be used as a vehicle for propagating awareness with regard to energy conservation, clean and efficient technologies and the consequences of Climate Change.

The University of Botswana falls under this Ministry and a number of research goes on in the National Institute of Research on biomass supply and demand and its consequences on the environment and household economics.

i) Ministry of External Affairs is responsible for international conventions and analysing international law pertaining to the conventions. Having signed the UNFCCC, the ministry has to analyse the implications of the convention and communicate these to the line ministries for action.

Fig. 3.2 Relevant institutional set-up for national planning related to Climate Change

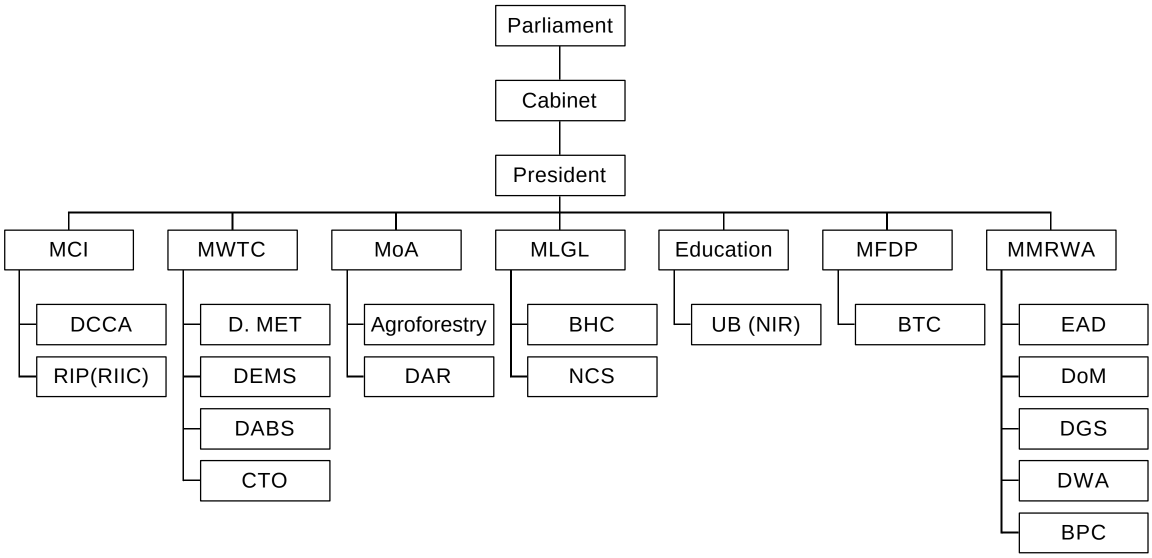
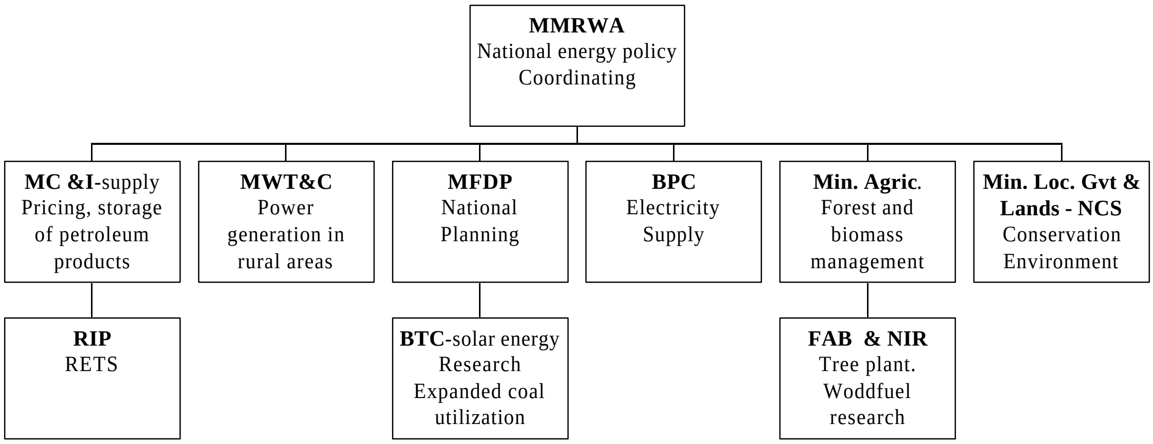


Fig. 3.3 Organisational structure of the energy framework



The abbreviations used is explained in chapter 3.10

3.3 Organisational overview for existing national climate change activities

There has not been much going in Botswana in terms of CC activities after signing the UNFCCC. The Department of Meteorology which is the national collaborating agency on CC issues and has been attending the INC and IPCC meetings.

At the present moment there is a committee on Ozone Depleting Substances (ODS). Members of this committee come from the following institutions:-

Department of Mines

Ministry of Foreign Affairs

Plant Protection

Ministry of Works, Transport and Communications (MWTC)- Planning Department

Department of Water Affairs

Ministry of Commerce and Industry

National Conservation Strategy agency

University of Botswana

Department of Meteorology (who are the chairman of the committee).

This committee is responsible for mapping out the country programme within the framework of ODS reduction schedule stipulated within the Montreal Protocol.

The same committee is to deal with CC issues (Meteorology pers. comm.). Currently the interim committee consists of Departments of Meteorology, Mines and the University of Botswana.

In the light of the importance of energy in GHG/GW/CC issues, it might be important to include the Energy Affairs Unit in the Committee.

There has not yet been a national effort to conduct GHG inventories or GHG reduction.

The study done by Zhou (1994) under the African Energy Policy Research Network (AFREPREN) is the first study which has produced some CO_2, CH_4 and N_2O inventories and preliminary GHG abatement options.

3.4 Review of existing studies and plans on cc and related issues in energy, land use , forestry, environment, economic development planning

The previous studies are more inclined to energy and forestry issues thus even the National plans in place are the Energy master Plan and the Forestry Plan. The National Conservation strategy relates to environmental issues and can be considered as an environmental Plan.

The National Development Plan is revised every six years and provides government 'thinking' on the economic and Development Planning.

3.4.1 The Botswana Energy Master Plan (BEMP, 1993)

BEMP was initiated in 1987 with GTZ funding for the Ministry of Mineral Resources and Water Affairs (MMRWA) (refer to figure 2.1.2) to which the Energy Affairs Division belongs. The over all goal of the Plan was to provide integrated Energy Planning to support efficient, dynamic and environmentally-sound energy policy. The energy policy for Botswana is still not available in final form but the Energy Affairs Division is working on it. BEMP dwells on economic performance as it affects energy demand and suggest least cost as a guiding principle for energy policy rather than self sufficiency. The government is also advised to firmly link its decisions to analytical work and sound project appraisals. BEMP(1993) analysed the individual energy fuel sub-sectors and made policy recommendations.

- On coal, BEMP recommends:-establishment and monitoring of technical standards to ensure efficient, safe and environmentally sound coal-burning equipment particularly boilers in industry and government institutions. Such application of efficient energy technologies could incorporate GHG mitigation options in a country whose power and industrial sectors are dominated by coal.
- Provision of technical assistance and extension services to institutional and industrial users.
- Implementation of demonstration projects within the government system. A policy is required to commit government institutions to use coal instead of fuelwood.
- Implementation of coal beneficiation to improve the quality of coal and reduce its environmental impacts.

BEMP recommends that MCI include energy conservation and recovery of social and environmental costs in future petroleum pricing and to involve the Energy Affairs (MMRWA) in the pricing exercise. The MCI is also to control price of LPG as it is increasingly being used in the household sector. Increase of strategic reserves is suggested but the cost implications would need to be carefully analysed.

BEMP states that the petroleum sub-sector has the largest potential for energy conservation and efficiency improvements opportunities. The potential for saving petrol and diesel in the transport sector was estimated to be 15%. This saving could result in a significant share of GHG being reduced.

The measures recommended by BEMP for woodfuel are to carry out resource assessment and to reduce fuelwood demand by charging stumpage fees and fuel substitution. Fuelwood consumption could also be reduced if government institutions like schools and military shifted to coal use.

Botswana can benefit from its excellent solar radiation and BEMP recommends that government resources be channelled to promote solar energy utilisation both solar water heaters and PV systems for rural use. Promotion of such a carbon-free renewable source will result in reduction of GHG emissions. There is a larger potential for exploiting the energy resource in the Southern African region.

With regard to electricity, BEMP concluded that regional power pooling was the most attractive option for Botswana to meet its future electricity demand than build new coal-power plants. Future coal power plants, apart from causing further GHG emissions will expose the government to financial risk. The proposed export power plant (2400 MW) has comparative advantages as it will generate income from RSA and the region from sale of power; diversify economy; improve trade balance with RSA and national security, and could provide backup power for the region when hydropower is affected by droughts. This project will however increase GHG emissions for Botswana by manyfold. There is however a large hydro potential in the region which can be exploited to meet the regional (including Botswana) electricity demand.

Government thrust of rural electrification, apart from being a possible development trigger, could also result in a significant share of avoided GHG emissions from woodfuel burning.

BPC are carrying out a tariff study following a recommendation by the BEMP.

3.4.2 The National Forestry Research Action Plan

This Plan was prepared by the Division of Forestry and Ecology in the Ministry of Agriculture as part of SADC exercise assisted by the other research organisations and NGOs associated with the Forestry sector in the country. The task force included members from the National Institute of Research (NIR); Forestry Association of Botswana (FAB); Thusano Lefatsheng; Botswana Furniture Manufacturers, Veldt products Research and the Energy Affairs Unit. The Plan covers the agricultural; energy and the forestry sectors and presents a number of forestry research programmes aimed at improving the livelihoods of the people of Botswana and their environment.

The programmes are in the areas of natural wood resources management (NWRM) involving the Acacia species in SE Botswana and woodlands of the Chobe District. NWRM will allow regeneration of natural woodlands thereby achieving sustainable supply of wood products including fuelwood. Sustainable supply of wood resources will ensure zero net GHG emissions from wood. Under Agro-forestry programmes, FAB and Department of Agricultural Research (DAR) will try new plant species which can be grown sustainably in Botswana. Fuelwood research under this Plan will look into possibility of irrigating fuelwood species and natural woodlands around areas of high fuelwood demand. The other aspects of the Plan entail building up institutional framework related to training and infrastructural development.

Botswana expresses in this Plan her willingness to cooperate with other SADC countries on these projects by sharing knowledge as some of the vegetation types are transboundary. Good forestry management apart from improving the microclimate and soil conditions will also result in improved CO_2 sinks.

3.4.3 The National Development Plan (NDP)

NDP is revised every six years and currently the NDP7 (1991) is in force. The NDP7 (1991-1997) recognises the need to diversify the economy which is dominated by diamonds and to ensure sustainable development. It sights the possible engines of growth as manufacturing and services which if successfully attained will result in increased consumption of commercial energy from fossil fuels.

The major objectives of the current NDP7 which also apply to all the sectors of the economy are :-

- To achieve rapid economic development through increasing the industrial base. The objective of this policy is to stimulate manufacturing and other industrial growth to create employment and increase exports to complement diamond exports which are not a renewable resource.
- To achieve sustainable development through efficient production techniques without endangering the environment.
- To have economic independence and this was with respect to Botswana's dependence on South Africa from which 80% of its imports come although Botswana does not pay duty under the South African Customs Union (SACU).
- To achieve social justice. This is with regard to making resources and services available to the whole population of Botswana e.g. providing cleaner energy sources (electricity and solar) to rural population.

NDP7 predicted the growth rates in Table 3.6 below within the Plan period in response to the above government policies.

If the GDP growth rates in Table 3.6 are achieved the associated energy demand will increase. Industrial growth depends on electricity (which in the case of Botswana is derived from coal) and petroleum products which both have implications for high GHG emissions.

Table 3.6 Expected economic growth in response to new policies

Sector	GDP growth rate %	Export Growth rate %
Agriculture	1.0	0.5
Mining	2.0	2.0
Industry	7.5	10.0
Services	6.5	10.0
Government	4-5	n/a

Source:NDP7

The fact that industrial growth is still small provides an opportunity for Botswana to install energy efficient technologies at the onset unlike in other countries with developed industries where they have to wait for the life span of the present technologies to expire before they can replace them with energy efficient technologies.

The government is also a major shareholder in the existing large industries namely mining, construction, power utility, meat products and is thus better placed to influence adoption of energy efficient technologies which can result in significant GHG reduction.

With regard to energy, the energy policy as stipulated in NDP7 is to be guided by four objectives namely to:

- secure a cost effective supply of energy by choosing an appropriate mix of energy sources to meet future energy demand.
- diversify supplies in order to reduce dependence on any particular source of supply and increase security of supply.

- develop and manage indigenous resources in order to increase self-sufficiency and sustainable development
- ensure that energy related activities are performed in an environmentally sound manner.

In addition the energy policy seeks to ensure that:

- consumers pay prices and tariffs that reflect the true cost of energy supply.
- traditional sources of energy are available to the rural population, are maintained and that new alternatives are introduced.
- the energy sector planning and management capabilities are improved in order to cope with the increasing requirements and complexities of the sector.

3.4.4 The National Conservation Strategy (NCS)

The NCS Agency is tasked with the overall environmental planning in Botswana. The areas identified as of environmental concern under the NCS are:-

Pressures on water resources

Degradation of rangelands and pasture resources

Depletion of wood resources

Exploitation of veldt products

Pollution of air, water, soil and vegetation

The Botswana National Conservation Strategy has been in place since 1990 and emphasis in implementation is placed on :-

- Improving environmental awareness
- Formulating standards and norms on environmental practice and the necessary legislation.
- Economic incentives
- Preparation of Action Plans and insisting on Environmental Impact Assessment

Both the Education/Research, and Research and Policy divisions already exist within the structure of the NCS Agency.

The issues related to energy in this Strategy conform to wood resources depletion and pollution to air, water and land.

With regard to wood resources depletion, the strategy places importance in increasing supply either through afforestation programmes or management of natural woodlands.

Pollution of water, in a country where portable resources are not everywhere abundant, by industrial processes *inter alia* energy processes will be monitored. Legislation will cover disposal of waste oils and toxic effluents and emissions from power generation.

Environmental air pollution from energy plants is presently monitored by the Department of Mines and the Botswana NCS will control emission and dispersion of toxic emissions. Standards are however not in place and this is one other area the environmental planning exercise will look into.

The NCS agency is taking a lead role in formulating legislation on Environmental Impact Assessment (EIA).To date the preparation of EIA have been accepted as part of the planning and implementation of several major projects despite the legislation still being formulated.

3.4.5 Previous Studies

The previous studies which have been carried out in Botswana which have some relevance to the present study are summarised in 3.7 below.

The several studies addressed a number of energy related issues which have implications on GHG emissions.

Table 3.7 Previous energy-land use Studies

Donor	Local coordinating organisation	Programme	Duration
NORAD	MLGL FU MoA FAB KRDA KDP SFB NIR	Labour based AE10 woodlots AE1 woodlots Seed collection Extension Extension Training Dukwe Study	1982- 1980s- 1987 1987 1986 1988 1984-88
UNDP/WORLD BANK	MMRWA	Utilisation of indigenous resources- coal and hydrocarbon exploration	1984
USAID	MMRWA	Renewable technologies- woodstoves and solar technologies	1984
ODA	ERL/MMRWA	Energy utilisation and requirements	1985-
SADC	ETC/SADC	Biomass supply- by satellite imagery	1987
UNDP	KRDA	Plantation	1987-89
ANEW	KRDA	Plantation	1987
EEC	FU MoA FAB	Technical support Public Tree planting	to start 1986-89
ODA	FAB MMRWA	Seedlings ERL-Rural energy study	1986-89 1984-85
SADC	MMRWA	ETC-biomass resource assessment	1987
GTZ	MMRWA	Energy Master Plan Coal Utilisation (ECUP- 1990)	1987 1987-
WORLD BANK	MMRWA	Urban Household Energy Survey (ESMAP, 1991)	1988-
USAID	FU MoA	Rural Afforestation	1980-84
IUCN	MLGL	Part of NCS	1985-89
HIVOS	FAB RIIC	Awareness Extension	1985- 1984-
GATE AGRO ACTION	RIIC RIIC	Biogas	1978-
IDRC	FAB	Research	1986-
CODEL	YWCA	Sehitwa Woodlot	1988-
NUFFIC	NIR NIR NIR	Production Ecology Germination of Savannah SPP Run off and Erosion	1988- 1988- 1988-
SADC	FAB	National survey of biomass/woodfuel activities	1992
ADB	ADB/Energy Affairs Unit (EAU)/ by EECG	Domestic Energy and Environment	1993-94
AFREPREN	EECG	GHG/GW/CC	1992-1994
ADB	ADB/EAU done by EECG	Energy-Environment interactions	1994-

Source: Walker, 1992 + additions

The UNDP/World Bank (1984) was intended to address the NDP5 objectives of substituting imported energy fuels particularly petroleum with coal in power generation and to assess the hydrocarbon (oil and gas) potential in prospective sedimentary basins to the NW and W of the country. The study focused on the status of energy sources in Botswana and identified potential for further use of the indigenous energy resources, particularly commercial energy sources in industrial development. The study also recommended restructuring of the institutional framework.

The BRET (1984) was funded by USAID and aimed at producing wood cook stoves and solar technologies for Botswana. This project produced 3000 stoves and only marketed 50% of them. Although promotion of the cook stoves continued until 1988, market penetration was slow so production and marketing was discontinued.

The forestry related projects in Table 3.7 including those of ERL (1985); ETC (1987); Kgathi (1987, 1989, 1992); Walker (1992) and Kgathi et al, 1993); Kgathi (in prep) focused mainly on the biomass resources situation, supply options and the fuelwood question in Botswana.

The ERL (1985) and ETC (1987) studies focused on woody biomass supply situation in Botswana. Both studies utilised satellite imagery (with very limited ground-truthing) to assess wood resources stocks.

The study carried out by Kgathi (1992) is a comprehensive study of the firewood collection, marketing, consumption and household economics in Botswana.

Kgathi *et al*. (1993) was a study of biomass production and consumption conducted in the 3 village towns of Molepolole, Mmankgodi and Khakhea. This study employed SPOT imagery and aerial photographs supported by ground truthing to examine the biomass stocks in the three areas. A questionnaire survey was also conducted to assess the fuelwood consumption levels and patterns in those areas.

Walker's (1992) study was a national biomass survey/woodfuel activities. Apart from studying the role of biomass in energy supply and demand, the other objective of the study was to carry out a survey of NGOs and government organisations actively involved in biomass projects or programmes (Table 3.7) and also to assess these institutions in relation to their ability to respond to present and future energy situations. The degree to which these organisations cooperate with each other and coordinate their activities was also assessed.

The World Bank (1991) project was part of the Energy Sector Management Assistance Programme (ESMAP). The project was carried out in the major towns (including the mine towns of Orapa and Jwaneng) and villages along the densely populated railway corridor. This project assessed the urban energy consumption patterns.

The ADB study (Zhou, 1994a) which was on the domestic energy consumption and its impact on the environment dealt with consumption patterns of all energy fuels/sources and the associated environmental impacts of fuelwood scarcity/deforestation and ground-level emissions. The study also produced a model for fuel projections based on population growth, per capita income levels and fuel prices.

The AFREPREN Study (Zhou, 1994b) dealt with the demands of the UNFCCC as they affect the Southern African countries and produced GHG inventories and preliminary abatement costing for Botswana.

The current ADB project (Zhou, in prep) addresses all aspects of energy-environmental interactions and apart from the environmental impacts addressed above also included GHG emission levels from the different sub sectors of the energy sector.

3.5 Energy Supply structure in Botswana

The energy sector in Botswana is characterised by modern/commercial (i.e. coal and oil) and traditional fuels (i.e. biomass). Botswana is well endowed with three energy carriers namely coal, fuelwood and solar energy but imports all its petroleum products. Other energy resources in the form of wind and biogas are available in very small proportions.

3.5.1 Coal

Coal reserves in Botswana are estimated to be in the region of 212.8 billion metric tonnes, categorised as in Table 3.8.

Table 3.8 Coal reserves in Botswana

Category	Estimates Reserves (X Million Tonnes)	(Million Toe)
Measured	3 340	1 275
Indicated	23 260	8 882
Inferior	21 976	8 392
Hypothetical	99 717	38 078
Speculative	64 089	24 473

Source Energy Unit, MMRWA - pers. comm.

The proven coal resources at the Morupule coal mine alone are estimated at 40 million tonnes and at the current annual production rate the proven resources will last for about 50 years.

The only operating mine, Morupule Colliery is situated in the northern part of the country about 270 km from the capital city of Gaborone. The underground mine is managed by the Anglo American Corporation Ltd. The mine currently produces about 900,000 tonnes of coal annually as run off mine but has a larger production capacity of over 1 million tonnes/year.

Over 95% of coal supply is locally mined and the remaining 4% of the coal is imported from South Africa the latter for use in industrial boilers in major industries e.g. BMC (takes over 75% of imported coal), Kgalakgadi Breweries and Botswana Breweries.

The historical coal supply from Morupule since 1973 when the mine opened is shown in Fig 5.1.1a. The quality of Botswana coal is presented in Tables 3.9 and show a relatively low carbon content and calorific value compared to international export coal.

Fig 3.4 Historical coal demand and supply 1981-1992

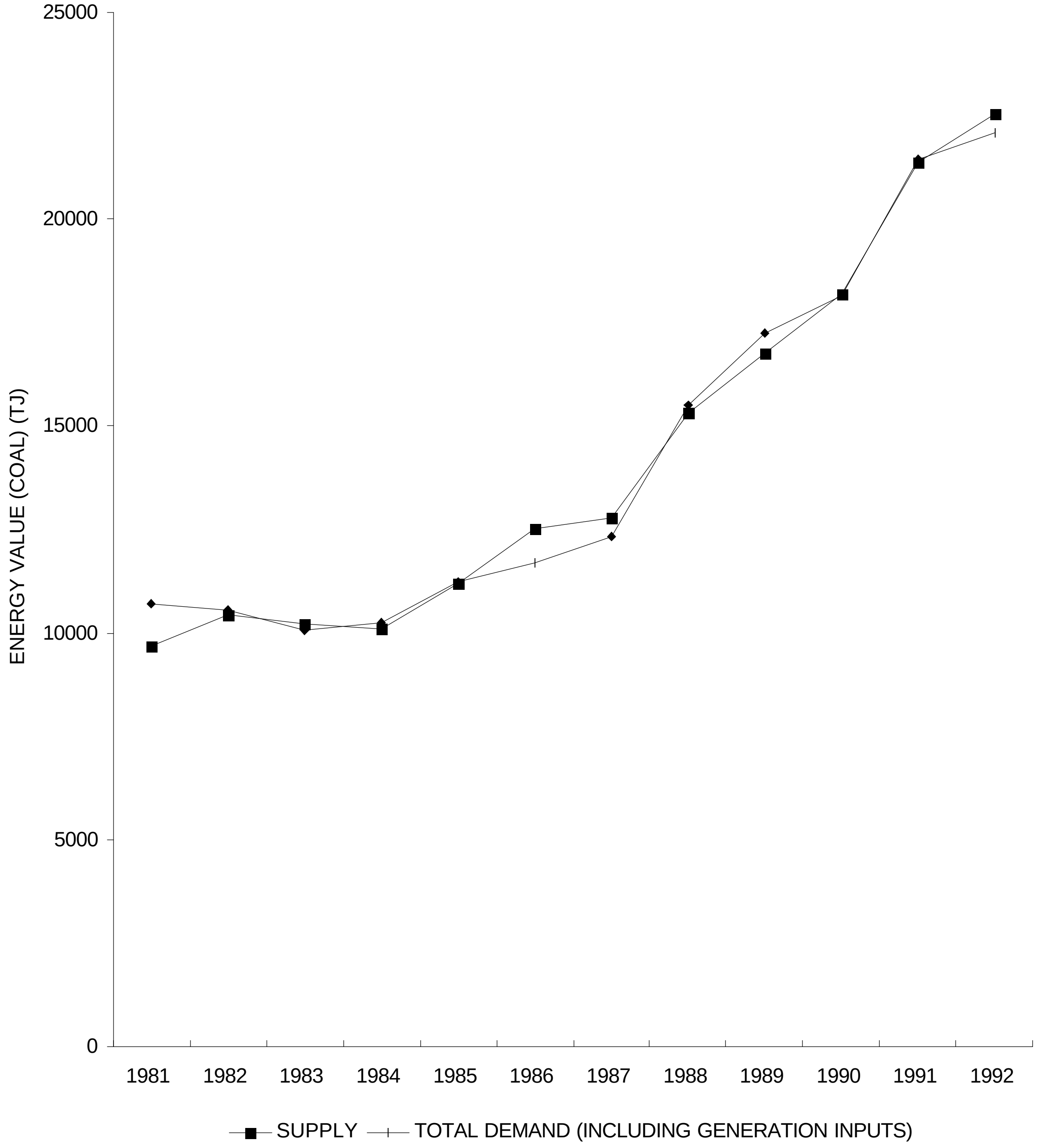


Table 3.9 Coal quality analysis

(i) Proximate analysis

Analysis	Value
Calorific value	24.2 MJ/KG
Moisture	5.7%
Volatile matter	23.2%
Fixed carbon	52.9%
Total sulphur	1.46%

Source: CSIR (South Africa)

(ii) Ultimate analysis

Analysis	Value
Carbon	61.41
Hydrogen	3.40
Nitrogen	1.36
Sulphur	1.46
Ash	18.20

Source: CSIR

3.5.2 Electricity

Most of the electricity generated in Botswana is thermal and is derived from coal. There are two coal-fired power stations located at Morupule (the coal mine) and Selibe Phikwe. A very small proportion (4MW) is generated by diesel stand-alone generators servicing villages remote from the national grid. The rest of the needed capacity and extra capacity is imported from Zimbabwe and South Africa. Table 3.10 shows the capacities of the various electricity generation sources and Table 3.11 shows the related transmission lines.

Table 3.10 Installed electricity Capacity

Power Station	Technology	Power Production GWh	Installed/available capacity MW
Morupule	Coal fired	802.9	132
Selibe Pikwe	coal-fired	98.1	62
ESKOM- South Africa	Transmission		75
ZESA -Zimbabwe	Transmission		75 (up to 120)
Sua Pan	Coal fired		20
Diesel generation	Diesel generation		6.29 MVA
Maun			4.00 MVA
Tsabong			0.85 MVA
Ghantsi			0.70 MVA
Tutume			0.35 MVA
Gomare			0.39 MVA

** BEMP 1993*

Table 3.11 Lengths of Transmission lines in Botswana

Voltage		Total Length (KM)
220 kV		902
132 kV		407
	Substations	Capacity (MVA)
220kv	Francistown	60
220kv	Orapa	80
220kv	Selibe Phikwe	60
220kv	Morupule	160
220kv	Sigoditshane	120
132kv	Gaborone South	60
132kv	Broadhurst	40
132kv	Lobatse	20
132kv	Jwaneng	90
132kv	Sua Pan	20
132kv	Maun	-
66kv	Kasane	-

Source: BPC, 1992

The Department of Electrical and Mechanical Services (DEMS) is said to operate a total of 20MW installed diesel capacity including generation in schools, hospitals, police stations and prisons (BEMP, 1993).

3.5.3 Petroleum Products

Botswana has no known oil reserves. During NDP6 (1985-1991) a government funded exploration program oriented towards prospecting for hydrocarbons in the western basins of Botswana showed minimum potential of oil reserves.

All Botswana's petroleum energy requirements are imported in refined form mainly through South Africa under the South African Customs Union arrangements. Very small additional quantities are imported through Zimbabwe and Namibia to supply settlements near the borders with those countries.

In South Africa, Botswana's supplies are procured from Durban, Sasol refineries or from South Africa depots (BEICIP, 1988).

Results of economic analysis of supply route options to Botswana by rail shown in Table 3.12 indicated that the South Africa route was the most economical.

Table 3.12 Comparative Supply routes for Petroleum to Botswana

Supply rail route	Distance (km)	Transport costs US$/mt
Durban-Gaborone	1060	66.90
Maputo- Francistown	1293	99.30
Ndola-Francistown	1430	97.40
Dares Salaam-Francistown	3195	195.10

Source:BEICIP,1988

Monitoring of petroleum supply, pricing, contingency planning and management of strategic reserves fall under the portfolio of the Ministry of Commerce and Industry (MCI). The actual procurement is done by subsidiaries of the International Oil companies namely:

B.P. Botswana (PTY) Ltd

Shell Oil Botswana (Pty) Ltd

Caltex Oil Botswana (Pty) Ltd

Total Botswana (Pty) Ltd

Engen Botswana (Pty) Ltd (Formerly Mobil)

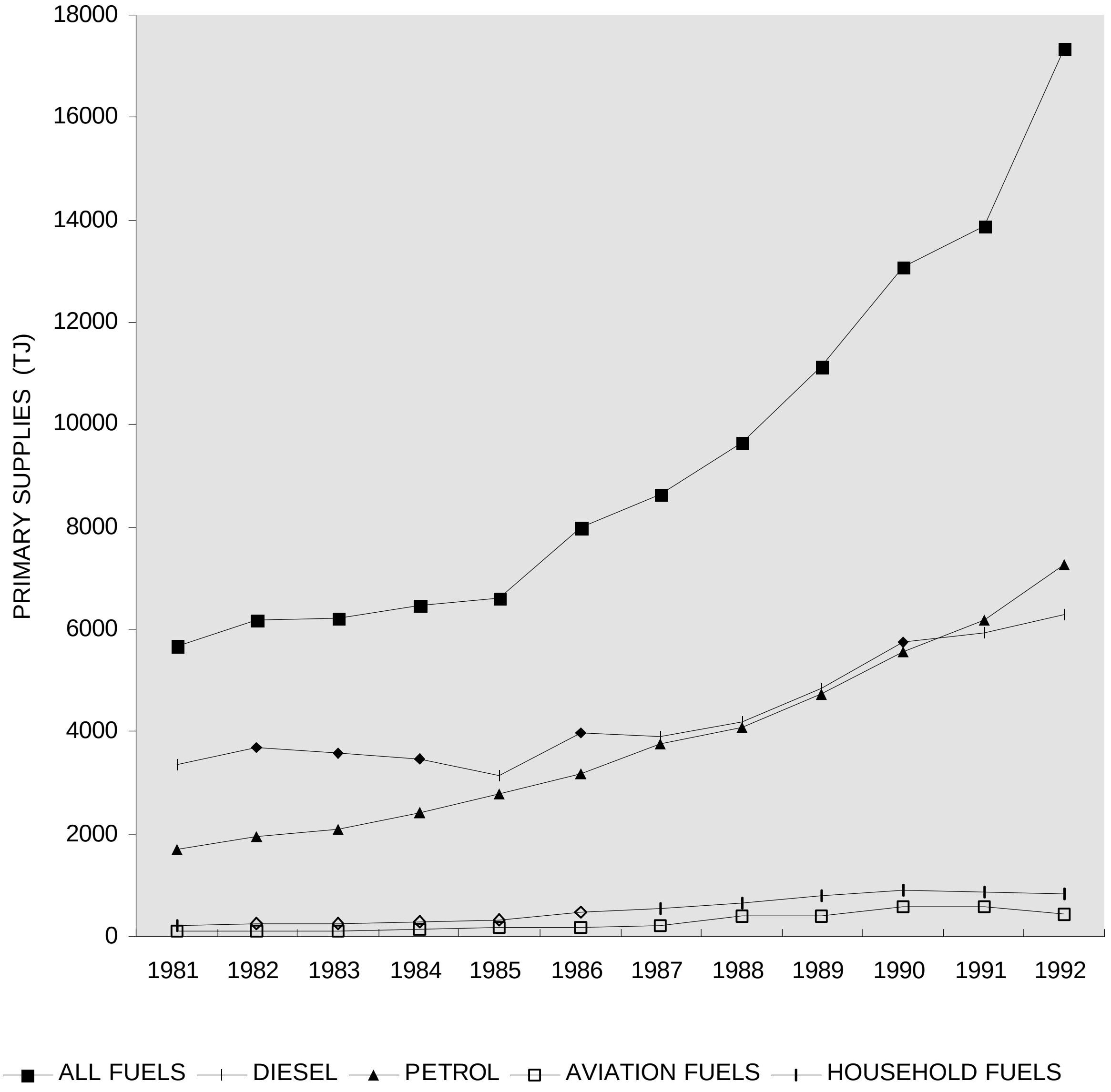
Petrochem (Botswana) (Pty) Ltd

The major petroleum products traded by these companies are petrol, diesel and illuminating paraffin. They also supply other products in smaller quantities. Petrochem has the exception of trading in lubricants only. LPG is sourced from South Africa by vendors and government does not monitor supply and pricing of the product.

The primary supply historical trend for petroleum products between 1981 and 1992 are presented in Fig. 3.5 below. The total supply of petroleum products increased dramatically after 1985 due to increased demand for petrol and diesel.

Petroleum energy imports are dominated by diesel and petrol, which are both mostly used in the transport sector. The two products constituted 84% of 1990 total petroleum energy imports. On average, LPG and paraffin, contributed 8.3%, aviation fuels, 4.4% and fuel oil & lubricants 3.4% of total imports.

Fig 3.5 Historical primary supplies of petroleum products 1981-1992



<u>*Strategic Reserves*</u>

Government has two major storage facilities exceeding those of the oil companies in Francistown and Gaborone as national strategic reserves. Government maintains storage facilities with a full capacity of 62,000 kl. The reserves are estimated to last for approximately 50 days at current consumption rates. Further reserves totalling 6000 kl are maintained by the private sector but these are not of strategic significance. The CCE/SADC (1988) study recommended strategic reserves sufficient for 90 days for all land-locked SADC member states.

3.5.4 Fuelwood

Reliable quantitative data on wood resources are still scanty and inventories continue to be updated by MoA.

The standing biomass stock estimated from remote sensing (ERL Energy Resources, 1985) is quoted at 16.4 million tonnes (Kgathi, 1992) and about 9.2 million tonnes (air dried weight) are fuelwood species.

Woody biomass loading in Botswana is varied and ranges from 3.6 ± 4.3 t/ha for shrub savannah to 48 ± 10.6 t/ha for dense forests (ERL, 1985). An average biomass loading of 15.8 tonnes per hectare is the average for the south east of Botswana (Otsyina and Walker, 1990) where the majority of Batswana have settled.

The provision of fuelwood ranges from 0.5 - 2 tonnes to 10-15 tonnes of dry wood per hectare per year depending on the vegetation zone Sekhwela, 1994).

Regeneration capacity ranges from 0.4t/ha to 1.2t/ha/year (Kgathi, 1992) with an average value of 0.93t/ha (Diphaha, 1992). Regeneration is low compared to the original/standing stock which ranges from 3.6 to 48 tonnes/ha (Kgathi, 1992)

In densely populated areas where there is heavy localised fuelwood demand the regeneration rate is low at 0.3 tonnes/ha/year compared to the national average of 0.93 tonnes/ha/year. The regeneration ranges from 0.3 tonnes/ha in the Kalahari Savannah to 2.1 tonnes/ha in the dense woodlands (Table 3.13).(Deduced from ERL, 1985).

Table 3.13 Standing stock density and regeneration rates.

Vegetation zone	Standing biomass stock (tonnes/ha)	Regeneration rate (tonnes/ha)
1.Sparse Vegetation e.g. grasslands	3.6 ± 4.3	0.3
2.Low Density Woodland- e.g. woodland	18.9 ± 6.6	1.0
3.Mid density woodland- e.g. Riparian	25.9 ± 2.7	1.4
4.Higher density woodland- e.g. Dense wood	48.0 ±10.6	2.1

Source: Kgathi 1992

The total national growing stock of woody biomass adds up to 1400 million tonnes and the estimated annual increment was 50 million tonnes (BEMP, 1993) which far exceeds the annual national wood demand of about 1.8 million tonnes. The SE parts of Botswana however have localised over-exploitation due to non-sustainable supply of fuelwood, timber extraction, land clearing for agricultural development and overstocking or overgrazing. At the local level there is evidence of net tree removal.

Contribution to wood supply from afforestation is small. Small scale plantation forestry initiated in 1970s under Rural Afforestation Programme has stagnated with 650 hectares. Although there are 12 nurseries with an annual production of 500 000 seedlings, production costs of wood under the prevailing conditions are high and production is low (5m^3 per ha/yr.). Considering the 636 ha, about 3000 tonnes of wood (for all purposes) are produced from the woodlots.

Other agroforestry activities are just confined to woodlots for screening species, research purpose including indigenous fruit trees.

The historical wood supply is shown in Fig 3.6. There was a marked increase in wood supply after 1989 although this results in about 50% statistical difference between the supply and the sum of the energy and non-energy demand. Fig 3.7 shows the development of the woodfuel demand by sector.

Fig 3.6 Historical wood supply and demand: 1981-1992

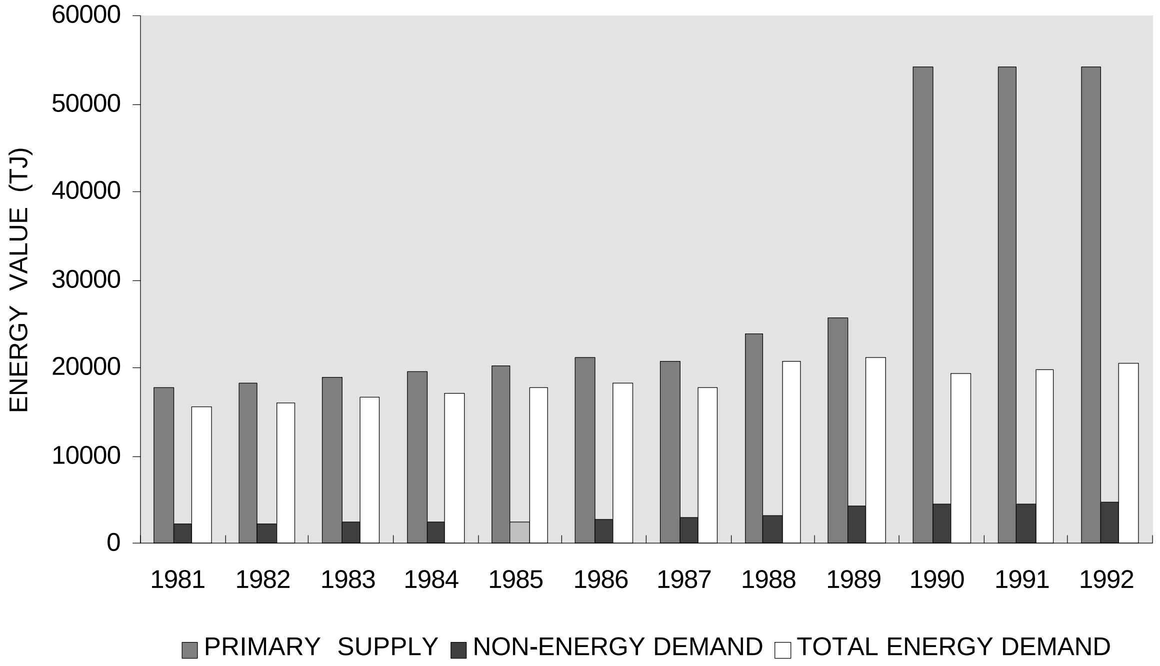
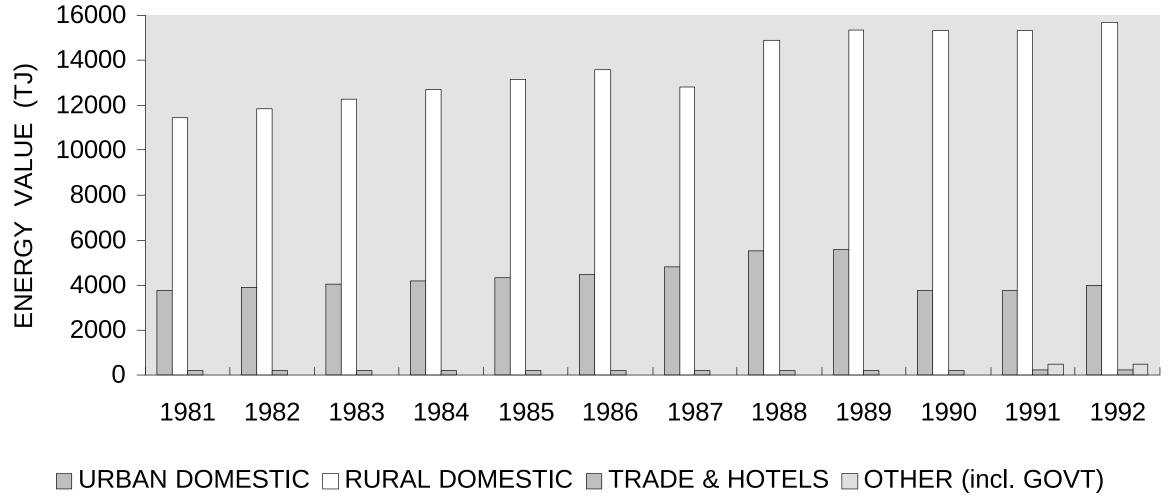


Fig 3.7 Woodfuel demand by sector: 1981 - 1992



3.5.5 Renewable energy sources

a) Solar: Botswana is endowed with excellent sunshine receiving 3000 - 3500 hours of sunshine per year and a mean annual insolation of about 2200 kWh/m^2 compared to European countries with 1000 kWh/m^2.

Monitored locations in Botswana receive about 20 MJ/m^2 per day on average ranging between 17.5 to 23.3 MJ/m^2 depending on latitude and season.

Based on installed solar water heaters (SWH), the installed solar capacity in Botswana is 10MW (BEMP, 1993) for SWHs with a net annual energy production of 30 GWh or 108TJ. PV systems for lighting and water pumping have a total installed capacity of 600 kWh (Table 3.14).

About 15000 SWHs are installed in Botswana with the BHC being the major consumer followed by Jwaneng Mine (2000 units).

Table 3.14 Solar installed Capacity in Botswana

Solar Devices	Installed capacity	Energy Production
Solar water heaters (10, 000 units)	10 MW	108 TJ or 30 GWh
PV Systems- Lighting and -Water Pumping (35 units)	600 kWh (40W- 10000W units)	

Passive solar architecture also offers potential in saving air conditioning and heating and designs have been tried with BHC and BTC houses which can eliminate use of air conditioners (pers. experience).

b) Wind

Wind energy have been exploited in Botswana during pre-independence times but at low volume. The sudden increase in oil prices in the early 1970's resulted in the recent interest in wind resources.

Wind speeds are generally low (< 3m/s) limiting the use of wind power for power generation. However some windpower has been installed especially in agricultural settings for pumping water from boreholes also reducing dependence on use of diesel powered pumps. RIIC (an NGO in Kanye) and Stewart and Lloyds have been the major suppliers of windmills in the country.

The Rural Industries Innovation Centre (RIIC) has been doing research on the use of wind energy mainly for water pumping. Wind speeds in the country have been recorded since the 1940's and wind-speeds varied for 2.4 m/s to 4.2 m/s as shown in Fig 5.1.5a. Areas with average wind-speeds in excess of 3.0 m/s, which is just sufficient for water pumping, are confined to the central and southern parts of the country with wind-speeds falling off to the north and in the areas along the South African border with Botswana.

RIIC began operating a pilot project in 1987. At present they provide technical support but manufacturing and installation of windmills is now limited due to low demand. Only about 5 windmills are installed at boreholes per year (RIIC pers. Comm.) although many more opportunities exist (over 200 boreholes/year). About 200-250 windmills have been installed in Botswana to date (Hodgkin et al., 1987).

c) Biogas

Biogas technology has recently been introduced in Botswana. After experimenting with Chinese and Indian biogas designs, the Indian biogas technology is widely used. The biogas facilities utilise animal waste which is often dispersed and poses problems of collection.

About 12 biogas plants have been installed for water pumping, lighting and cooking purpose in Botswana and evaluation by RIIC showed that 9 of them are operational each producing about 2-2.5 m^3

per day (22MJ/m^3). The technology is however not considered to be a strategic option for Botswana (BEMP, 1993).

Opportunities are available to use methane generated at urban landfills for household use especially in Gaborone and Francistown where sizeable dumps exist but this has not been adopted yet and will require upfront costs for gas reticulation.

d) Crop residues

The major crops grown in Botswana are sorghum, maize and millet and based on area planted with each crop and a average crop yield, the crop residue generated in the past are presented in Table 3.15

Table 3.15 Crop residue production 1980-1990 (1000 tonnes)

Crop	1980	1984	1987	1990
sorghum	456.4 (397.1)	171.9 (149.5)	398.65 (346.83)	534.45 (464.97)
maize	173.4 (150.9)	12.3 (10.7)	20.13 (17.51)	151.73 (132.01)
millet	43.6 (37.9)	25.3 (22.0)	16.76 (14.58)	27.43 (23.86)
Total	673.5 (585.9)	209.5 (182.2)	435.54 (378.92)	713.61 (620.84)

( ) Converted to tonnes of wood equivalent

Source: BEMP 1987 + own additions

Substitution of fuelwood by crop residues can allow sustainable supply of fuel but the crop residues are inferior as an energy source to fuelwood.

3.5.6 Draft Power

The proportions of draft power by the various animals and vehicles are presented in Table 3.16

Table 3.16 Proportions of daft power by source

TYPE	%
cattle	33.4
donkeys	17.4
tractors	39.3
others	10.0
TOTAL	100.0

Source: CSO, 1990- Agricultural statistics

It is clear from Table 3.16 that cattle, donkeys and others contribute over 60% of the draft power making a significant saving on diesel (tractor) consumption and hence avoided GHG emissions.

3.6 Energy demand

Botswana's energy consumption has been dominated by the domestic/household, transport and industry (including generated power) sectors. In 1990, the three sectors accounted for 96% of the total energy demand. The historical steadily increasing energy consumption pattern by sector is presented in Fig 3.8 and the 1990 sectoral consumption levels in Fig. 3.9. The 1990 fuel consumption by sector are shown in Fig. 3.10.

The total energy supply and demand by fuels and sector for the 1990 energy balance are presented in Table 3.17 and the total energy intensity of production are depicted in Fig 5.2d and 5.2e at 1985/86 constant prices.

Based on 1990 energy balance it is clear that the domestic sector is the dominant total energy consumer in Botswana accounting for over 51% of the total demand in 1990 (Fig. 3.9). The major energy carrier consumed in the household sector is fuelwood.

The energy- income elasticity has been increasing in the historical curve (Fig.3.11 and 3.12).

Fig 3.8 Energy supply/demand and sectoral distribution : 1982 - 1991

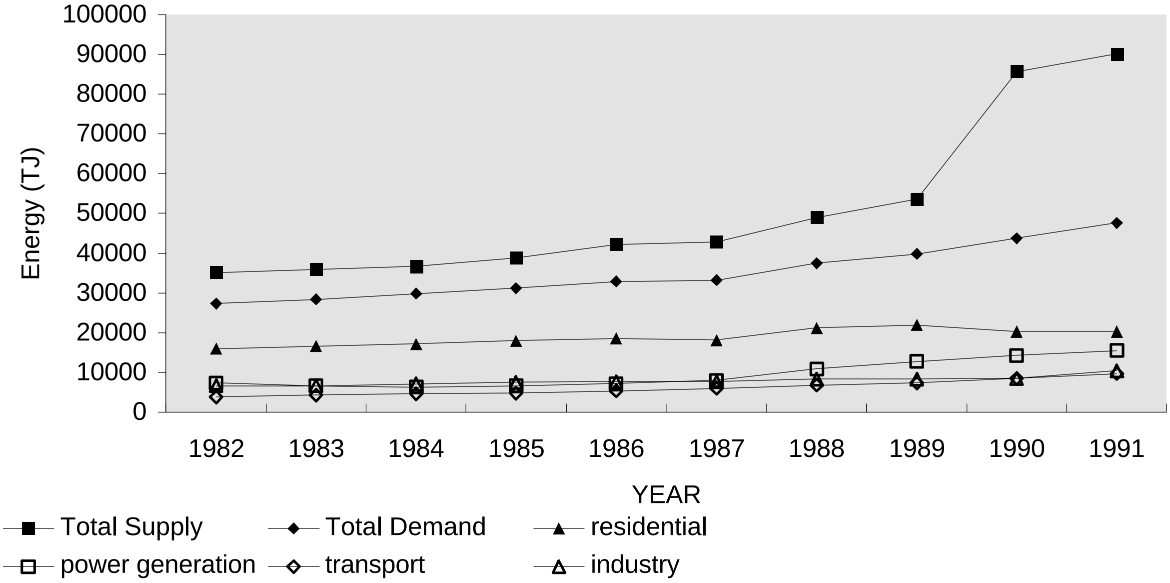


Fig 3.9 Sectoral energy consumption: 1990

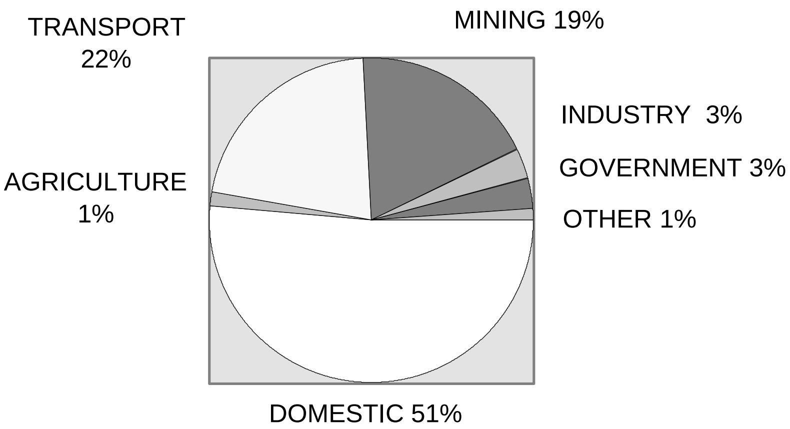


Fig 3.10 Fuel consumption by sector and type : 1990

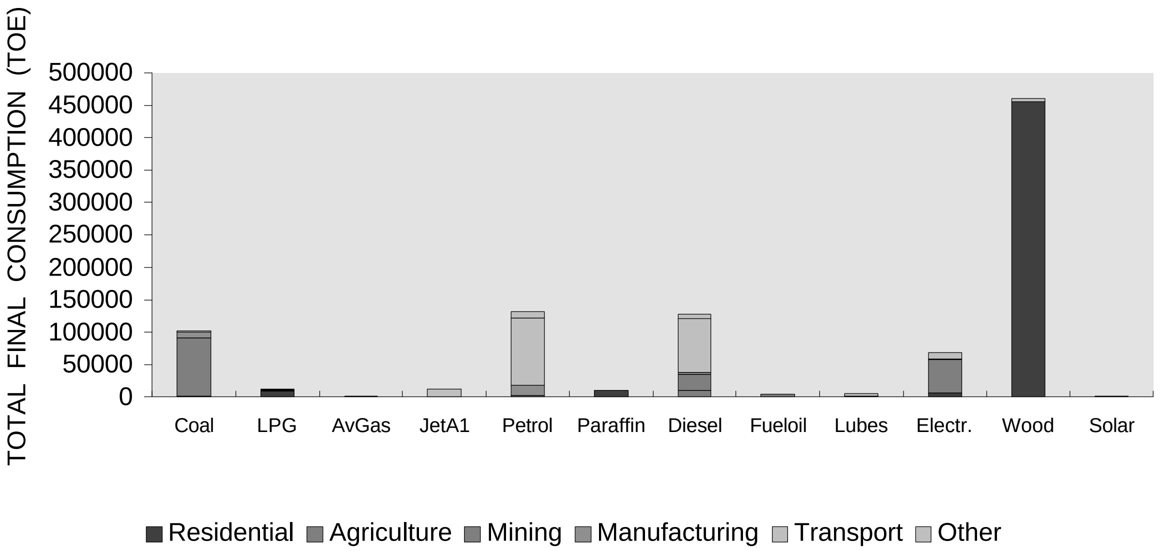


Fig 3.11 Comparative growth in GDP and energy demand: 1982 - 1992

Fig 3.12 Development of energy/GDP elasticity: 1982 - 1991

Table 3.17 Botswana National Energy Balance, 1990 (Terajoules; 1TJ = 23.866 TOE)

Fuel Conversion TJ/original units	Coal 24/kt	LPG 0.05/t	Avgas 0.03/kl	Jet A1 0.03/kl	Petrol 0.03/kl	Paraffin 0.04/kl	Diesel 0.04/kl	Fuel oil 0.04/kl	Lubes 0.04/kl	Electricity 3.6/gwh	Wood 16/kt	Solar 1	Other RE. 1	Total
1 Primary Production	19056										54116			73172
2 Imports	864	364	83	498	5534	423	5760	74	232	350		21	1	14205
3 Stocklifting	1740													1740
4 Exports														
5 Stockpiling														
6 Primary supply (1+2+3-4-5)	18180	364	83	498	5534	423	5760	74	232	350	54116	21	1	85638
7 Transformation Inputs (steam)	13848						387	73	12					14320
8 Transformation outputs										3513				3513
9 Consumption of transformation plants	360									398				398
10 Transmission and distribution losses										175				175
11 Net supply (6-7+8-9-10)	4332	364	83	498	5534	423	5373	1	220	3290	54116	21	1	74258
12 Statistical differences	40	-161				-23	0	-201	0	425	30348			30428
13 Final consumption	4292	525	83	498	5534	446	5373	203	220	2866	23768	21	1	43831
14 Non-energy consumption											4468			4468
15. Final energy consumption by sector	4292	525	83	498	5534	446	5373	203	220	2866	19300	21		39362
16 Residential	41	411				420				286	19087	19		20263
17 Urban	41	393				268				264	3772	19		4758
18 Rural		18				151				22	15315			15506
19 Agriculture					15		450		23				1	488
20 Industry	4155	48	1	15	734	2	1127	184	42	2162				8471
21 Trade and hotels	48	17								63	213	1		364
22 Transport			82	483	4330	22	3468		155	114				8518
23.Social and Pvt services		8								50				58
24 Government	48	41			456	3	328	18		304		1		1199

**source: BEMP (1991)-Energy Unit, MMRWA*

Fig. 3.11 Comparative development in GDP and energy demand 1981-1991

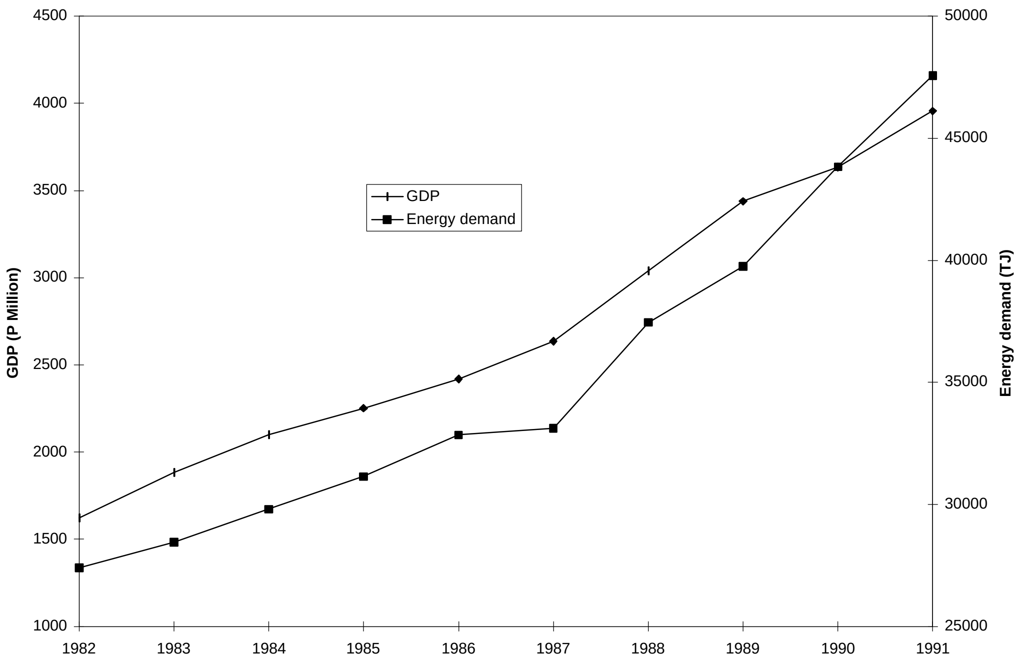
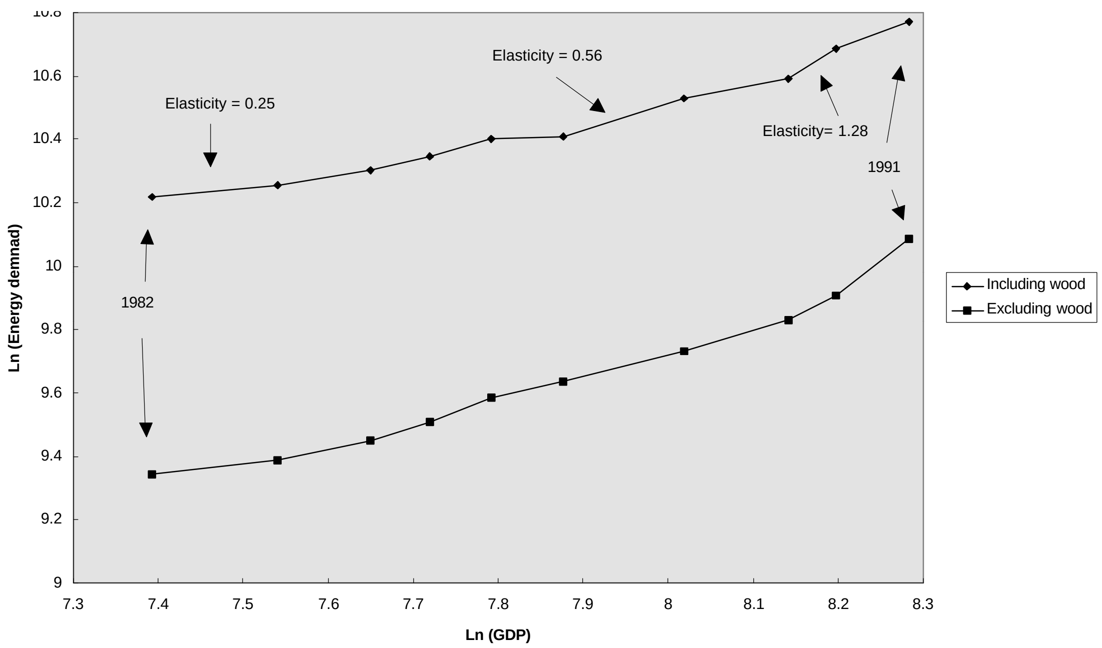


Fig 3.12 Energy-GDP elasticity.



3.6.1 Coal

Local coal consumption closely matches supply (refer to Fig 3.4) and is ever increasing. Fig 3.13 shows coal consumption by the different sectors of the economy in 1990. Coal contributes 15% in the final energy consumption. Coal in 1990 was is mainly consumed in power generation (76 %) and the rest in industry (23.6 %). There was insignificant coal consumption in the residential/domestic, government and transport sectors (<0.5%).

The main consumers are Morupule Power station which is located next to the mine, Selibe Phikwe Power Station, and Soda ash-plant in Sua Pan. Other consumers include meat processing, textile manufacturing, breweries, brick yard, government institutions and house holds.

Power generation largely depends on coal and total demand increased markedly in 1987 corresponding to the commissioning of the Morupule power station.

The mining sector is the second largest consumer of direct coal after power generation although there is a gentle decline in consumption after 1989, probably due to fluctuations in smelter activities corresponding to flating nickel/copper international prices.

It must be noted that of the 173649 TOE (7276 TJ) consumed in the mining sector, 52% of it was from coal and 28.9% is contributed as electricity also generated from coal. The importance of coal to Botswana is thus demonstrated by its significant contribution to the mining sector which is the mainstay of the economy.

As a result of promotion of coal under the Expanded Coal Utilisation Programme (ECUP, 1991) institutions and to a lesser extent households have taken up coal for various end-uses Table 3.18.

Fig.3.13 Coal consumption by sector:1990

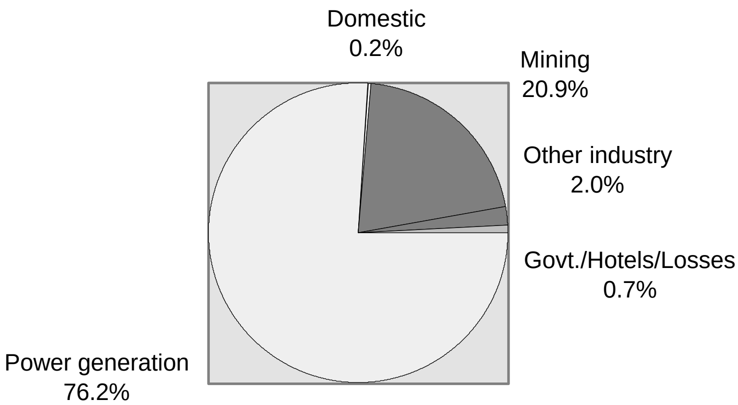


Table 3.18 Coal consumers under ECUP.

Consumer	No. of Consumers	End-use
Government Schools	37	Cooking
Hospitals	15	Steam and hot water
Vocational institutions	8	Steam and hot water
Households		Cooking/space heating

3.6.2 Electricity

The main consumer of electricity is the industry (78% of total) particularly the mining sector which consumed 73.3% (Table 3.19). The mining sector has been the largest consumer of electricity since before 1982 followed by the commercial and residential sectors. In the latter sectors electricity shares increased markedly after 1987 (Fig 3.14). The other mining activities consumed less than 1% of the available electricity. Demand in the residential and commercial/ government sectors is also on the increase. Between 1981 and 1992, electricity consumption increased by 65% in the residential sector, 52% in commercial and government. Table 3.19 shows the proportion of electricity consumption in the different sectors of Botswana in 1990.

Table 3.19 Electricity consumption by sector in Botswana 1990.

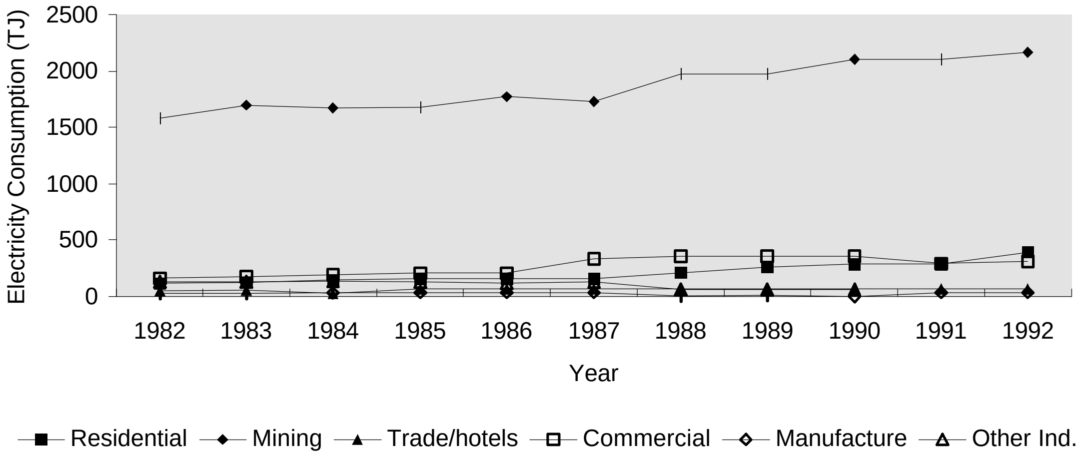
Sector	% Electricity Consumption
Mining (BCL Cu-Ni) (Diamonds)	73.3 (41.9) (31.4)
Government/Commerce	10.6
Other industry	2.1
Other	4.0
Residential	10.0 -Rural 0.8% -Urban 9.2%

Electricity tariffs are about the highest in the region. In 1988 Botswana's tariffs were about 10 times those of Zambia (Zieroth, 1990), 5 times that of the city of Harare (Zimbabwe) and nearly 3 times that of South Africa. Zambia and Zimbabwe have lower tariffs since they mainly depend on cheaper hydroelectric power which Botswana does not have. Botswana can also benefit from excess hydropower in the region through the regional power pooling.

Although South Africa depends on coal power stations, it's fuel costs and hence generation costs are lower than in Botswana and with economies of scale can afford to charge lower tariffs.

A government subsidy is necessary to encourage uptake of electricity as an energy source in the rural areas (Diphaha, 1991, Kgathi, 1992). A subsidy already exists in that government pays for extension of grid to rural villages and potential consumers only pay for connection fees (Energy Affairs, pers. comm.). To bring the electricity line to consumers' households, consumers pay 40% deposit and the rest is paid in ten years at just 8% interest rate compared a commercial interest rate of 15%. The government pays the other 60%.

Fig 3.14 Historical Electricity consumption by sector



3.6.3 Fuelwood

In Botswana, as in other countries in the region, consumption of woody biomass in form of fuelwood is predominant. Fuelwood is mainly used in the household sector and is supplied from indigenous wood stocks. Of the final energy consumption in 1990, 46% was contributed by wood. 96 % of the fuelwood energy was consumed by the residential sector with the rural sub-sector consuming 77.32% and urban sub-sector 19%. The remaining 3.7% consumed by Trade and Hotels sector.

A number of fuelwood survey studies conducted in the densely populated SE part of the country estimated the average annual fuelwood consumption per capita as in Table 3.20.

Table 3.20 Estimated per capita fuelwood consumption in S.E. Botswana

Source	Per Capita consumption
Jelenic and van Vegten (1981)	1.04- 3.10 kg/day (0.38- 1.13 tonnes/year)
ERL (1985)	1.40 kg/day (0.51 tonnes/year)
Kgathi 1993	0.3-1.1 kg/day
Zhou (1994)- ADB Project	1.46 kg/day (0.53 tonnes/year)

The consumption levels in the household, institutions and rural industries are shown in Table 3.21

Table 3.21 Fuelwood consumption in the domestic sector, institutions and rural industries.

Sector	Tonnes/yr.	TJ/year	TOE/year	% of sector requirements
Household -	139193	2227.0	53150	18.89
-Rural	375327	6005.2	143320	50.93
Institutions				
- Schools	142428	2278.9	54388	19.33
-Clinics	71757	1148.1	27401	9.73
Rural Industries- Bakeries	4200	67.2	1604	0.57
-Beer Brewing	4031	64.5	1539	0.55

Source: Kgathi, 1994; Sekhwela, 1994

On further analysis, the problem of wood scarcity can be attributed to the fact that the commodity is used for a variety of purposes and wood for other purposes is also harvested from the same woodlands where fuelwood supplies are derived from.

The annual total wood harvesting for various uses estimated by ERL (1985): Otsyina and Walker (1990) is shown in Table 3.22

Table 3.22 Wood uses in Botswana by quantity

Activity	Tonnes	TOE	Equ.area(ha)
Woodfuel	34000	12983	2152
Housing	34 00	1298	215
Cattle post fencing	170000	64915	10759
Bush fencing- fields	204000	77899	12911
Total	377000	157095	26037

Source: Otsyina and Walker, 1990

Note: The figure for fuelwood excludes the collected proportion.

Three companies also held licences to harvest timber in the Chobe Forest reserves and processed 12000 M^3 of tropical hardwood per year. About 65% of the harvested wood in the timber industry is wasted and can be utilised as fuelwood. Some of the offcuts were used for charcoal production which has now been discontinued by government for fear of exacerbating forest depletion. The left overs from timber processing were burnt contributing to air pollution and GHG emissions although the quantities released were small compared to the emissions from the total fuelwood consumption.

3.6.4 Petroleum Products

The trend for petroleum products consumption is shown in Fig 3.15 below. Consumption of petroleum products closely matches supply hence the supply pattern is responding to the demand satisfactorily.

Petroleum products excluding LPG contributed 32% of the total final energy consumption in 1990 and 96 % of this was consumed in the transport sector, particularly the road sub-sector. Consumption of petroleum products has been increasing at 9.6% annually due to increased activity in the road transport.

Sectoral consumption trends of each petroleum fuel are discussed in brief below.

a) LPG

LPG alone contributed about 1% of the final energy consumption and 78% of it was consumed in the residential sector. The urban sector consumed 96% of the LPG consumed in the residential sector.

The trend in LPG consumption is characterised by gradual growth from 1981-1986. (Fig. 3.16) during which period it constituted 0.3% of total energy demand (i.e. 1.7% of petroleum energy demand).

b) Aviation gasoline and Jet-fuel

Aviation fuels increased sharply after 1987 after construction of the Sir Seretse Khama airport thus traffic increased in the country (Fig 3.15).

The demand pattern for aviation fuels has experienced similar changes. Taken together, Aviation Gasoline (AvGas) and Jet Fuel (Jet A1) comprised 0.33% of total energy demand (2.1% of petroleum energy demand) in the period 1981-1984; gradually rising to 0.44%

(2.5% of petroleum) in 1985-1987 and sharply to 0.71% (4.2% of petroleum) thereafter.

Fig 3.15 clearly shows that the demand for jet fuel began to rapidly outstrip that for Avgas which continued to grow at a modest rate, averaging 12% p.a. while jet fuel averaged 22% p.a.

c) Petrol and Diesel

Consumption of Petrol and diesel has been increasing continuously (Fig 3.15).

The demand for petrol constitutes the largest demand of all petroleum energy (PE) demand -43% of total PE demand in 1990. At 14.3% of total fuel demand it is the third largest of all fuels consumed, after fuelwood and coal. Demand has grown at the average rate of 13.7% p.a. in the period 1981 - 1990. Diesel demand share is 41% of PE (12.9% of all sources) with growth rate 7.7 % p.a.

Diesel is mainly used in long distance haulers and trains for transportation of freight and passengers. The mining sector is the second largest consumer followed by the diesel power generation. Diesel is also used in electricity generation (6.5% of diesel energy supply) as a transformation input.

Further demand on diesel is created by mechanical energy demand for water pumping for village water supplies (where villages are not on the electricity grid) and for agriculture - especially livestock watering in the cattle posts.

Diesel is also used in industry (both manufacturing and construction) and mining to provide motive power to various types of machinery including drilling rigs, compactors, etc.

d) Paraffin

The domestic sector accounted for 94% of total paraffin energy demand in 1990, 64% of which was used in the urban sector. The Trade and Hotel sector demand is 4.9% of total paraffin demand. The remaining 1% is accounted for by the Government sector (0.6%) and Mining sector (0.4%). Demand has grown at an average rate of 13.6% p.a. between 1981 and 1990.

e) Fuel Oil

Consumption of fuel oil increased in the mining sector after 1988. The sector is the largest consumer (64%) of the fuel followed by power generation(29.6%) and government (6.4%).

Fig 3.15 The historical demand of some petroleum products: 1981-1992

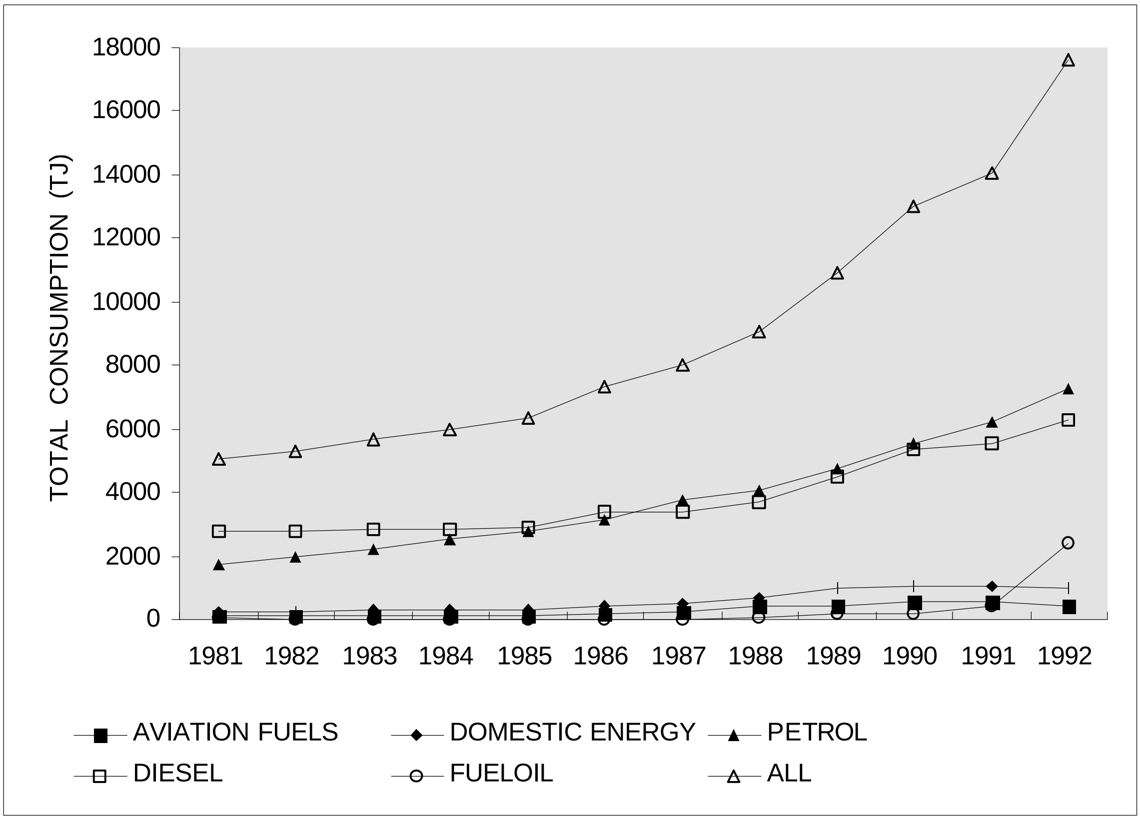
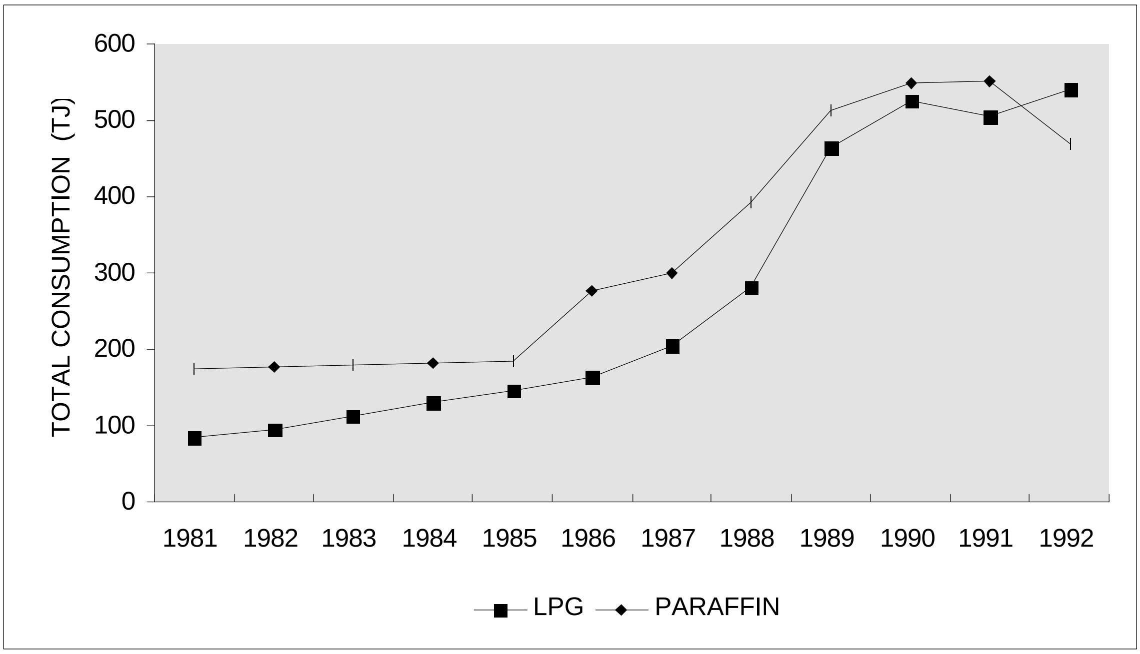


Fig 3.16 Historical demand of LPG and paraffin consumption: 1981 - 1992



3.6.5 Renewable Energy Sources

a) Solar

At present about 15000 solar water heaters are in use in Botswana. The BHC, a housing parastatal is the largest single operator followed by the mines (Mosimanyane, 1994). Government institutions such as clinics, hospitals and houses also use solar water heaters.

Projected demand in 2010 is estimated at 45455TJ but supply will fall short (only 51TJ). The annual solar supply/demand in 1990 was 21TJ and 90% of it was consumed in the urban household sector.

PV systems in Botswana are used for lighting, water pumping, refrigeration, communication and fence electrification. Botswana Telecommunications utilise large PV systems (10,000 W) to power its microwave stations. Households and smaller institutions can use 40W capacity for lighting. The Government institutions are the major beneficiaries of lighting and refrigeration PV systems. Some villages are also benefiting from government pilot projects e.g. Manyana village 40 km W of Gaborone.

35 PV water pumps are used by the Department of Water Affairs for water lifting in some villages. The PV water pumps can compete with diesel powered pumps but is not competitive in comparison with electricity.

Technology dissemination can benefit from government pilot projects and credit facilities if they become available but the stumbling block to uptake of PV systems is are the low conversion efficiencies (15%) and the high up-front costs.

b) Wind energy have been exploited in Botswana during pre-independence times but at low volume. The sudden increase in oil prices in the early 1970's resulted in the recent interest in wind resources.

There are about 250 wind turbines installed in Botswana for water lifting mainly in the farming areas of Ghantsi and Barolong Districts and Wild Life Areas. It is not known how many of the installed wind pumps are still in operation (Hodgkin et al., 1987).

c) Biogas

Biogas digesters installed for water pumping and lighting and cooking purposes are not yet making a significant contribution to sustainable energy supply in Botswana. The biogas digesters utilise animal waste which is often dispersed and poses problems of collection.

3.7 Energy Projections

The demand forecasts for each fuel are summarised in Table 3.23 for base case, low case and high case. The scenarios are based on the response of the major consumers in the future and the projections assume The Macroeconomic Model of Botswana (MEMBOT) which projected the rates of growth for each sector as in Table 3.24.

Table 3.23 Projected energy demand growth rates by sector and fuel

Fuel/source with sectors	Growth rate - base case %	Growth rate low demand %	growth rate-high demand scenario %
Coal -BPC	5	-15	5
-BCL	0	-20	1
-Soda Ash	0	0	2
-Others	7	2	10
Fuel oil -BPC	5	-15	5
-BCL	0	-20	1
-Diamonds	0	0	3
-Others	5	2	10
Aviation gas-Transport	6.8	3	8
-Industry	2.0	-10	5
Jet A1 -Transport	5	3	9
-Industry	2	0	5
Petrol -Transport	7	2	9
-Government	7	3	9
-Industry	2	0	5
Diesel -Transport	7	3	9
-Government	7	3	9
-Mining	2	-5	5
-Others	3	3	5
LPG- -Urban households	12	5	15
-Rural households	5	3	6
-Others	5	2	6
Paraffin-Urban households	8	5	12
-Rural households	5	3	6
-Others	4	2	6
Lubes -Transport	7	3	9
-Industry	2	-10	5
-Others	5	2	5
Wood -Urban households	1.0	-6	8
-Rural households	3.5	1	4
-Others	3.0	-10	6
Electricity -Households	5	3	7
-BCL	5	-20	5
-Government	5	5	7
-Diamonds	5	0	5
-Others	5	3	7
Solar -Urban households	6	2	12
-Rural households	4	1	12
-Others	4	1	12

Table 3.24 GDP annual growth rates by sector

Sector	Growth rate
Agriculture	1.9
Mining	1.4
manufacturing	6.9
Construction	-7.9
Trade and hotels	6.8
Transport	9.3
Social services	5.1
Government	13.8

The projections assume constant energy intensity of GDP for the base year and assume that initial figures for the reference year (1990 or 1991) are correct to ±10%.

The fuel consumption will be affected by growth rates in the major fuel consumers for the base, low and high scenario cases (BEMP, 1993).

3.8 Greenhouse gas (GHG) emissions from Botswana

Assessment of GHG emissions for Botswana was carried out for CO_2, CH_4 and N_2O gases. Emissions were estimated for sources in the energy sector but also included the other sectors of the economy closely following the IPCC sector definitions.

3.8.1 CO_2

Combustion of coal, petroleum and biomass, and deforestation are the major sources of CO_2 in Botswana. Emissions were calculated for both locally mined and imported coal. In the case of fossil fuels and biomass, CO_2 emissions depend on the carbon contents of the fuels and were calculated using the IPCC default emission coefficients.

CO_2 contribution from deforestation involve a lot of uncertainties regarding both emissions from decayed and combustion of removed wood, and 'sink ' losses hence the estimates need to be continually improved as new relevant information becomes available. There are no records on the rate of deforestation in Botswana and figures for CO_2 emissions were derived from a once-off project by Otysina and Walker (1990).

There is presently no cement production in Botswana but production will soon start at Palapye during NDP7 (BDC, pers Comm.). CO_2 emissions from this source will be included in the projected emissions.

Table 3.25 Emission-coefficients for the different GHG sources.

Fuel type	Kg CO_2/GJ	Kg CH_4/GJ	Kg N_2O/GJ
Coal (1tonne of coal=0.7 Toe)	95**	0.0062**	0.025**
Coke	108.2**	0.0965**	0.022**
Gasoline, Jet Fuel	73**	0.0965**	0.022**
Diesel	74**	0.0441**	0.026**
Paraffin	78**	0.0114**	0.022**
LPG (0.83 Toe)	65**	0.0441**	0.026**
Wood	0	0.15**	0.003**
Deforestation	10t/ha*** (7-18t/ha)		
Soil gases	3.92t/ha*		
Nitrate fertilizers			0.26% Weight/weight**
Landfills	-	25-75 kg/tonne	-
Enteric Fermentation:		Pr animal	
Cattle		55kg/yr	
Sheep		11kg/yr	
Goats		11kg/yr	
Pigs		0.8kg/yr	
Horses/donkeys		19kg/yr	
Animal Waste		Kg/Pr kg waste	
Cattle		0.081	
Sheep		0.13	
Goats		0.13	
Pigs		0.29	
Chicken/ducks		0.187	
Horses/donkeys		0.26	

*source: * Fearnside 1992*

*** OECD/Danish Budget for Greenhouse Gases 1990*

****Foley 1991; Subak et al. 1992*

3.8.2 CH_4

CH_4 emissions were derived for ruminant animals, fossil fuel extraction (i.e. coal mining), distribution and combustion, and wood combustion.

Botswana has a major beef industry. CH_4 emissions were calculated for domesticated ruminant animals in the country namely beef cattle, goats and sheep, using coefficients (OECD/UNEP Guidelines 1990) in Table 3.25 The CH_4 emissions were derived for both enteric fermentation and animal waste.

3.8.3 N_2O

A large % of NO_2 emissions are known to arise mainly from fertilizer application. The other sources are fossil combustion (IPCC, 1991) and biomass burning (Subak et al, 1992).

The GHG inventory for Botswana was derived for the base year 1990 in compliance with the IPCC guidelines (see Table 3.26).

3.8.4 Summary of GHG emissions

Comparative emissions of CO_2, CH_4 and N_2O for the energy sector and other various sources in Botswana for base year 1990 are presented in Table 3.26. The per capita emissions are based upon an estimated population in 1990 of 1.271 million . The emission density calculated with an area of 581730 km^2 . The emission per unit of GDP is based upon a GDP of 3633.6 million Pula.

Table 3.26 GHG emissions for various sources in different sectors of Botswana-for Base year 1990

1000 tonnes	CO_2	CH_4	NO_2	CO_2 Equivalent
Coal combustion	1689	0.114	0.459	1814
Coal mining-Fugitive emissions		10.641		117
Petroleum products-combustion	1028	0.895	0.336	1129
Wood-fuel-combustion		3.467	0.058	54
Deforestation, cutting and burning	1522	3.034	0.061	1572
Ruminant animals (enteric and animal waste)		528.609		5815
Nitrate fertilizer			0.023	6
Soils	2			2
Landfill		1.460		16
Total(all considered sources)	4241	548.220	0.937	10525
Total energy sources Total fossil fuels	2717 2717	15.117 11.650	0.853 0.795	3114 3060
Per Capita emissions -all sources -fossil fuels	 3.3 2.1	 0.43 0.009	 0.0007 0.00059	 8.0 2.2
Emission density ($Tonnes/KM^2$)- all sources -Fossil fuels	7.3 4.7	0.94 0.02	0.0015 0.0013	18.0 4.9
Tonnes emissions/GDP-P1000 -all sources -fossil fuels Note: 85/86 constant prices	1.17 0.75	0.15 0.003	0.00025 0.00022	2.8 0.8

(22) % of total; * Fearnside (1992) estimates used.** this figure is an underestimate as it does not include wild animals, it however includes goats etc.

*** Gaborone Figure only: 10-25M^3 CH_4 per coal tonne mined, 0.9- 4.0 M^3 CH_4 post mining-coal-tonne; 670 tonnes/$10^{6\ m}3$ of methane- IPCC default values

In Table 3.27 the total and per capita CO_2 emissions are compared for selected countries from the region and industrialised region.

Table 3.27 Compared total and per capita annual CO_2 emissions for selected countries-1990

Country	Size of country (km^2)	Population (million)	Total CO_2 emissions (million tonnes)	Emission density (tonnes/Km^2)	Per Capita CO_2 emissions (tonnes)	Remarks
Botswana	581764	1.3	2.7	4.6	2.0	for energy sector only
Zimbabwe	390000	10.4	16.3	41.8	1.6	for energy sector only
Senegal	196200	6.9	14.5	73.9	2.1	might include other sources apart from energy
Brazil	-	144.0	680.0	-	1.9 [4.7]	[4.7] includes deforestation
Denmark	43093	5.2	56.2	1304.2	11.0	large because its an industrialised country

3.8.5 Sectoral GHG Analysis

Contributions of CO2 by the different sectors in Botswana are presented in Table 3.28

Table 3.28 Sectoral CO_2 emissions by fossil fuels in 1990 (1000 tonnes)

Sector	Coal	Petroleum	Total
Residential	3.8	59.5	63.2
Transport		625.4	625.4
Power generation	1274.0	34.5	1308.6
Mining	349.1	101.6	450.7
Manufacturing	20.3	49.7	70.0
Other Industries	33.1	56.4	89.5
Commercial	4.4	62.3	66.7
Trade and Hotels	4.4	2.8	7.2
Agriculture		36.1	36.1
Total	1685.3	1028.3	2713.6

In the energy sector power generation is the largest CO_2 emitter largely by coal combustion. The transport sector only consumes petroleum products and is the next largest CO_2 emitter.

There is general increase in CO_2 emissions in all sectors since 1981 except in mining and other sectors where there has been declines between 1986 and 1990 (Table 3.29).

Table 3.29 Historical sectoral CO_2 emissions 1981,1986 and 1990 (1000 tonnes)

Sector	1981	1986	1991
Power generation	66.6	668.7	1308.6
Transportation	224.3	349.8	625.4
Residential/Domestic*	13.3	30.1	63.2
Mining	404.6	454.4	450.7
Other	58.0	307.7	256.8

**Coal, LPG and paraffin contribution*

Contribution by anthropogenic activity for CO_2, CH_4 and N_2O emissions and their CO_2 equivalents are presented in Table 3.30. Energy and deforestation are the major sources(≈ 100%) of CO_2 and agriculture, in form of animal husbandry contributes about 60% of methane (CH_4) share in Botswana. The N_2O emissions in Botswana are mainly produced during burning of fossil fuels (coal and petroleum products). Based on the IPCC, 1992 global warming coefficients for the three gases, agriculture becomes the dominant GHG emitter followed by the energy sector and deforestation in decreasing order (Table 3.30)

Table 3.30 Percentage GHG contribution by anthropogenic activity in Botswana, 1990.

Sector %	CO_2	CH_4	N_2O	CO_2 equivalent
Energy	64.1	2.7	91	30
Deforestation	35.9	0.6	6.5	15
Agriculture	0	96.4	2.5	55
Other	0	0.3	0	0
Total	100	100	100	100

** x 11 for CH_4 to CO_2*

x 270 for N_2O to CO_2

3.9 Opportunities for GHG mitigation

3.9.1 General case

General GHG mitigation options either short term or long term can be derived in accordance with IPCC recommendations.

a) improved energy efficiency to cut CO_2 emissions

b) utilisation of cleaner/low carbon energy resources and technologies as a measure to cut CO_2 emissions.

c) improved forest management to improve CO_2 sinks and reduce loss of these sinks by deforestation.

d) improved livestock waste management (CH_4 reduction), altered use and formulation of fertilizers (reduce N_2O emissions) and other changes of agricultural land use while maintaining food security.

The long term GHG options will depend on future R & D to produce new technologies. The behavioural tendencies normally take longer to change. New options will also emerge as a result of continued monitoring of the global change.

In the energy sector, currently the single biggest sources of anthropogenic GHGs with the greatest opportunities for GHG mitigation are:-

a) application of efficient technologies in the energy sector (at energy supply and end-use levels).

b) substituting fossil fuels with free/low CO_2 like new and renewable energies (solar, wind, nuclear, hydro, biomass). Use of low carbon fuels like natural gas can be used to replace high carbon fuels like coal and petroleum.

c) energy conservation measures like reduction of leaks from steam pipes and switching/quenching off lights/fires/electric machinery when not in use.

d) controlling transport related-emissions

The policy strategy for choosing what options to implement first should be guided by:

a) large GHG reduction per unit cost i.e. achieving GHG reduction at lowest cost.

b) those with maximum economic benefit as a result of GHG reduction should be chosen first.

c) options that reduce more than one GHG should also be given priority

d) in choosing these options policy makers should also consider broader interests than they are designed for i.e. economic efficiency and GHG reduction. Policies should also address issues of equity, national security, public acceptability (e.g. the case for nuclear power) and ancillary environmental benefits like reduction of pollution in general. On the technological aspects, policies should encourage technology transfer and adoption, R & D and innovation in environmentally-clean technologies.

3.9.2 GHG Mitigation options for Botswana

In this study the sector targeted for GHG mitigation is the energy sector. The significance of the energy sector as a GHG emitting sector has been adequately demonstrated in the previous discussions. The abatement options selected in this study are intended to reduce CO_2 with any reduction in CH_4 and N_2O achieved in the process taken as bonus.

Options for GHG mitigation and costing should therefore target energy sub-sectors causing the largest emissions namely power generation, transport and the residential sector. The selection of abatement options should also be based on the principle of least-cost and feasibility of implementation. Greatest opportunities for least cost CO_2 reduction options are in energy efficiency improvements at both supply and end-use levels. Protecting or replacing the forests is also important to preserve CO_2 sinks.

The residential sector should focus particularly on the rural sector to address the problem of CO_2 emissions by deforestation and fuelwood burning. Proposed abatement options for Botswana are presented in Table 3.31 Implementation of these options will require the necessary policies and institutional framework. Implementing and affected institutions are included in Table 3.31.

Table 3.31 Abatement options based on the sector fuel matrix (For the institution see list of Abbreviations and acronyms, below).

Sector	Coal	Petroleum	Wood	Electricity	Solar	Wind	Biogas
Household - Rural			woodstoves [EAD;BTC]		PV for lighting [EAD]		cooking with biogas [RIIC]
Household-Urban		Shift from fuelwood to LPG [MCI]		Prepaid meters[BPC] Geyser timer BHC] CFLs for lighting [BHC]	Solar water heaters [BHC]		Landfill gas-reticulation [GCC]
Power Generation	Increase Boiler efficiency [BPC]	Improve coal ignitability e.g. by coal beneficiation to reduce fuel oil consumption [BTC],[BPC] Connect to grid or use PV for remote areas [BPC];[EAD]		Use power imports for base load [BPC] Power factor correction [BPC]	Long term Centralised solar PVs [BPC ;MMRWA]		
Transport	-	Road improvement & maintenance [MWTC] Urban planning-remove road cul de sac and proper road planning [MWTC];[GCC] Increase urban rail transport[BR; BPC] Improve truck efficiency [Freight transport] Shift to rail freight [BR]		Electrify rail system [BPC;BR]			
Mining	Improve furnace efficiency [BCL]	Improve coal ignitability to save on fuel oil [BTC],[BPC]		Improve motor efficiency [Heavy Industry]			
Manufacture	Improve boiler efficiency [Large industry-[BMC; KB;BB]			Improve motor efficiency [Heavy Industry- e.g. [BCL; Debswana]			
Construction					Passive solar design in urban houses [DABS, BHC;BTC]		
Commerce		Proper planning of trips [CTO]		CFLs for lighting [Govt.;hotels] *Energy management systems [Govt.;hotels]			
Agriculture	-	-	Reaffore-station [MoA;FAB..]	Use electricity [BPC] [DWA]	PV solar water pumping [EAD; DWA]	Wind-mills for water pumping [DWA; RIIC]	Substitute diesel with biogas. [DWA;RIIC]

3.10 Abbreviations and acronyms

ADB - African Development bank

AFREPREN- African Policy Research Network

BCL - Bamangwato Consolidated Limited

BDC - Botswana Development Corporation

BEMP - Botswana Energy Master Plan

BHC - Botswana Housing Corporation

BMC - Botswana Meat Commission

BPC - Botswana Power Corporation

BR - Botswana Railways

BRET - Botswana Renewable Energy Technology (project)

BTC - Botswana Technology Centre

BTEL - Botswana Telecommunications

CC - Climate Change

CFL - Compact Fluorescent lamp

CGCM - Coupled General Circulation Models

CSIR - Council of Scientific and Industrial Research- South Africa

CSO - Central Statistical Office

CTO - Central Transport Organisation - Botswana

DEMS- Department of Electrical and Mechanical Services (MWTC)

DABS- Department of Architectural and Building Services MWTC)

DoM - Department of Mines (MMRWA)

DWA - Department of Water Affairs

EAD - Energy Affairs Division (MMRWA)

ECUP - Expanded coal utilisation Project

EIA - Environmental Impact Assessment

ERL - Energy Resources LTD

ESKOM- Electricity Supply Commission of South Africa

ESMAP- Energy Sector Management Assistance Programme (world bank)

ETC -Energy Technical Consultants? Foundation

FAB - Forestry Association of Botswana

GDP - Gross domestic Product

GHG - Greenhouse gases

GNP - Gross National Product

GTZ - German Aid Organisation

Govt - government

GW - Global Warming

HH - Household

ICSU - International Council of Scientific Union
IPCC - Intergovernmental Panel on Climate Change
kWh - Kilowatt- hour
LDV _ Light Duty vehicle
LPG - Liquid Petroleum Gas
MCI - Ministry of Commerce and Industry
MLGL - Ministry of Local Government and Lands
MoA - Ministry of Agriculture
MMRWA- Ministry of Mineral Resources and Water Affairs
MWTC - Ministry of Works, Transport and Communications
NCS - National Conservation Strategy
NDP7 - National Development Plan no.7
NIR - National Institute of Research Development and documentation
NRSE - New and Renewable Sources of Energy
NWRM - Natural Wood Resources management
OECD - Organisation of Economic Cooperation and Development
ODS - Ozone Depleting Substances
P - Pula
Pvt - Private
RETS - Renewable Energy Technologies
RIIC - Rural Industries Innovation Centre
SACU - South African Customs Union
SADC - Southern African Development community (formerly SADCC)
SWH - Solar Water Heaters
TGLP - Tribal Grazing Land Project
UNDP - United Nations Development programme
UNEP -United Nations Environmental Programme
UNESCO- United Nations Educational, Scientific, Cultural Organisation
UNFCCC -United Nations Framework Convention on Climate Change
WCP - World Climate Programme
WMO - World Meteorological Organisation

3.11 Calorific value of fuels

Power station coal	24.00 GJ/ tonne
Industrial coal	29.30 GJ/tonne
Diesel	35.52 GJ/kl
Gasoline	31.74 GJ/kl
LPG	46.40 GJ/kl
Paraffin	34.34 GJ/kl

Jet A1	34.34 GJ/kl
Aviation Gas	31.03 GJ/kl
Firewood	16.30 GJ/tonne
Charcoal	30.00 GJ/tonne

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3.13 Maps of Botswana

Fig. 3.16 General Map of Botswana

Fig. 3.17 Rainfall map of Botswana

Fig. 3.18 Transport routes of Botswana

4. Tanzania report

4.1 Country description

4.1.1 Physical features

Tanzania's location is in Eastern Africa between the longitudes 29^0 East and 41^0 East, Latitudes 1^0 and 12^0 South. Its land frontiers are as follows: In the north are Kenya and Uganda; to the west are Burundi, Rwanda and Zaire. Southern frontiers are Zambia, Malawi and Mozambique and to the east is the Indian Ocean.

The total area of Tanzania territory is 945,234 km^2 distributed as follows: -Tanzania Mainland has 881,289 km^2 , Zanzibar 2450 km^2 and the waters bodies have 61,495 km^2 . The major water bodies are:

Lake Victoria 34850 km^2 , Lake Nyasa 13350 km^2 , Lake Rukwa 2850 km^2 and Lake Eyasi 1050 km^2. The arable land is 3,634,000 hectares.

Tanzania's climate is of mainly two rainy seasons. The main occurrence is in March to May while the other one is in October to December. Generally, there is a well-distributed rainfall throughout the year. Peak occurrence is in March to May.

4.1.2 Demographic information

In 1990 Tanzania had an estimated population of 24,347,000 people (see table 4.1). In 1967 the country had an estimated population of 12,314,000 people. The annual population growth estimate is 2.8 percent (1978-1988 estimates). Historically development has been associated with urbanisation of society. In Tanzania for example proportion of the population in rural area has been decreasing over time. Before independence the proportion was 97%. It decreased to 95% in 1965, 85% in 1978 and 75% in 1988. It is in anticipation that this proportion will decrease further by the year 2000.

The spectacular growth of urbanisation has been partly due to rural-urban migration. Tanzania's urban population as a percent of total population was 7% in 1970 compared to 34% in 1991. The average growth rate of urban population has declined from 12.7% between 1970 and 1980, to 10.1% between 1980 and 1991. However, population of the urban areas has increased significantly. For example, in 1991 Tanzania cities of more than one million people had population 6% of the total. This is higher than population 2% of the total population in 1965. The projected urban growth in Tanzania can be seen in table 4.17.

Dar es Salaam city population increased significantly over time. In 1967 its population was 250,000 which increased, reaching nearly one million in 1978. For Dar es salaam the population as a percent of total population was 7% in 1990. The current population estimates of Dar es Salaam is above 2 million people.

Table 4.1 Tanzania population estimates 1967-1992 (1000 inhabitants)

Place/Year	1967	1978	1988	1990	1992
Mainland	11959	17036	22486	23670	25151
Zanzibar	355	476	641	677	722
Total Population	12314	17512	23126	24347	25873
Pop.Density/km^2	14	20	26	28	29

Source: Bureau of Statistics

4.2 Economic development and planning

Economic data for Tanzania are from the economic surveys and the planning commission of the President's office.

4.2.1 Tanzania national planning system

Tanzania introduced the Rolling Plan and Forward Budget (RPFB) planning system in 1993/94 financial year. This system aims at improving the government planning and budget system, through the introduction of the following aspects:

- strengthen links between planning and budgeting,
- set effective framework for medium term planning (3 years),
- introduce improved forecasting of macroeconomic variables,
- reinforce the link between macro and sectoral policy,
- strengthen the link between policy and allocation of funds,
- improve recurrent expenditure planning,
- reduce the number of development projects through setting of priorities,
- ensure that all foreign funds are recorded in the government budget, and
- introduce a degree of flexibility in project implementation.

The RPFB which has replaced the Five Year Plan and Annual Plan also aims at:

- providing an overview of development of the general economy in relation to each sector,
- enabling the government to decide more precisely on its development objectives for the economy as a whole and for each sector and
- provide a means of allocating limited funds to those activities, which are more effective in achieving government development objectives.

4.2.2 Tanzania economic performance

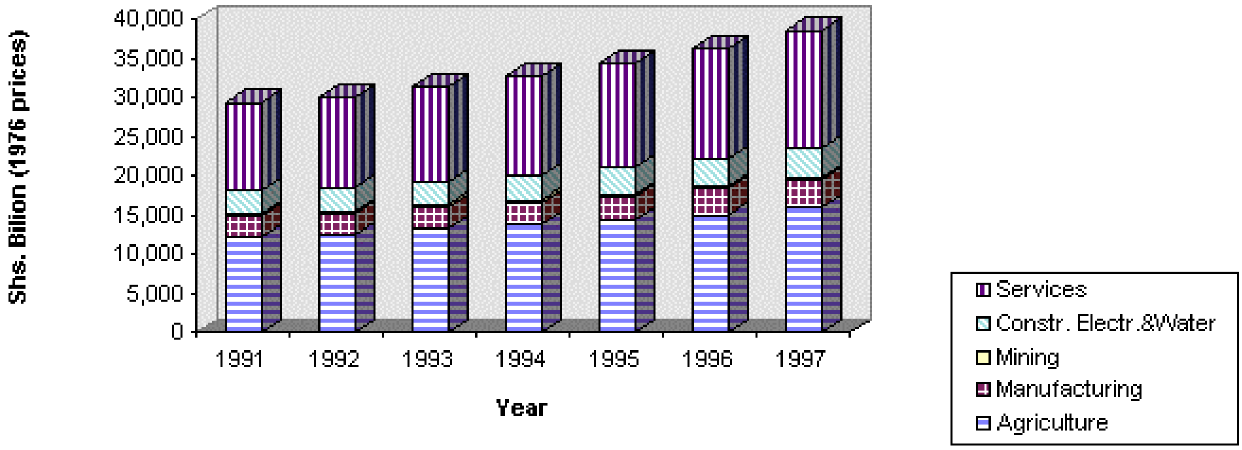
The historical performance of the Tanzania economy from 1976 to 1992 is in three phases.

The first phase is the period between 1976 and 1980. In this phase the average rates of growth rose from 0.4 percent in 1977 reaching 2.92 in 1980. During this period the **agricultural sector** accounted for 40.8 percent of the total GDP on average. The **Manufacturing sector** on the other hand did at best accounting for 12.2 percent of the total GDP on average at constant prices.

The second phase is the period between 1981 and 1983 where the average annual growth rate was the lowest at 2.38 percent in 1983.

The third phase is the period between 1983 and 1992 during which the performance in the economy was somehow better than the previous phases. This period registered the highest average annual growth rate of 5.09 percent in 1987, the lowest growth rate being 2.63% in 1985. Furthermore, from 1986 to 1992 the annual growth rate has been above the population growth rate of 2.8 percent. In this period the **agricultural sector** accounted for 46.1 percent of the total GDP on average at constant prices. **The manufacturing sector** on the other hand accounted for 8.2 percent of the total GDP on the average at constant prices.

Fig. 4.1 GDP growth trends by sector in 1976 prices (Tshs million)



Note: The present exchange rate is 1US$ = 600 Tshs

Table 4.2 GDP growth trends by sector in 1976 prices (Tshs million)

Sector	Actual			Projected			
	1991	1992	1993	1994	1995	1996	1997
Agriculture	12,150	12,418	13,328	13,691	14,256	14,991	15,855
Manufacturing	2,607	2,663	2,719	2,874	3,061	3,273	3,516
Mining	317	366	296	322	357	397	446
Constr. Electr.&Water	3,018	3,060	2,930	3,150	3,316	3,517	3,750
Services	11,241	11,599	12,061	12,668	13,289	14,072	14,975
Total GDP	29,333	30,106	31,334	32,707	34,279	36,250	38,543

Source: Planning Commission

Investment at constant prices has more or less followed the same trend as GDP. It showed an increasing trend in the period 1976 to 1979 and declining trend in 1980 reaching lowest level in 1980 and thereafter started to increase.

The gap between exports and imports has been widening from shillings 544 million in 1976 to shillings 211707 million in 1991. This resulted from increasing value of imports accompanied with declining value of exports over the period.

Economic activities can influence the emission levels of a country in a great deal. Sectoral contribution toward the economic development has an implication on the greenhouse gas emission levels.

4.3 Climate change studies in Tanzania

4.3.1 Source and sinks of greenhouse gases in Tanzania

In order to assist the Government meet its obligations under the UNFCCC, the Centre for Energy, Environment , Science and Technology has been commissioned to undertake a study on greenhouse gases sources and sinks in Tanzania. The main purpose of the study is to identify and quantify anthropogenic sources of atmospheric emissions of greenhouse gases in the country. In particular, the study aims at increasing the quantity and quality of base-line data available in order to further scientific understanding of the relationship of greenhouse gas emission to climate change. Furthermore, the study aims at the identification of nations policy and technological options that could reduce the level of emissions in the country. The study is being funded by the Global Environment Facility (GEF) through the United National Environment Programme (UNEP), and the International Development Research Centre (IDRC) through its assistance to CEEST for a comparative study of greenhouse gas emissions of Tanzania and Zimbabwe. Presented below is a summary of preliminary results of the emissions of greenhouse gases in Tanzania.

4.3.2 Preliminary results of the sources and sinks of GHG study

A preliminary study has been carried out to determine sources and sinks of greenhouse gases in Tanzania. Results obtained in the study of sources and sinks of gases are based mainly on default emission factors. There is need for more research to establish country specific emission factors especially in agriculture, livestock and land-use sectors.

Table 4.3 shows the GHG emissions from various sources in Tanzania. The emissions from land use changes and forestry are still under preparation, but preliminary result show that this sector is a net emitter of CO_2 .

Table 4.3 Summary of greenhouse gas emissions and removals 1990 (Gg=Mt)

Sources and Sinks	CO_2	CH_4	CO	N_2O	NOx
WASTE MANAGEMENT					
Solid waste management	47.60	24.46			
Municipal waste water management		2.20			
Industrial waste Water management		19.75			
Total	47.60	46.42	0.00	0.00	0.00
ENERGY INDUSTRY AND TRANSPORT					
Natural Gases	0.34				
Coal	0.12	1.68			
Thermal Power Generation	73.12	5.28	645.90	1.80	880.90
Traditional Biomass Fuel		266.98	3358.80	2.33	38.83
Cottage Industry		0.02	13.24		0.36
Stationary Combustion in Industry Sector	1158.41	0.02	6.32		2.72
Mobile Combustion in Transport Sector	1424.17	0.41	47.71	0.03	14.41
Total	2566.00	274.39	4072.0	4.16	937.22
AGRICULTURE AND LIVESTOCK		95.85			
Rice Cultivation					
Agricultural Crop Residue Burning		297.09	953.16	0.57	13.50
Nitrogenous Fertilizer Uses				0.12	
Enteric Fermentation		488.05			
Domestic Animal Wastes		26.17			
Total		907.16	953.16	0.69	13.5
LAND USE AND FORESTRY	**				
Forest Clearing for Permanent Agricultural Land		9.32	81.56	0.06	1.51
Grassland Conversion for Agricultural Land	**				
Abandoned Managed Land	**				
Accessible Natural Forests	**				
Shifting Cultivation	**	2.68	23.42	0.02	0.43
Man-made Flooded Lands		0.04			
Savannah Burning		63.00	1662.00	2.00	21.00
Total	**	75.04	1766.90	2.08	22.94
INDUSTRIAL PROCESSES					
Cement Production	343.83				
Pulp and Paper Production	5.79				
Total	349.62	0	0	0	0
Grand Total	97961.00	1734.00	6792.10	6.93	973.66

Note: Blank means not applicable

** Data under preparation

4.3.3 The country study on GHG mitigation in Tanzania

The Centre for Energy, Environment, Science and Technology is currently undertaking a mitigation costing study, which is being done with the assistance of the GTZ and the UNEP Collaborating Centre on Energy and Environment at Risø. The preliminary results of the study consist of the following mitigation options for Tanzania:-

Table 4.4 Mitigation options analysed in the study

Sector	Option	Description
Energy Supply	Advanced electricity generation technologies	Installation of 230 Mw of combined cycle power plants instead of simple cycle gas turbines
	Efficiency Improvements	Increase the efficiency of existing power generation systems by repowering and improvements in transmission and distribution systems
	Charcoal production	Improve the conversion efficiency of charcoal kilns
	Coal mining	Optimise the methane release from coal mines
	Renewable technologies	Development of renewable energy technologies: solar energy, photovoltaics, wind turbines, biomass, geothermal.
Industry	1. Cement Production	
	Production management	Installation of automatic control system for reducing the amount of fuel used and improving production efficiency
	CO2 recover system	Installation of CO2 recovery system. Recovered CO2 can be used for other industrial applications
	Fuel switching	Substitution of fuel oil by natural gas in two production plants
	Production mix	Production of blended cements such as pozzolanic cements, blast furnace slag cement and Portland cements in order to reduce the amount of fuel used for calcination and the amount of lime per unit of cement produced
	2. Pulp and Paper	
	Efficiency improvements	Optimisation of the recovery boiler in order to reduce both the amount of lime and energy use
	Recovery of CO2	Recovery of CO2 from calcination by absorption of CO2
	3. Other Industries	
	Energy efficiency improvements	Energy efficiency improvements in existing plants which includes maintenance, improved steam production and management, cogeneration, motor drive system improvements

Table 4.4 Mitigation options analysed in the study (cont.)

Sector	Option	Description
Transport	Vehicle efficiency	Improvements of vehicle technical efficiency
	Improve system efficiency	Improvements in traffic flow, increase vehicle load factor, improve vehicle maintenance, traffic operation, training and management
	Modal split	Rehabilitation and further development of rail system
	Urban transport	Implementation of city train in Dar es Salaam
Household and Service Sector	Electrical appliances	Efficiency improvements on electrical appliances
	Cookstoves	Increase energy efficiency of biomass use in cookstoves
	Waste management	Waste management including landfills and waste water treatment
Agriculture and Livestock	Agricultural practices	Reduction of methane and carbon emissions through better practices related to fertilizer application, rice cultivation, an loss of soil organic carbon from cultivated soils
	Livestock husbandry	Better livestock husbandry including better breeding and feeding practices
Land Use and Forestry Sector	Forest management	Forest management includes: i) maintaining the existing stocks through forest protection and conservation; and ii) expanding carbon sinks by means of afforestation, reforestation, enhanced regeneration and agroforestry practices
	Grasslands and rangelands	Grasslands and rangelands options are focused on maintaining or increasing carbon sequestration through better soil management, and sustainable agricultural practices

4.4 The analysis of energy demand and supply

Energy is the determinant of the level of development of a country. for most underdeveloped countries, biomass fuels play the dominant role in the energy balance sheet. On contrary, commercial energy sources dominate the energy balance sheet of developed countries. For Tanzania, Woodfuel account for the bulk of the energy used in the economy. Commercial energy sources are mainly petroleum, electricity and to a lesser extent coal. Historical per capita consumption of woodfuel has been estimated to be about 0.35 TOE. The structure of energy supply and energy consumption in 1990 is shown in the energy balance depicted in table 4.5.

Table 4.5 1990 Energy Balance (TJ)

Commodity	Coal	Crude	Fuel oil	Diesel	Kero-sene	Gaso-line.	Electricity	Sub-total	Wood	Char-coal.	Bio-mass	Total
Production	178						5134	5312	444600		43219	49313
Imports	644	26531	596	11274	5986	909		45940				45940
Exports			-5263					-5263				-5263
Stock change												
Total supply	822	26531	-4667	11274	5986	909	5134	45989	444600		43219	53380
Oil refineries		-26531	11485	5927	2631	4356		-2132				-2132
Power plants				-1735			755	-980				-980
Coke ovens												
Kilns									-52896	11519		-41377
Losses	44		322	309	190	210	1197	2272				2272
Total net supply	818	0	6496	15157	8428	5055	4695	40649	391704	11519	43219	48709
Omissions												
Final	818		6496	15157	8428	5055	4695	40649	391699	11519	43219	48708
Agriculture			2077	1547	60		218	3902	6143		8699	18744
Industry	461		3980	4238	227	176	1190	10272	49635			59907
Transport			427	8104	634	4876		14041				14041
Other			12	1268	61		1973	3314	18120			21434
Household					7446		1315	8761	317801	11519	34520	37260

Fig.4.2 shows the structure of energy consumption by sectors. Note the predominant role played by biomass and petroleum products fuels in the Tanzanian economy.

Fig. 4.2 Structure of energy consumption by fuels

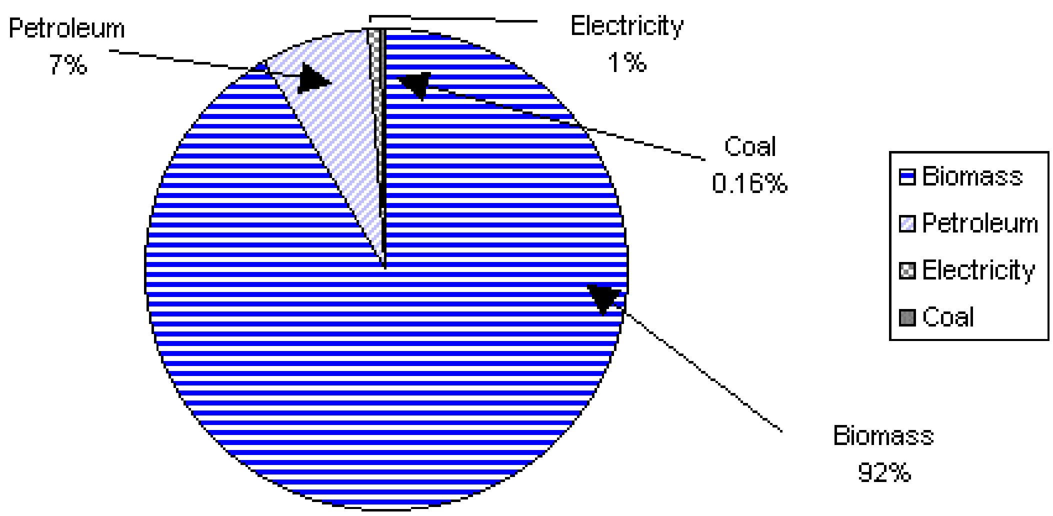


Table 4.6 Projected Consumption of Various Fuels (1000t)

Fuel Type	1990	2000	2010	2020
Oil Products	729.4	1028.3	1655.7	2707.5
Coal	82.26	134.0	206.0	317.0
*Woodfuel	9000.00	11862.0	16420.0	22729.6
**Natural Gas	00	153.0	226.4	226.4

* Units in tonnes of oil equivalent

** Units in millions of cubic metres

Fig. 4.3 Energy demand by sector by year for all fuels (Percent Share)

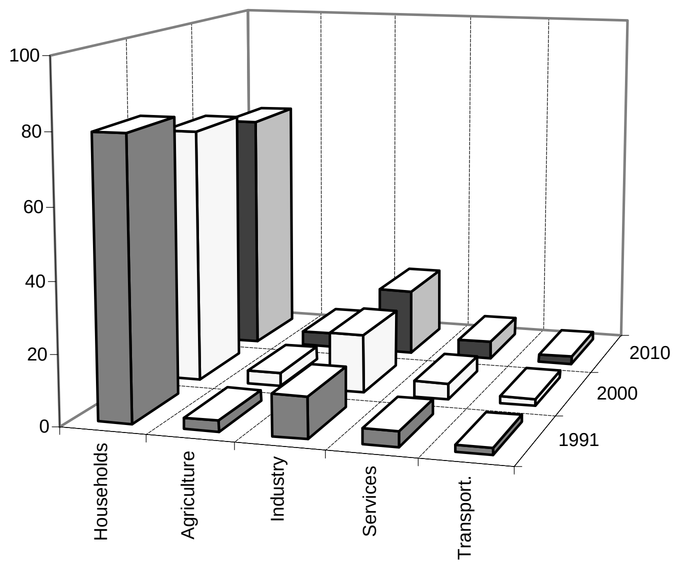


Table 4.7 Woodfuel consumption pattern in Tanzania 1993

User	Quantity in M^3
Rural households	32,100,000
Urban households	5,400,000
Tobacco curing	459,800
Salt production	350,000
Fish smocking	218,000
Bakeries	150,000
Tea drying	108,000
Pottery and ceramics	20,000
Sugar processing	8,000
Lime production	4,400
Honey and beeswax processing	840
Total	38,819,140

4.4.1 Electricity demand

According to TANESCO the share of electricity to the total energy balance is about 0.96 percent (excluding thermal power which is covered under petroleum products). Per capita consumption of electricity is about 60 kWh. Based on demand forecast studies estimate of average growth rate of electricity demand is about 7.4 percent between year 1990 and 2000 and falls to 5.5 percent between year 2000 and 2015. Table 4.8 provide detailed load forecast for TANESCO national grid as revised in August 1992. Population having access to electricity is about 6 percent, mainly in urban areas. Installed transmission and distribution lines total 10,661 km. of which 1,620 km are of 220 kV, 1041 km are of 132 kV and 8000 km are of 33 kV and 11 kV. Average tariff is about US$ 0.06/kWh. Electricity demand is mainly centred in the industry, commercial and household sectors.

4.4.2 Load forecast for the TANESCO grid system

Based on the reference electricity load forecast, reviewed in 1992 using expected hydrology, i.e. arithmetic average of 40 hydrological sequences, the electricity generation expansion had been projected by TANESCO as shown in tables 4.8 - 4.10.

Table 4.8 TANESCO grid system load forecast (revised 1992)

Year	Total sales (GWh)	Annual growth (%)	Maximum demand (MW)	Annual growth (%)
1990	1254		263.7	
1995	1842	7.0	394.0	5.7
2000	2558	5.7	510.0	5.7
2005	3334		666.0	5.1
2010	4279		854.0	5.1
2015	5493		1097.0	5.1

Table 4.9 Electricity generation pattern based on actual units generated

Year	Hydroelectricity generation (GWh)	Thermal power generation (GWh)	Total generation (GWh)	Growth rate (%)
1984	782	140	922	7.58
1985	887	131	1018	10.28
1986	1034	111	1145	12.64
1987	1149	121	1270	11.11
1988	1249	81	1330	4.57
1989	1419	94	1513	13.73
1990	1549	80	1629	7.67
1991	1713	96	1809	11.00
1992	1649	269	1918	6.07
1993	1797	181	1978	3.08

Source: TANESCO

Table 4.10 Generation expansion sequence

Year	Generation type	Installed capacity (MW)	Cost in millions of US$
1994	CT20	2 x 18.5	30
1997	CT25	3 x 20.0	45
1999	Kihansi	3 x 60.0	173
2002	CT50	1 x 43.6	34
2003	CT50	1 x 43.6	34
2006	CT50	1 x 43.6	34
2007	Rumakali	4 x 51.0	347
2010	Ruhudji	3 x 85.0	425
2014	Mpanga	2 x 80.0	268

Note: CT = Gas turbine in Dar es Salaam using industrial diesel oil (IDO), the other plants are hydro based.

Utilisation of natural gas from the Songo Songo field is not included in the reference expansion plan in table 4.10. (it is used in the abatement option in table 4.12). At the moment there is no pipe line from the field. A feasibility study concerning a pipeline to Dar es Salaam is being carried out. Utilisation of the Mnazi Bay gas field is more uncertain as further work on the reservoir needs to be done to delineate the gas reserves.

4.4.3 Power generation

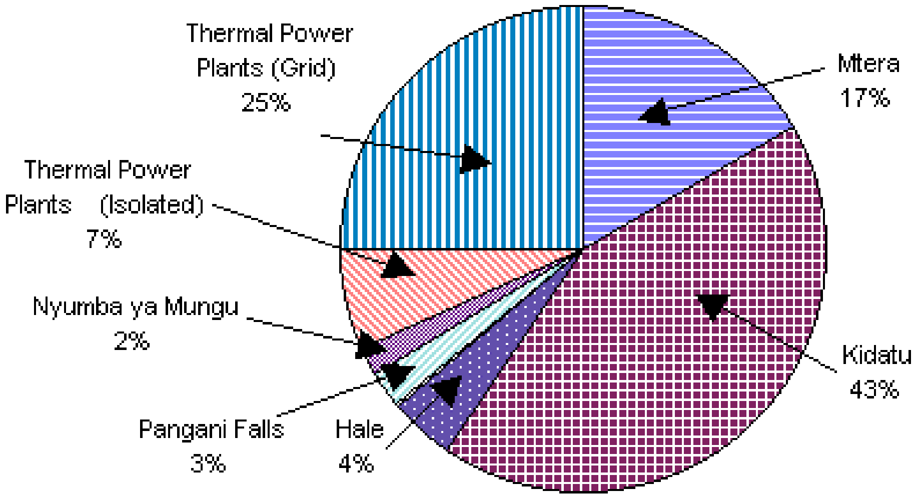
The present power system is composed of isolated and interconnected grid system. The grid system consist of hydro and thermal plants as described above. The bulk of the isolated system consist of thermal plants powered by diesel engines. The total installed capacity in Tanzanian

(grid connected + isolated) is shown in table 4.11 and figure 4.4.

Table 4.11 Existing power capacity (1990)

Power plant	Rated capacity (MW)
Mtera	80
Kidatu	204
Hale	21
Pangani Falls	13
Nyumba ya Mungu	8
Thermal power plants (grid)	32
Thermal power plants (isolated)	120
Total	478

Fig 4.4 Existing power capacity (total capacity 478 MW in 1990)



The total installed capacity in 1990 was 478 MW of which 446 MW was connected to the central grid.

Total installed capacity of the isolated power plants in 1990 was 32.82 MW generating about 64,312,569 kWh per year. Most of these plants are old and in dire need of spare parts to make them operational. The thermal power plants connected to the grid have largely been operated as peaking power plants and the hydro providing the base load. The total installed thermal capacity in 1990 was about 120 MW producing about 15,782,675 kWh.

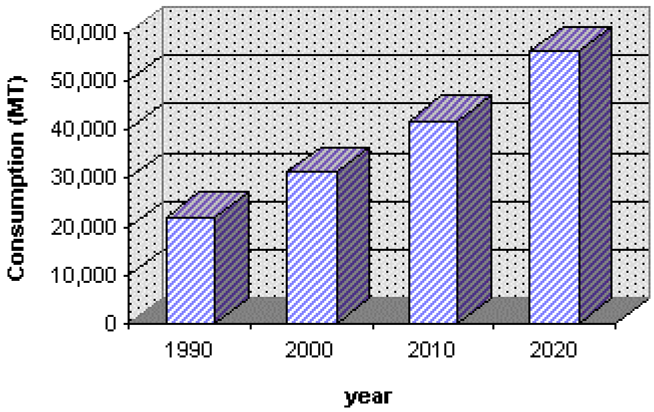
In 1993 two combustion turbines with a rated capacity of 36MW each were added into the grid system to bridge growing power shortfall due to poor hydrological conditions in the water reservoirs. It is estimated that the contribution of the thermal power plants in the interconnected grid system will grow with addition of natural gas in the least cost power generation expansion programme.

Isolated Power stations

The trend of consumption of fuel in the isolated thermal power stations is provided in Fig. 4.5 In 1990 the isolated stations consumed about 22,000 tonnes of IDO .IDO is industrial diesel oil normally called fuel oil.

Assuming an average annual growth rate of power demand of about 6.0% between 1990 and 2000 and 5% between 2000 and years thereafter, consumption of IDO in isolated stations will increase to 56,000 tonnes in 2020. This however assumes that the isolated stations will remain dependent of thermal power generation.

Fig. 4.5 Consumption trends of IDO at isolated power stations



There are 5 regions (Mtwara, Lindi and Ruvuma in the south, and Rukwa and Kigoma in the west) which are not connected to the national electricity grid. The remaining 15 regions are connected to the grid, but there are a number of load centres in those regions which are not connected. These areas are serviced by isolated thermal stations which are mainly powered by diesel engines. The goal is to interconnect these areas with the national electricity grid so as to improve reliability of supply. According to the energy master plan, interconnecting the remaining regions including the associated rural electrification programmes will be accomplished within a time period of 15 years to the year 2005.

Interconnected grid system thermal power generation stations

The thermal generation in the national electricity grid system has largely been used for peaking purposes to supplement the hydro generation during high demand hours. However as demand for power increases as it is the case now (1990's), more and more thermal generation has been called to augment power. In the short and medium term perspectives, thermal power generation in the interconnected grid system is expected to contribute more and more. The reason being long lead times to commission new hydro power schemes, draught conditions in the main water catchment areas and ever increasing competition of water resources.

In 1990, the installed capacity of the thermal units connected to the grid was 119.95 MW. Out of this, 82 MW was the available capacity. In 1994 two new combustion turbines rated at 36 MW have been added to the system. Several new combustion turbines are expected to be installed in the near future as part of the least cost expansion programme. Table 4.10 provided a sequence of installation of thermal units fuelled by IDO in the national grid based on TANESCO's least cost generation expansion programme..

It is expected that by year 2000 most of the present diesel power plants will have been retired and replaced by combustion turbines. From year 2007 new power generation schemes will largely be dominated by hydro. The thermal power plant expected to be built will operate both as a base load and for peaking depending on the hydrological conditions. In most cases however, they are expected to provide base load. Possible contribution of the thermal power plant in the grid system is expected to be as obtained in table 4.12

Table 4.12 Expected generation from thermal power plants connected to the grid

Year	Generation in GWh	Consumption of IDO in tons	Consumption of natural gas in million m^3
1990	16	5500	0
2000	500	0	153
2010	660	0	226
*2020	1000	0	340

Source: MWEM, TANESCO (3,9,18)

*Consumption of natural gas is based on an assumption that more reserves will be brought on line for use in power generation.

4.4.4 Petroleum requirement and resources

All Tanzania's petroleum requirements are imported. About 500,000 metric tons is imported as crude oil and refined at the TIPER refinery in Dar-es-Salaam. The refined products of about 400,000 metric tons is imported. (1994). Although there is no local production of liquid hydrocarbons, there is sizeable reserves of natural gas discovered in early 1970's. So far the gas has not been produced but plans are underway to develop and produce the resource in the near future.

4.5 Energy production and greenhouse gas emissions

In the evaluation of the greenhouse gas emissions from energy production, emission factors employed are those provided by the IPCC methodology for establishing greenhouse gas emission inventories.

Corresponding trends of greenhouse gas emission assuming the isolated stations remain dependent on thermal power generation. The methodology used in establishing the emissions remain the same as provided for in the IPCC handbook on greenhouse gas emission.

4.6 GHG abatement options in energy production

In the power subsector a number of technological options exist which can beneficially be used to reduce emissions of greenhouse gases into the atmosphere. These include efficiency improvement of present installed equipment, retrofitting of thermal power plants to improve combustion efficiencies, retiring the present less efficient thermal power plants in favour of more efficient thermal power plants or hydro power plants as well as demand side management.

4.6.1 Options for isolated thermal power stations

There are 5 regions (Mtwara, Lindi, Ruvuma, Rukwa and Kigoma) which are not connected to he national electricity grid but are usually served with isolated thermal power generators. The following are possible options which exist for the 5 regions to improve or interconnect with predominantly hydro based grid system.

Mtwara and Lindi regions could benefit from the development of Mnazi bay gas system to use natural gas for power generation in Mtwara. The proposal call for installation of 10 MW gas power plant to supply Mtwara which is connected to Lindi and Masasi This option could be implemented during 1996-2000 planning cycle. It will afford a reduction of emissions of greenhouse gases by more than 40% of CO_2 emission at the end of implementation.

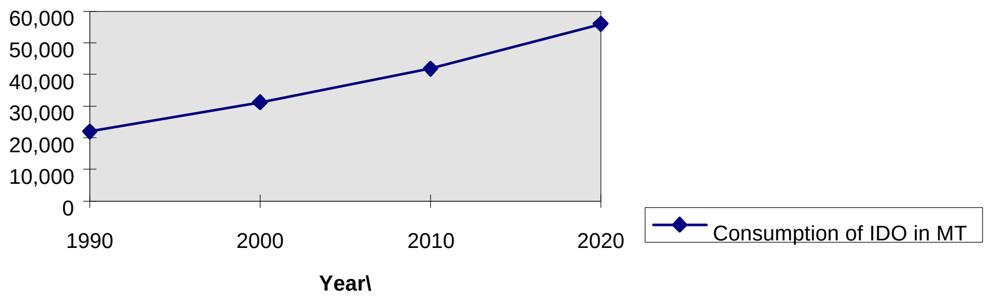
Ruvuma region is expected to benefit from cheap reliable power from the grid once the Makambako substation is put in place. The cost of this programme is expected to be US $20 million. This is not a mitigation option per se since it is provided for in the Energy Sector Master Plan to the year 2005.

The Rukwa region is expected to be connected by 132 kV link from the Zambian grid through Mbala. The Zambian grid is predominantly hydro. The programme is expected to be implemented between 1995-2000 at a cost of US$ 3.0 million.

Kigoma region is heavily dependent on thermal power production. To improve reliability of supply options that exist include interconnecting with the Burundi electricity grid. The other option will be to develop the Malagarasi hydro power scheme which is however expected to take a while since it is far down the least cost power generation options available under the power master plan.

The trend of consumption of fuel in the isolated thermal power stations is provided in Fig. 4.6. In 1990 the isolated stations consumed about 22,000 metric tons of IDO. Assuming an average annual growth rate of power demand of 6.0% between 1990 and 2000 and an average of 5% growth rate between 2000 and years after consumption of the industrial diesel oil (IDO) in isolated stations will increase to 56,000MT in 2020. This however assumes that the isolated stations will remain dependent of thermal power generation.

Fig. 4.6 Consumption trends of IDO in isolated power stations



Source: TANESCO

Corresponding trends of greenhouse gas emission assuming the isolated stations remain dependent on thermal power generation was provided in table 4.12 The methodology used in establishing the emissions remain the same as provided for in the IPCC handbook on greenhouse gas emission.

Principally, the central objective is to try to minimise the emissions of CO_2 as much as possible. Mitigation measures as described in the text will be able to reduce the emissions of greenhouse gases from the isolated stations, improve the reliability of supply and reduce cost. The plan call for interconnection with the grid in the case of the Ruvuma region, interconnection with neighbouring states in the case of Rukwa and the Kigoma regions and installation of combustion turbines to save Mtwara and Lindi regions.

4.6.2 Options for thermal power plants interconnected to the grid system

For thermal power plants in the interconnected system, three options exist for mitigating green house gas emissions: (i) improving the expected thermal power plants to be installed from the proposed simple cycle power plants to *combined cycle power plants*; (ii) opting for *all hydro generation sequence;* and (iii) *combination of power sharing with neighbouring states and opting for hydro generation* instead of installing thermal units.

Options (ii) and (iii) will result in a 100% reduction of greenhouse gas emissions into the atmosphere whereas option (i) will afford some reduction of the greenhouse gas emission. The likelihood of option (ii) and (iii) being implemented during the planning horizon is small because of cost and time implication. Analysis of the mitigation option is however limited to option (i) since it is most likely to be implemented considering that it is within the existing least cost option of power generation.

Opting for combined cycle power plants as opposed to simple cycle gas turbines is expected to bring about reduction in CO_2 emissions. This is basically due to relatively high efficiencies obtainable in combined cycle of order of 52% as compared to 30-35% for the simple cycle. In addition, combined cycles power plants have an advantage of short installation time and very low emission levels of NO_x. The exhaust gases consist of typically 3-3.5 % CO_2 (by volume), corresponding to emission level of approximately 0.4 kg CO_2/kWh.

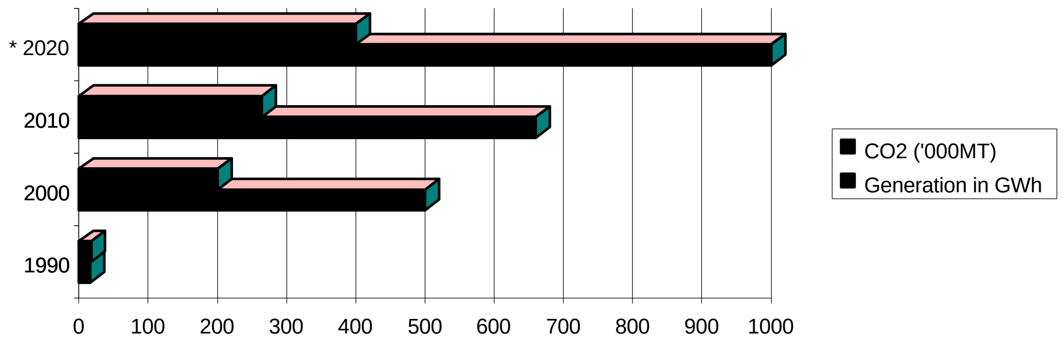
Under this mitigation option it is assumed that the presently installed combustion turbines will not be converted to combined cycle but the new combustion turbines expected to be installed in future will be combined cycle power plants fuelled by natural gas from Songo Songo. The cost for the combined cycle power plants has been estimated to be about US$ 1000/kW. The total costs for the combined cycle plants are shown in table 4.13. When compared with table 4.10 the cost increase can be seen.

Table 4.13 Cost of mitigation options for grid connected thermal stations

Year	Generation type	Installed capacity (MW)	Cost in millions of US$
1997	CT25	3 x 20.0	60.0
2002	CT50	1 x 43.6	43.6
2003	CT50	1 x 43.6	43.6
2006	CT50	1 x 43.6	43.6

Fig 4.7 provides details of emissions under the mitigation options based on the above methodology.

Fig. 4.7 Emission of CO_2 from the mitigation option in the grid connected plants



Comparison between the baseline emissions and the emissions with implementation of mitigation options shows a significant reduction of CO_2 emission. Fig. 4.8 provides details of the comparison between the base case and the mitigation case.

Fig 4.8 CO_2 emission from thermal power generation

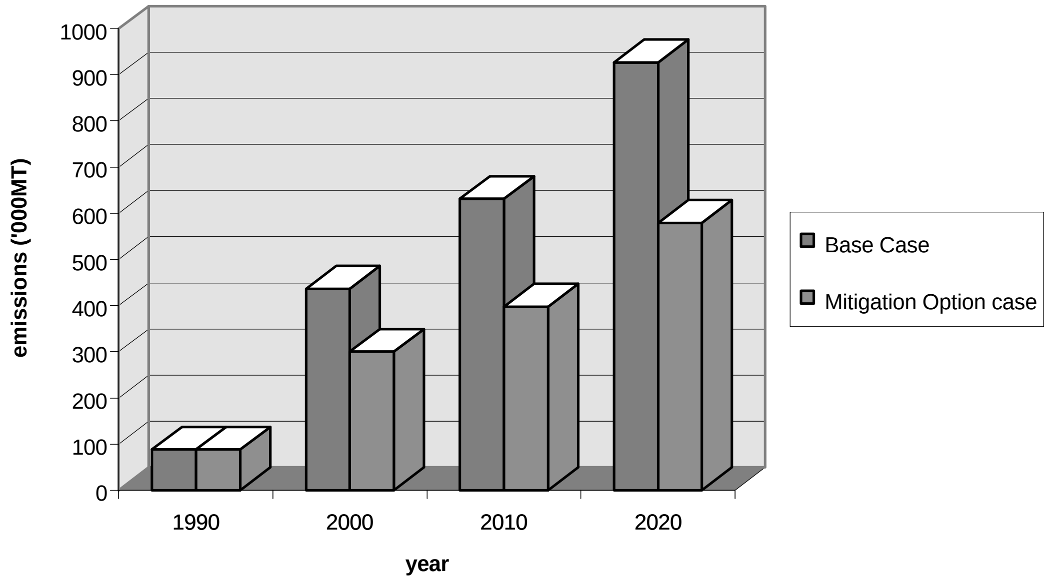
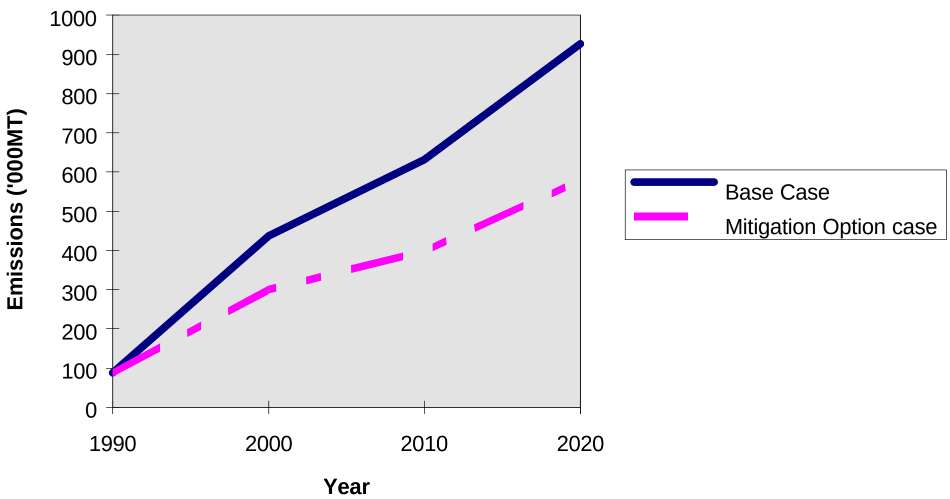


Fig. 4.9 Comparison of CO2 emissions between reference and abatement case for the power sector



4.7 Transportation and CO_2 emissions

Transport plays a multipurpose role in the pursuit of development goals in Tanzania. It enables the transportation of goods and services between and within production and market centres. Trade with the rest of the world is only possible because of the existence of a transport infrastructure which enables the movement of both imports and exports. The Government is committed to improve the various transport networks by making significant investments in the Integrated Roads Project, the Railway Restructuring (TRC and TAZARA) and Port Modernisation Projects.

The transport sector contributes 5.6% to GDP and accounts for 16% of total public expenditures. One of the main reasons for the large share is that the Government, through parastatals, owns most of the transport infrastructure, i.e. roads, railways, airports, harbours, as well as inland waterways. Except for the railway, users of transport infrastructure own the operating equipment such as motor vehicles, cycles, ships, boats etc.

The objectives of the sector are to provide efficient and effective domestic and international transport services. In addition, the objectives are to maximize both foreign and local revenue generation in the transport sector, and to minimise transport related environmental hazards.

4.7.1 Transportation modes and GHG emissions in Tanzania

Almost all models and types of vehicles (cars, trucks, buses, tractors, etc.) used in Tanzania are imported either as new or reconditioned vehicles. Many countries (USA, UK, Germany etc.) have standards and specifications for vehicles (and other products) intended for importation or local production. Of late, specifications related to pollution and environment have been critical.

Unfortunately, Tanzania has neither standards nor specifications for the many models of imported vehicles. Worse still even the operational legal standards on emission related conditions are non existent. As such it results into highly polluting levels of emissions from these vehicles. Obviously the growing high levels of CO_2 contribute greatly to GHG and similarly the NO_x associated with transport sector.

In order to reduce CO_2 emissions new vehicles with efficient engines must be introduced into the automobile market. These could include turbo charged engines and stratified engines. In the latter case, fuel is burnt in stages and hinders greatly the formation of, in particular NO_x. For NO_x emission reduction, catalytic converters, that reduce NO_x to N_2 are compulsory on all new cars in Japan, USA and several countries in Europe. Legal application should be considered to enforce this.

This could be for example in form of what is enforced in Britain for checks in emission level before road licenses are issued by the Ministry of Transport (MOT).

4.7.2 Transportation infrastructure and CO_2 emissions

Most of the transport system in Tanzania is via road infrastructure, at most 30% of the road systems are presently in good conditions. A study based on economic aspects reveals that the Tanzanian economy could be loosing nearly US$ 200m a year in direct cost due to deteriorated transport infrastructure and its inefficient operation.

The quantified cost for mitigating CO_2 and N_2O is non documented. However suggested alternatives are good road system which would result in low CO_2 emission per power or km travelled. In addition, switching to other sources of energy as in H_2 powered vehicles could reduce CO_2. In the same category non fossil fuels should be encouraged, these could be ethanol and methanol.

Table 4.14 Summary of options for minimising GHG emissions in transportation

GHG	Options for Reduction
CO_2	- Efficient engines thus higher Power/CO_2. - Proper vehicle maintenance - Fuels with non or low carbon content. - Good road systems/. - Improved Railway system. - City Train
NOx including N_2O	- New engine models as Turbo & Stratified Combustion Chamber Engine - Catalytic Converters - 3 way for also CO and unburned Hydrocarbon - Good Road Systems/Proper Maintenance

4.8 Cement production and CO_2 emissions

Cement industries are significant contributors to GHG emissions in Tanzania. There are three cement processing industries in Tanzania namely, the Tanzania Portland Cement Company (TPCC), in Dar Es Salaam, The Tanga Cement Company (TCC) in Tanga and the Mbeya Cement Company (MCC), in Mbeya. Their designed capacities are:

TPCC	520,000 MT/year
TCC	500,000 MT/year
MCC	250,000 MT/year
Total	1,270,000 MT/year

There are only two major processes for making cement, namely the wet and the dry process. The wet processing is especially effective when the raw materials contain more than 20% water (by weight). The mixture of raw materials is then ground in a tube with more water to form a slurry. This is more energy intensive than the dry process (e.g. energy requirements of a long kiln per ton of clinker are 5.0 - 6.0 GJ for the wet process and 3.4 - 5.0 GJ for the dry process). Since the raw material for cement production in Tanzania contain less than 20% (by weight) the wet processing method is not the best, and therefore dry process is the one used in Tanzania. Table 4.15 gives a summary of possible options for reducing CO_2 emissions in cement production.

Option	Advantage/Disadvantage
1. Installation of automatic control system	reduces the amount of fuel used and improves production efficiency
2. Installation of CO_2 recovery system, which can be sold for other industrial application	reduces the amount of CO_2 emitted to a larger extent. It is expensive because of high dust load in flue gases
3. Fuel switching from fuel oil to natural gas	reduce CO_2 emissions because of low emission factor of the natural gas compared to that of fuel oil and coal
4. Production of blended cements such as pozzolanic cements, blast furnace slag Portland cements	reduces the amount of fuel used for calcination and the amount of lime per a given quantity of cement production rate
5. Use of vertical shaft kilns	uses less energy than rotary kiln. Only economical for smaller plants i.e. less than 300 t/day
6. Recovery of waste heat	reduces the necessary length for pyroprocessing, shorter kilns are needed

Table 4.15 Summary of options for reducing GHG in cement production

4.9 Pulp and paper production and GHG emissions

Pulp and paper production is in the Southern Paper Mill (SPM) factory in Mufindi. From the technology point of view SPM uses up to date technology in paper making for the type of pulp produced. The SPM intends to use coal as a major source of fuel. However based on the emission factors provided by the IPCC the amount of CO_2 produced will remain the same. However, one can consider to pulp other non wood fibres such as sisal fibres (which take a very shorter time to regenerate) to reduce the rate of CO_2 sink destruction.

Table 4.16 GHG emissions reduction options for pulp and paper production

Option	Advantage/ Disadvantage	Feasibility
1. Optimisation of Recovery Boiler	reduces the amount lime needed, uses less energy and not costly	feasible
2. Recovery of CO_2 from calcination by absorption of CO_2	reduces most of the CO2 and uses existing installations	feasible
3. Afforestation	maintaining CO_2 sinks	feasible
4. Fuel switching	natural gas has less emissions factors than fuel oil and coal	not feasible because of infrastructure

The main focus is mainly on those industries that contribute significantly in the GHG emissions. These include cement production and pulp and paper production. Analysis of technologies used in this sector is based on short, medium and long term plans. This is used for the establishment of baseline and mitigation scenarios.

4.10 Options in residential and commercial energy use

The main mitigation scenarios are based on increased use of improved biomass end use devices (i.e. charcoal and wood stoves and ovens). The other important option is switching from the use of biomass to electricity. Fuel switching will also contribute to reduce the GHG emissions as most of electricity consumed is from hydropower stations.

Other measures which include introducing efficient lighting devices, air conditioning systems, water heater, electric ovens, and electric irons are aimed at reducing the electricity consumption.

Charcoal Stoves

It is estimated that in the year 1990 there were about 78,743 improved charcoal stoves. The reference scenario penetration is 3% annually reaching a saturation of 90% in the year 2020. With an option of the penetration of 5%, by the year 2010 all urban households will be using improved charcoal stoves having at least 30% efficiency.

Wood Stoves

There are two common types of technologies of improved wood stoves in the country. These are portable metal/ceramic stove and mud/ceramic fixed stove. Their efficiency ranges from 15% to 20%. The traditional wood stoves have the efficiency ranging from 5% to 10%. Introducing improved wood stoves of efficiency 20% at a penetration of 2% annually means that by the year 2020 there will be 1,816,018 improved wood stoves.

Crop Residues Stoves

Introducing improved crop residues stoves of efficiency 15% at a penetration of 1% annually means that by the year 2020 there will be 163,222 improved crop residue stoves.

4.11 The non energy sectors

The non energy sectors comprise the agricultural, land use and forestry and waste disposal sub sectors.

4.11.1 The Agricultural sector

Agriculture is the most important sector in Tanzania's economy. It employs about 80% of the population's workforce and accounts for over 50% of GDP at factor cost and 75% of foreign exchange earnings. Furthermore, it is the main source for food supply and raw material for the industrial sector as well as the major market for industrial goods.

The objectives of the agricultural sector are:

(a) To achieve national self sufficiency in food

(b) To raise incomes of all Tanzanians especially the rural poor

(c) To promote sustainable production and environmental protection

(d) To increase foreign exchange earnings

(e) To produce and supply raw material for the industrial sector.

Analysis in this sector, focuses on crop activity as well as livestock husbandry. The main activities considered are those that are in the GHG emissions, Sources and Sinks study. These include, rice cultivation, burning of agricultural residues in cotton, sugar cane and coffee production and livestock development.

Rice cultivation and methane emissions

Methane emission reduction by irrigation water management

Both irrigated paddy cultivation which is about 10% and lowland rain-fed paddy cultivation which is about 70% will need better water management option with a view of reducing methane emissions. Introduction of irrigation management practices with a view of mitigating methane emissions will have to involve regular drainage of the paddy field and increased aeration of the irrigation water.

Regular drainage of the paddy field

Current water management on irrigation schemes tend to be very unsophisticated and inefficient. Strategic drainage of the rice fields can be carried out several times during the growing season without any loss in yield. Timely draining and rewatering of fields can actually improve yields especially if mixed with appropriate fertilizer applications. This system is relevant to lowland rain-fed paddy cultivation where paddy is grown along river basins and inland valleys. This option could be difficult to apply in situations where water is scarce as the quantities required to re establish the standing water conditions may not be available when required.

Although rice does not actually require standing water the skill levels and or work load required of the farms may be high. However with farmers training and extension services on strategic water management in paddy fields this scenario can be attainable. However, the effect may not be more than 50% under field conditions and the experience has shown that about 30% reduction in emissions is achievable.

Increased aeration of Irrigation water

Methane is produced through anaerobic decomposition of organic materials in the paddy fields. The amount emitted is believed to be a function of among other things, the redox-potential. The Redox potential could be affected if the irrigation water contained more dissolved oxygen.

Water flowing in an irrigation system is constantly being aerated as a result of turbulence. It is possible however to increase rates of aeration as the water flows through the irrigation system and into the field. First, cross canal structures can be designed so as to encourage increased aeration, by means of baffles or other features in the spilling basins or on the spillways.

Nutrient management

Management of fertilizer application is possible to all irrigated and lowland rain-fed paddy cultivation through either training and extension services. CH_4 production could be reduced by 20%.

Reduced Growing season

Methane emission is also a function of a time frame required to meet the condition necessary for methanogenesis. Hence reduced growing season will reduce methane emissions. For reducing the growing season two aspects have to be considered critically;

First, the varieties which are currently favoured for various characteristics like aroma generally take about 110-120 days to harvest, without reducing the productivity. Short term varieties will obviously reduce methane emissions. This approach has the advantage of growing a second, non-rice crop using residual moisture which remains in the field.

Early preparation of seed nurseries.

The second aspect arises from the large quantities of water needed for land preparation at the beginning of the growing season. Farmers are reluctant to start the seedling nursery until the first significant flush of water has arrived. Thus while they are waiting for the seedlings to grow before transplanting there is an unnecessary period during which methane producing conditions could develop. But if alternative water sources could be developed at the start of the season the land preparation time could be reduced and therefore the time required for methane emissions could be reduced.

Shallow hand dug wells represent a good opportunity for achieving this. At the very least they could be used to irrigate a common seedling nursery which could maintain seedlings in a viable state until such time as the river delivers the pre saturation quantities needed.

Livestock husbandry and methane emissions

Almost all cattle, sheep and goats in Tanzania are kept under Traditional Livestock Sector. The national cattle herd consists mainly of indigenous cattle (97%), the Tanzania short horn Zebu. These, are kept under pastoralism, extensive agropastoralism and intensive agropastoralism. Enhancing animal productivity with a view of reducing methane emissions could be done by any or a combination of the following options:

Improved nutrition

IPCC estimates that improved Nutrition through Supplementation of natural Feed and other strategies can reduce Methane emissions between 10% and 25%. The quality and quantity of feed available for the ruminants in the Traditional Sector depends on the agroclimatic conditions.

Uneven distribution of livestock has led to over grazing and land degradation in areas with large stock numbers, particular in areas with low and erratic rainfall. Under this state of affairs improved nutrition with a view of both increased productivity and reduced methane emissions could be achieved through the following approaches;

Use of better pastures

Improved livestock productivity and subsequent reduction in methane emissions is feasible through use of improved pastures. Improved forage grass and legumes are known to produce more dry matter per unit area than natural grasslands. Costs and benefits for pasture improvement will determine the feasibility of this approach for each zone; however as the traditional livestock sector (97% of cattle) depends basically on natural pasture; improvement of these natural pastures is the most feasible way to improve nutrition and productivity.

Feed Supplementation

Feed Supplementation is feasible where there is relatively readily availability of crop residues. Information now exists on better utilisation of crop residues and non-conventional feed resources such as water melon. A good integration of crop production and livestock husbandry can lead to adequate availability of crop residues for livestock use. Supplementation of natural feed with alternatives like molasses and urea multinutrients blocks is also possible.

The feed available will depend on the type of crops grown in the area in question. Through extension services and training farmers can easily learn how to better use the crop residues available in their areas for livestock feeding. It should be made clear that low quality roughage are generally low in protein, minerals, vitamins and starch and that Supplementation especially with nitrogen and starch is essential if the additional energy released after upgrading has to be used efficiently.

Reduction in stock numbers / Destocking.

Destocking is probably the most obvious option to reduce CH_4 emissions. Destocking particularly in zone I and II is a viable option both because it reduces the absolute numbers of livestock responsible for enteric fermentation and at the same time improves the carrying capacity particularly in the central regions. Destocking however has never been an easy approach due to the importance of having more cattle and the security they bear in times of catastrophes. Attempts to reduce stock numbers should therefore include measures to improve the livestock welfare through increased health services and development of marketing infrastructure so that farmers will be able to keep a small but economically viable herd.

Improved Nutrition through increased feed Digestibility

This option can be achieved through either mechanical or chemical processing of the feed. IPCC has estimated that feed processing can reduce methane emissions by between 10% and 25%.

Mechanical processing of feed

Mechanical treatment of feed is possible through the existing farmers extension services system and through introduction of low cost feed processing technology.

Chemical processing of the feed

Research activities concerning upgrading of various locally available low quality roughage using a wide range of chemicals such as ammonia released from hydrolyzed urea, sodium hydroxide solution and naturally occurring Magadi (a sodium sesquicarbonate salt) started since 1975. Hence the range of possible chemical substances to be used in the various zones for upgrading low quality roughage should be based on this long term research. Chemicals, should include locally occurring substances such as Magadi soda which is found in large quantities in many areas, fungi and other micro-organisms, enzymes etc.

Improved breeding

Improvements in the genetic potential of the Traditional Livestock will improve the productivity within this subsector; and hence considerably reduce methane emissions. Under the existing conditions this approach may be viable through establishment of artificial insemination and/or improved bull centres in each zone.

A well designed program has to make sure that either Artificial Insemination or Improved bulls reach the majority of livestock keepers. For the improved livestock sub-sector, emissions are about 2.5% of total emissions; and any mitigation strategy will mainly lie in improved breeding approach.

4.12 Forestry and land uses - CO_2 emissions and removals

There are two avenues considered to be achievable as far as the existing policies, legislation, institutional arrangements, and the mitigation implementation potential are concerned. These two are basically: maintaining the existing land-based carbon stock, and expanding the land-based carbon sinks.

4.12.1 Maintaining existing land based carbon stock

This avenue has a bearing on improvement of existing land-use management, enhancement of land-use productivity, and calls for measures to reduce deforestation rate. The land use management options include the following:-

a) Forest Protection and Conservation -

Measures to store more carbon in vegetation, soil and water bodies require both national macro-programs or individual initiatives to manage vegetative natural resources multipurposely. Such initiatives include wildlife and tourism promotion, soil and water catchment conservation, and protection of endangered species. Encouraging natural vegetation regeneration in game reserves is another avenue in maintaining the same land area at improved carbon stock.

b) Increased efficiency in woody forest product utilisation -

This refers to woody forest products management with selective tree harvesting, harvesting for multiple end-uses, bioenergy initiatives such as casamance and half-orange brick kilns, briquetting, gasification, and energy plantations.

4.12.2 Expand land-based carbon sink potential

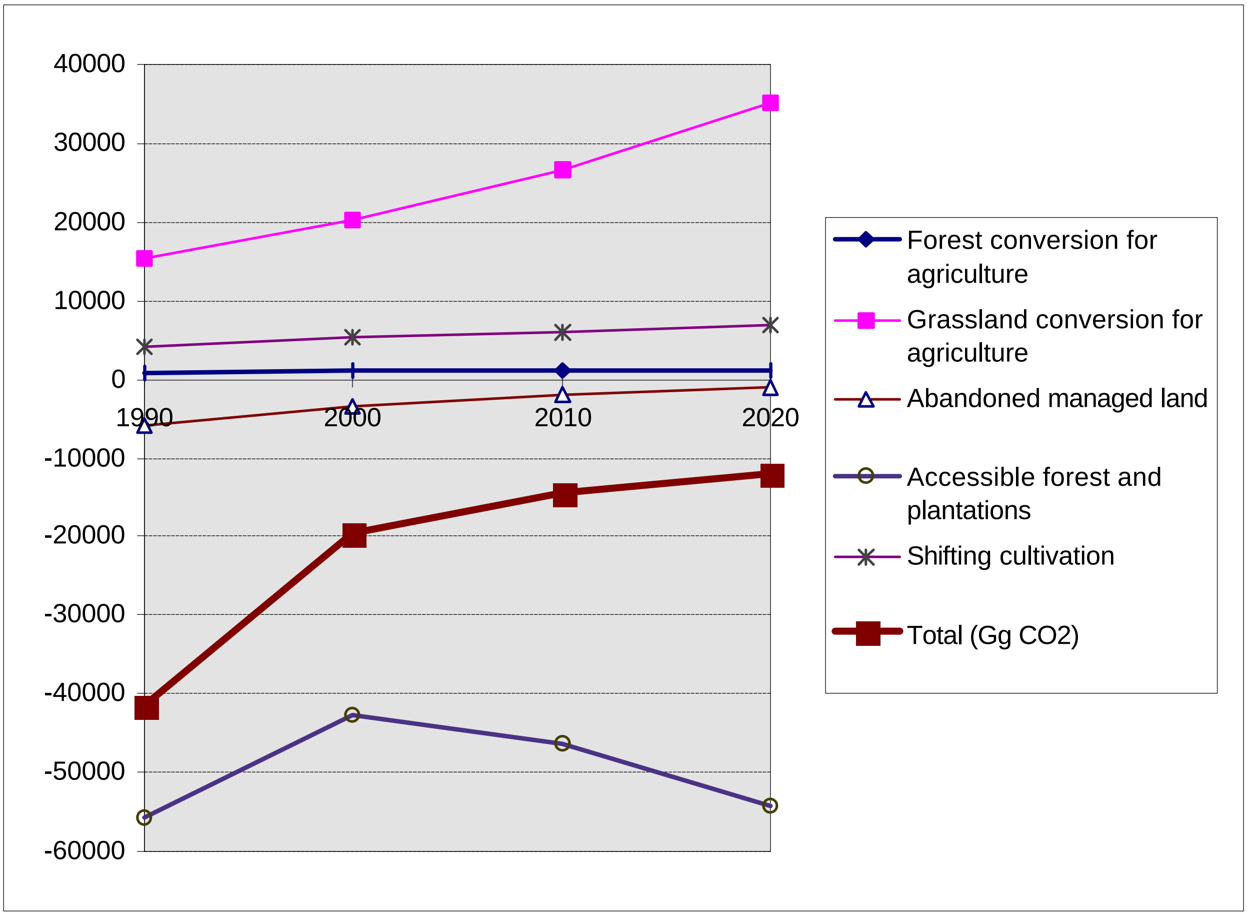
One of the two major mitigation avenues is to expand the stand of trees, other vegetation covers, and the pool of carbon in wood products through afforestation, reforestation, enhanced biomass regeneration, agroforestry, and community.

Afforestation - Planting trees (exotic species) on bare land, with above-ground biomass density commensurate to the objectives of afforestation programmes. Drought resistant tree species will be considered to be suitable for afforestation.

Reforestation - Establishment of new forest by seedling or, more generally, by planting nursery-grown trees or forest land that fails to restock naturally with adequate number of the right species of trees. Replanting exotic or indigenous species or allowing natural regeneration of deforested areas include enhanced biomass regeneration in fallow lands.

Agroforestry - The increased production of wood, fodder, and food crops on the same piece of land. Agroforestry is a land-use management system of growing woody perennial in spatial or sequential arrangements with agricultural crops or animal production or both. It is a wide term encompassing inter-cropping, wind-breakers, animal husbandry, and non-timber farms for bee wax, honey, bamboo, and medicinal production.

Fig. 4.10 CO2 emissions and removals Land and Forestry mitigation options



Urban tree planting - Tree planting programmes aimed at stimulating and developing sustainable tree husbandry culture in both neighbourhoods to form a greenbelt, shades and aesthetic environment. People are encouraged to grow trees for multiple uses, bring public forests or woodlands under proper management for sustainable and high productivity if they may rely on small scale woodlot. For Tanzania, in order to bridge the gap between sustainable demand and supply of forest products a year, about 200,000 ha of woodlot need to be established each year for a minimum of 10 years. The current tree planting rate of about 20,000 ha a year is very marginal, thence efforts need to be made in endeavour to step-up the current tree planting rate by ten times.

4.13 Waste management

The Dar es salaam city generates about 1,500 tons of organic waste (wet weight). Based on the assumption that urban population growth will follow a falling pattern as experienced between 1960's, 1970's and 1980's, the waste generation is assumed at the rate of 0.5 kg per capita, and the methane generation is calculated using the following expression. Table 4.4 provides the urban population projections.

Table 4.17 Projected urban population growth

Year	1990-1995	1996-2000	2001-2005	2006-2010	2011-2015
Growth %	7.0	6.0	5.0	4.5	4.0

Also it has been assumed that the collection efficiency shall be increased progressively to 85% by the year 2015. The Power Generation Taka Gas Project is part of existing plans and thus is treated as baseline activity. It is assumed that over 60% of total waste is used. For a biogas plant using 150 tons of organic waste per day from different sources like Household, Market, Abattoir, Brewery etc.

5. Zambia report

5.1 Zambia overview

5.1.1 Biophysical environment

Zambia, a landlocked country in South Central Africa, is bounded by eight countries which are : Zimbabwe, Zaire, Angola, Tanzania, Malawi, Botswana and Mozambique. Its area is approximately 752,600 km^2 . Protected areas like forest reserves and national parks cover 74,400 km^2 and 59,400 km^2 respectively (see figure 5.11), crop land (plus fallow) covers 158,400 km^2 .

Zambia has three seasons and these are rain, cool and hot seasons. The rain season which is wet and warm covers the period from November to April. The cool season is from April to August during which temperatures range from 17^0C and 27^0C. The hot season is experienced between mid August and mid November. Temperatures are between 27^0C and 32^0C during this period.

5.1.2 Human Population

The Priority Survey I 1991 report of Central Statistics Office (CSO) gave an estimated population of 7.9 million people in 1991. The country had a population density of 10.5 person per km^2 .

Tables 5.1 and 5.2 show growth rates of population in large urban areas and population distribution by rural/urban in the provinces in 1990.

Table 5.1: growth rates of population in large urban areas

District	Population 1965	Population 1980	Growth rate 1965-80	Population 1990	Growth rates 1980-90
Chililabombwe	44862	54737	1.8	76848	3.4
Chingola	103292	130875	2.1	167954	2.5
Kabwe	65974	136875	6.3	166519	2.0
Kalulushi	32272	52146	4.3	75197	3.6
Kitwe	199798	266286	2.6	338207	2.4
Livingstone	45243	63275	3.0	82218	2.6
Luangwa	96282	110907	1.3	146275	2.8
Lusaka	262425	535830	6.2	982362	5.9
Mufulira	107802	135535	2.1	152944	1.2
Ndola	159782	250502	4.0	376311	4.0
Total urban (including Small Urban)	1192116	2258500	5.6	3285766	3.7

Table 5.2: Population distribution by rural/urban in province 1990

Province	Rural	Urban	% Urban	Density
Central	509588	216023	29.8	5.4
Copperbelt	150845	1428697	90.5	50.4
Eastern	888104	85714	8.8	14.1
Luapula	443669	83036	15.8	10.4
Lusaka	166507	1041473	86.2	55.4
Northern	744338	123457	14.2	5.9
North-Western	337547	45599	11.9	3.0
Western	536114	71383	11.8	4.8
Total Zambia	4532681	3285766	42.0	

Zambia is among those sub-Saharan countries with high population growth rates. Table 5.1 shows that Lusaka, Kabwe, Kalulushi and Ndola had highest growth between the period 1965-80 of over 3.0%. During this period the average growth rate for the urban area was 5.6%, a significantly higher figure than normal. This could be probably explained due to the economic boom which prevailed during this period and lack of population policy at the time. Between 1980-90, however, the average growth rate in major cities tailed to 3.7% with Lusaka and Ndola leading with 5.9% and 4.0% respectively.

Zambia is also the most urbanised country south of the Sahara. As shown on Table 5.2 urban population in 1990 was 42.0% with Copperbelt, Lusaka and Central Provinces with the highest contribution of 90.5%, 86.2% and 29.8% respectively. The high urban population ratio in these three provinces can be attributed to large intensity mining activities and commercialisation during the first years after independence in 1964.

In 1964 urban population was 20% and 29% in 1969. The 1969, 1980 and 1990 national census reported total population of 4.0 million, 5.7 million and 7.8 million people respectively (CSO 1990). This implies that population has been growing at a rate of 3.1% per annum between 1969 and 1980 and 3.2% per annum between 1980 and 1990.

5.1.3 Population and environment

Since independence, there has been no commitment and comprehensive population policy in the country. As a result, the country, until recently has not been able to identify population issues of urban and rural sectors separately.

The absence of such a policy has led to the deterioration of environment quality.

5.2 The Economy

5.2.1 General overview

The Zambian economy is dominated by the mining sector with copper being the major export product, contributing over 90% of the country's foreign exchange earnings. It is also the major source of Government revenue. Manufacturing is the second most important sector followed by agriculture.

The Gross Domestic product (GDP) in 1990 was 9376.0 million ZK in constant 1985 factor prices. Table 5.3 shows the contribution of the various sectors to GDP.

With a population of 8.11 million the GDP per capita was 1260.90 ZK This is a decline from the 1990 figure at current prices of ZK1592.30 which was the highest in the first ten years.

Table 5.3 Contribution of various sectors to gross domestic product in 1990 in 1985 constant factor prices

Sector	Million ZK	% Share
Agric/Forestry/Fishing	1097.00	12.5
Mining	2092.00	22.3
Manufacturing	2034.00	22.5
Elect/Gas/Water	86.00	0.92
Construction	376.00	5.6
Wholesale/Retail Trade	1126.00	12.01
Transport/Communication	622.00	6.63
Community/Social/Personal services	843.00	8.99
Other Services (1)	1234.00	13.16
Subtotal	9510.00	
Other(2)	-134.00	
GDP at factor costs	9376.00	

Due to rounding off the % total does not sum up to 100%

Source-World Bank Report to Zambia No:11570-ZA of 1993

1-Includes Hotels, Financial, Real Estate and Business Services

2-Inputed Bank Service charges

Shown on Tables 5.4 and 5.5 is the Gross Domestic Product (GDP) by sector of current prices between 1988 - 1992 and constant prices respectively.

Table 5.4 Gross domestic product by sector at current prices (K'million) 1988-1992

Sector	1988	1989	1990	1991	1992
1. Agriculture & Fishing	3905	6390	14175	28132	32470
2. Mining & Quarrying	6280	10042	25272	33755	61410
3. Manufacturing	6865	13027	25510	61725	90000
4. Electricity, Gas, Water	334	308	635	1909	3600
5. Construction	1338	3019	6300	10911	18150
6. Trade, Hotel & Restaurant	3697	8963	13148	24021	43750
7. Transport, Storage & Communication	2237	3116	6861	15812	30380
8. Real Estate, Bus & Financial Services	2313	6837	13290	24832	39600
9. Services (including Public Admin)	2728	4148	9484	19254	34800
10. Less: Imputed banking service charges	(239)	(769)	(1471)	(2726)	(4500)
Total GDP at factor cost	29458	55081	113204	16879	34970
Indirect taxes net subsidies	1365	3624	10283	16879	32000
Total GDP at market prices	30823	58705	123487	234504	381740
Average exchange rate US$1 = ZK	8.22	12.90	42.75	51.20	192.0

Source: CSO

Table 5.5: Gross domestic product by sector at constant 1985 prices (K'million), 1988 - 1992

SECTOR	1988	1989	1990	1991	1992
1. Agriculture & Fishing	1205	1188	1097	1159	704
2. Mining & Quarrying	2203	2186	2092	1858	2047
3. Manufacturing	1874	1903	2034	1879	1800
4. Electricity, Gas, Water	90	72	86	94	90
5. Construction	386	380	376	338	330
6. Trade, Hotel & Restaurant	1007	1068	1126	1184	1250
7. Transport, Storage & Communication	585	604	622	641	675
8. Real Estate, Bus & Financial Services	1177	1205	1234	1331	1320
9. Services (including Public Admin)	820	831	843	855	872
10. Less: Imputed banking service charges	(129)	(131)	(134)	(146)	(150)
Total GDP at factor cost	9218	9306	9376	9193	8938
Indirect taxes net subsidies	837	845	854	834	811
Total GDP at market prices	10055	10151	10230	10027	9749
Average exchange rate US$1 = ZK	8.22	12.90	42.75	51.20	192.0

Source:CSO

From Table 5.5, it is evident that GDP at factor and market prices remained essentially the same between 1988 and 1992 without registering noticeable increases in GDP.

Below the performance in three main sectors is described.

5.2.2 Sector performance

a) Mining sector

Mining has been the backbone of Zambia's economy. Copper industry still provides about half of Government revenue and 85% of the country's export earnings. Over the recent past, however, there has been a decrease in the production of copper due to deepening shafts and reduced concentration of ores. This has resulted in reduction of its contribution to GDP.

b) Industrial sector

Zambia's industrial sector is small but fairly diversified with food, beverages and tobacco forming the largest subsector in terms of employment, investments and output. Other important industries are textiles, saw milling, cement products and pharmaceutical. Recently metals, paper products, and chemical industries have been established.

Agriculture Sector

Although agriculture accounts for about 13% of GDP it provides livelihood for half of Zambia's population.

Small scale farm families make up over 90% of farming population. Main crops that are grown in Zambia are maize, sorghum, and cassava. Other cash crops are irrigated wheat, cotton, oilseeds, coffee, tobacco, and horticulture crops.

5.2.3 Macro-economic performance

The economy of Zambia was characterised by a growth period between 1964 and 1974. A gradual economic decline followed after 1974. Rapid growth of the economy during 1960s and early 1970 was primarily due to the booming of the copper prices. However, from 1974 to 1975 the price of copper dropped from US$0.90 to US$0.50 per pound (lb). From 1974, the GDP has fallen significantly while population growth has remained high, causing a decline in per capita income, from US$705 GDP in 1981 to US$551 in 1987.

Poor performance of the Zambian economy in the 80's brought about a breakdown in social services delivery systems. By late 1991, approximately 40% of young children suffered from chronic malnutrition and households spent an average of 70% of their income on food (CSO).

The new government has embarked on reforms that will turn around the economy. Therefore, environmental strategies must complement macro-economic measures aiming to provide the right incentive structure for sustainable economic growth development.

5.3 Structural adjustment programme and privatisation

At the time of take-over of the Movement for Multiparty Democracy (MMD) Government in November 1991, the Zambian economy was characterised by numerous problems such as high inflation, overvalued exchange rate, unattractive interest rates, controlled prices, large budget deficits, broken down infrastructure, shortage of basic goods and services, loss making parastatals, etc.

In the last three years, the MMD Government with support from the IMF, World Bank, and other bilateral institutions have introduced Structural Adjustment Programmes with emphasis on free market and liberalised macro-economic policies. Some of the major measures introduced include removal of subsidies, freeing of interest rates, removal of exchange control regulations, a market determined exchange rate, privatisation of the parastatal sector.

These measures have no doubt brought up significant achievements. Macro-economic stability is being achieved through reduction of inflation and interest rates from over 150% and 100% to 35-40% and 30-35% respectively. Exchange rate is stabilising with a corresponding effect on food prices being stable. Infrastructure is gradually being rehabilitated.

The privatisation programme continues to make steady progress with 12 out of over 150 companies privatised.

The measures have also brought about negative effects particularly in the productive sectors of the economy notably agriculture, and manufacturing. Performance in the manufacturing sector in particular has been declining over the last three years during which period about 50,000 people have lost employment.

At the same time, the products from this sector are unable to compete in the domestic and international market place.

In the early stages of the introduction of the Structural Adjustment Programme, high interest rates and inflation contributed significantly to the decline in the performance of manufacturing and agriculture sectors, the latter further being aggravated by the drought and a liberalised marketing system.

However, as interest rates and inflation stabilise, the agriculture and manufacturing sectors of the economy are bound to improve. However, the improvement and survival of the manufacturing sector will largely depend on the need to enhance competitiveness and efficiency of the productive sector through increased productivity and provision of good quality goods and services. This can only be achieved through investment in new technologies and processes and accompanied by an aggressive research and development programme.

As far as the energy sector is concerned, the structural adjustment programme has entailed liberalisation of the pricing system. Energy based industries are now able to charge economic tariffs to their customers, taking account of all the economic factors including replacement and operational costs, and profit. However, due to the prolonged period in which most of the tariffs were uneconomic, it will take some time for the energy industry to stabilise especially as for re-investment in technology and plant and machinery is concerned.

5.4 Overview of the institutional set up for national planning related to the environment

Climate convention has been signed under the jurisdiction of the Ministry of Environment and Natural Resources. There are currently 23 Ministries which have a bearing the environment. The major ones being:- The Ministries of Environment and Natural Resources, Mines, Agriculture, Lands, and Energy and Water Development. Within these Ministries, there are altogether 28 pieces of legislation on the environment.

In accordance with the proposed National Environmental Action Plan the following are the recommendations:-

i) The Ministry of Environment and Natural Resources must formulate environmental policies and co-ordinate and monitor the implementation by other ministries.

ii) Environmental Impact Assessments must be demanded from investors and developers and evaluated independently.

iii) The Environmental Council of Zambia (ECZ) should designate environmental officers in line Ministries and local authorities to ensure that environmental issues are considered during project development and implementation.

iv) An authority must be established either in the Ministry of Lands or in the Town and Country Planning Department to co-ordinate land use planning.

v) The power of the Chiefs over traditional land should be rationalised.

5.5 Organisation overview for the existing national climate change activities

As discussed earlier, the Ministry of Environment and Natural Resources has the overall jurisdiction of environmental issues and will make the natural communication on environmental issues and policy

Environmental Council of Zambia (ECZ) has the statutory powers to regulate the environment.

In view of the inter disciplinary nature of the climate change activities, the Ministry of Energy and Water Development through the Department of Energy has strong relationship and influence on the nature of energy used and its effect on the environment.

5.6 Review of existing studies and plans on climate change

The first attempt to address some of the problems of climate change was through the Ministry of Energy and Water Development through a comprehensive proposal on Climate change involving compilation of national data, greenhouse gases inventory, vulnerability assessment and adaptation options.

Through initiatives by GTZ and US government, the implementation of climate change has been with the Ministry of Energy and Water Development concentrating on greenhouse inventories, technological options and abatement costing, whilst the environmental Council of Zambia (ECZ) is concentrating on the vulnerability and adaptation components of the study. The two projects are supported by GTZ and US Governments respectively.

In addition the Environment Action Plan addresses the issues of climate change through a number of recommendations.

5.7 Energy sector

5.7.1 Energy supply

The country is well endowed with indigenous energy resources, mainly coal, hydro power and woodfuel. Petroleum products are the only major energy import. Nationally woodfuel contributes the largest share of final energy consumption which was 66% in 1988 and 59% in 1990 (Energy Statistics Bulletin-1990 DOE)

Zambia's hydro power potential stands at over 4000 MW and has developed over 1630 MW. The country has an electricity generation capacity of 1795 MW which includes thermal and gas turbines (owned by the mining conglomerate), diesel sets (8MW) and mini hydro power stations (50MW). Table 5.6 below shows installed electricity capacity in Zambia.

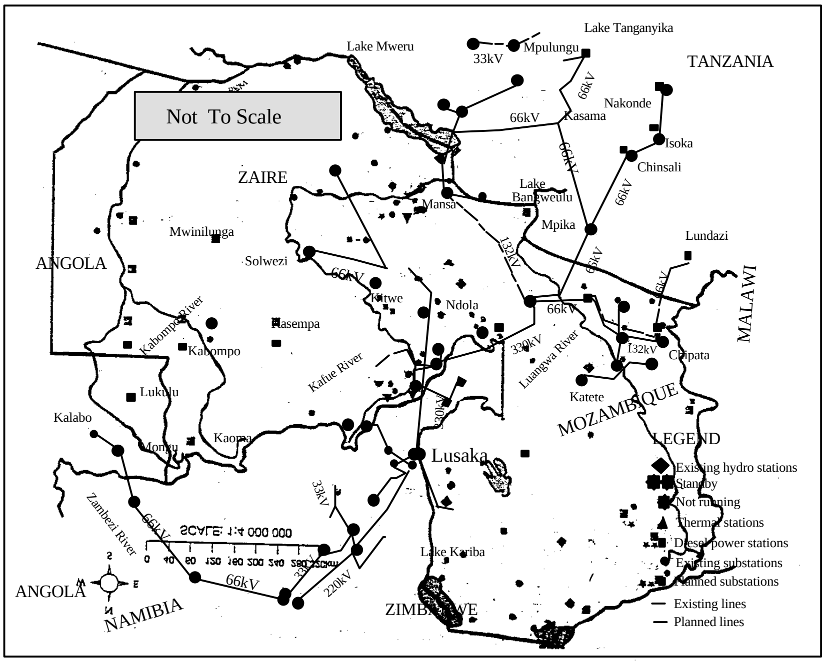
Location		Capacity (MW)
1.	Kafue Gorge	900
2.	Kariba North	600
3.	Victoria Falls	108
4.	Musonda Falls	5
5.	Lusiwasi	12
6.	Chishimba Falls	6
7.	Lunzua	1
8.	Kabwe (ZCCM)	38
9.	ZCCM (Gas Turbine)	80
10.	ZCCM (Waste Heat)	40
11.	Diesel Generators	5
Total		1795

Table 5.6 Installed Capacity

Out of 1795 MW electricity capacity, 1,670 MW is hydro electricity, 80 MW Gas turbine, 40 MW Waste heat, and 5 MW diesel generators supplying isolated systems in North Western Province. The hydro electricity scheme is interconnected. In addition, the Zambian power system is interconnected at high voltage with neighbouring Zimbabwe and Zaire and at lower voltage to Northern Botswana and Namibia. The power system in Zambia is shown on Fig 4.1.

The main hydro power stations are located on Zambezi and Kafue rivers. At Kariba there is the Kariba North Bank Power Station with 600MW capacity. Victoria Falls Power Station on the Zambezi has got an installed capacity of 108MW. On the Kafue river there is the Kafue Gorge Power Station with a capacity of 900MW. The power is mainly generated in the south and transmitted to the main consumption centres in the north of the country. The map below shows national grid network.

Figure 5.1 Map of Power system in Zambia



Source: From B.S.Chitala, M.Sc. Thesis, Rural Electrification in Northern Thailand, ITC, The Netherlands, 1994.

Table 5.7 shows the total energy balance for Zambia for the year 1990. The balance consists of primary and secondary sources of energy.

Energy Balance 1990	Primary energy					Secondary energy											Total
Unit: PJ	Spiked crude oil	Coal	Hydro	Wood	Total primary	Pre-mium	Regu-lar	Diesel/ gasoil	Av. fuel	Kero-sene	Fuel oil	LPG	Bitu-men	Elec-tricity	Char-coal	Total secondary	
Domestic production		10.50	29.00	188.80	228.30											0.00	228.30
Imports	30.00				30.00											0.00	30.00
Variation in stocks	-0.18	-0.43			-0.61	0.02	0.02		0.35	0.01						0.40	-0.21
Total supply	29.82	10.07	29.00	188.80	257.69	0.02	0.02		0.35	0.01						0.40	258.09
Exports		1.20	3.10		4.30	0.06	0.70	0.20			0.03	0.09				1.08	5.38
Domestic supply	29.82	8.87	25.90	188.80	253.39	-0.04	-0.68	-0.20	0.35	0.01	-0.03	-0.09				-0.68	252.71
Refineries	-30.00				-30.00	4.32	1.80	10.24	2.70	1.60	5.04	0.22	0.27			26.19	-3.81
Electric. utilities			-26.01		-26.01									25.50		25.50	-0.51
Kilns				-93.50	-93.50										22.80	22.80	-70.70
Total transformation	-30.00	0.00	-26.01	-93.50	-149.51	4.32	1.80	10.24	2.70	1.60	5.04	0.22	0.27	25.50	22.80	74.49	-75.02
Distribution losses					0.00									1.90		1.90	1.90
For final consumption	-0.18	8.87	-0.11	95.30	103.88	4.28	1.12	10.04	3.05	1.61	5.01	0.13	0.27	23.60	22.80	71.91	175.79
Adjustment		-0.09		-23.45	-23.54	-0.02	0.14	-2.30	0.60	-0.40	1.16	-0.03	0.20	0.90	2.09	2.34	-21.20
Urban households				9.30	9.30					1.10					17.10	18.20	27.50
Rural households				94.40	94.40					0.40					2.60	3.00	97.40
Total households		0.08		103.70	103.70	0.00	0.00	0.00	0.00	1.50	0.00	0.00	0.00	2.10	19.70	23.30	127.00
Agriculture & forestry				3.50	3.50	0.05	0.004	0.38	0.20	0.004	3.20			0.70		4.54	8.04
Mining		5.60		0.05	5.65	0.10	0.01	3.30		0.36	0.43	0.16		15.71		20.07	25.72
Industry & Commerce		3.80		11.40	15.20	0.30	0.05	1.60		0.10	0.03			2.30	0.90	5.28	20.48
Government & Serv.		0.90			0.90	0.28	0.14	0.50		0.004	0.19			1.72		2.83	3.73
Transport					0.00	3.60	0.80	6.60	2.40	0.01		0.01		0.04		13.46	13.46
Total final consumption	0.00	10.38	0.00	118.65	129.03	4.33	1.00	12.38	2.60	1.98	3.85	0.17	0.00	22.57	20.60	69.48	198.43

Table 5.7 Energy balance for Zambia, 1990 (unit PJ)

5.7.2 Energy demand

Tables 5.8 - 5.11 shows the structure and the historic development of the final energy consumption in Zambia. Table 5.8 shows the high share of the final energy consumed in the mining sector. Petroleum accounts for 15% of national energy requirement. Its consumption is dominated by the transport sector which accounts for 52% of petroleum use, with the mining sector taking a proportion of 27.4%. Other petroleum consuming sectors are Commerce and Industry 9.7%, households 5.5%, Government and Services 3.7% and agriculture and forestry 1.7%.

The local consumption of Coal is confined to three sectors as shown on Table 5.8: Mining 53.8%, Commerce and Industry 36.8%, and Government and Services 9.3%. In 1990 coal accounted for about 6% of total energy consumption. The contribution of coal to total energy supply has been declining over the years due to supply constraints at Maamba.

Table 5.9 shows final consumption of conventional energy excluding woodfuel by sector and by source between 1986 to 1990.

Tables 5.11a - 5.11e show final energy consumption by source and sector including woodfuel for each of the years 1986 to 1990, including woodfuel. The conversion factor used to produce the tables is 1 PJ = 23400 TOE.

Table 5.8 Final energy consumption by sector including woodfuel

Sector	Energy Consumption (% of Total)			Woodfuel
	Coal 374920 Mt	Electricity 6350 GWh	Petroleum 597250 Mt	
Agriculture & Forestry	0.0	2.8	1.7	2.8
Commerce & Industry	36.8	9.8	9.7	9.3
Mining	53.9	70.8	27.4	0.1
Transport	0.0	0.2	52.0	19.1
Households	0.0	9.1	5.5	68.7
Government & Services	9.3	7.3	3.7	0.0
Total	100	100	100	100

Table 5.9 Final Energy Consumption by Sector excluding Woodfuel

Unit: PJ	1986	%	1987	%	1988	%	1989	%	1990	%
Households	2.50	4	2.80	5	2.60	4	2.90	4	2.95	5
Agriculture & Forestry	1.03	2	1.20	2	1.22	2	1.80	3	1.14	2
Mining	30.90	52	28.39	48	27.60	45	32.00	48	27.00	47
Industry & Commerce	11.51	19	12.51	21	14.00	23	13.00	19	11.00	19
Government & services	2.10	4	1.93	3	2.84	5	3.93	6	3.21	6
Transport	11.70	20	12.70	21	13.20	21	12.70	19	12.05	21
Total	59.74	100	59.53	100	61.46	100	66.33	100	57.35	100

From Table 5.9, it is evident that final consumption of conventional energy has remained essentially constant between 1986 and 1990. Conventional energy consumption is predominant in the mining, industrial, and transport sectors with ratios of 47%, 19% and 21.0% in 1990 respectively. The household and agriculture sectors consume relatively small amounts of conventional energy with ratios of 6% and 2% respectively.

Table 5.10 Final energy consumption 1977-1990 by source excluding woodfuel (unit PJ)

Unit: PJ	Petroleum products	%	Electricity	%	Coal	%	Total
1977	33.3	47	20.8	29	17.4	24	71.5
1978	31.1	43	20.0	28	21.4	30	72.5
1979	27.6	42	20.4	31	17.0	26	65.0
1980	28.4	43	20.8	31	17.1	26	66.3
1981	27.9	44	21.5	34	13.0	22	62.4
1982	26.0	41	22.9	36	14.0	23	62.9
1983	25.5	41	22.8	37	13.4	22	61.7
1984	23.5	40	22.4	38	12.8	22	58.7
1985	22.5	39	22.6	39	13.1	22	58.2
1986	21.6	36	23.6	40	14.5	24	59.7
1987	23.3	39	23.9	40	12.3	21	59.5
1988	24.1	39	23.3	38	13.9	23	61.3
1989	29.8	45	23.3	35	13.0	20	66.1
1990	23.5	41	23.3	41	10.4	18	57.2

From Table 5.10, showing the development in the period 1977-1990 it is clear that the contribution of petroleum products and coal showed a decline from 47% and 24% in 1977 to 41% and 18% in 1990 respectively. In the case of coal, the decline is largely due to difficulties of investment being focused by the only mine, Maamba Colliery. For petroleum products, this has been due to a decline in economic activities especially in the mining industry. Electricity, on the other hand, has experienced an increase from 29% to 41% mainly due to aggressive electrification programme coupled by consumers switching over to use of electricity for their respective purposes.

Table 5.11a Final energy consumption by sector and source including woodfuel (1986)

Unit: PJ	Petrol		Diesel/ LSG	Jet A1/ Av.Gas	Kero-sene	Fuel oil	LPG	Electri-city	Coal	Fire wood	Char-coal
	Premium	Regular									
Households					0.68			1.83		81.55	23.42
Agriculture & Forestry			0.65		0.01			0.36		8.70	
Mining	0.07	0.06	3.10		0.26	2.64		17.05	7.74	0.01	0.10
Industry & Commerce			1.16		0.14	0.80	0.10	3.27	6.05	8.69	0.60
Government & services					0.01	0.26		1.14	0.69		
Transport	3.35	0.80	5.87	1.70	0.02						
Total	3.42	0.86	10.78	1.70	1.12	3.70	0.10	23.65	14.48	98.95	24.12

Table 5.11b Final energy consumption by sector and source including woodfuel (1987)

Unit: PJ	Petrol		Diesel/	Jet A1/	Kero-	Fuel	LPG	Electri-	Coal	Fire	Char-	Total
	Premium	Regular	LSG	Av.Gas	sene	oil		city		wood	coal	
Households					0.81			2.00		83.90	24.20	110.91
Agriculture & Forestry			0.63		0.01			0.50		6.93		8.07
Mining	0.07	0.05	3.26		0.41	2.80		17.30	4.54	0.01	0.08	28.52
Industry & Commerce			1.47		0.14	0.80	0.09	2.90	7.08	9.12	0.60	22.20
Government & services						0.05		1.23	0.65			1.93
Transport	3.84	0.79	6.05	1.98	0.02							12.68
Total	3.91	0.84	11.41	1.98	1.39	3.65	0.09	23.93	12.27	99.96	24.88	184.31

Table 5.11c Final energy consumption by sector and source including woodfuel (1988)

Unit: PJ	Petrol		Diesel/	Jet A1/	Kero-	Fuel	LPG	Electri-	Coal	Fire	Char-	Total
	Premium	Regular	LSG	Av.Gas	sene	oil		city		wood	coal	
Households					1.09			2.56		87.60	18.37	109.62
Agriculture & Forestry			0.55		0.02			0.43		5.53		6.53
Mining	0.08	0.04	2.82		0.48	2.80		16.95	4.40	0.01	0.07	27.65
Industry & Commerce			1.71		0.77	0.52	0.06	3.38	8.32	9.57	0.64	24.97
Government & services					0.040			2.69	1.26			3.99
Transport	4.72	0.75	6.88	1.98	0.02			0.05				14.40
Total	4.80	0.79	11.96	1.98	2.42	3.32	0.06	26.06	13.98	102.71	19.08	187.16

Table 5.11d Final energy consumption by sector and source including woodfuel (1989)

Unit: PJ	Petrol		Diesel/	Jet A1/	Kero-	Fuel	LPG	Electri-	Coal	Fire	Char-	Total
	Premium	Regular	LSG	Av.Gas	sene	oil		city		wood	coal	
Households					1.09			1.83		90.13	19.03	112.09
Agriculture & Forestry	0.09	0.02	0.88		0.10			0.68		4.41		6.18
Mining	0.09	0.03	3.87		0.48	3.20		16.12	7.31	0.01	0.06	31.18
Industry & Commerce	1.33	0.31	3.88		0.47	0.18	0.01	2.08	4.54	10.06	0.67	23.53
Government & services	0.33	0.21	0.53		0.004	0.01		1.69	1.16			3.94
Transport	3.52	0.65	6.30	2.22	0.01			0.03				12.74
Total	5.37	1.23	15.46	2.22	2.17	3.38	0.01	22.43	13.00	104.62	19.76	189.65

Table 5.11e Final energy consumption by sector and source including woodfuel (1990)

Unit: PJ	Petrol		Diesel/	Jet A1/	Kero-	Fuel	LPG	Electri-	Coal	Fire	Char-
	Premium	Regular	LSG	Av.Gas	sene	oil		city		wood	coal
Households					1.45			2.13		92.73	19.71
Agriculture & Forestry	0.05	0.004	0.38	0.02	0.004			0.66		3.52	
Mining	0.10	0.01	3.33		0.36	3.20		15.71	5.61	0.004	0.05
Industry & Commerce	0.29	0.05	1.57		0.36	0.43	0.16	2.27	3.82	10.56	0.90
Government & services	0.29	0.15	0.48		0.004	0.03		1.72	0.97		
Transport	3.58	0.79	6.56	2.44	0.01	0.20	0.01	0.04			
Total	4.30	1.00	12.33	2.45	2.20	3.85	0.18	22.53	10.41	106.81	20.67

From Tables 5.11, it is evident that out of Zambia's total final energy consumption of 187 PJ in 1990, firewood accounted for 57%, charcoal 11%, electricity 12%, petroleum 15% and coal 5%. Other energy sources such as wind, geothermal and solar are insignificant.

5.8 Energy resources in Zambia

Zambia is fortunate to be endowed with energy resources. Woodlands and forests are estimated to cover 50 million hectares or 66% of the total area. Table 5.12 shows land cover and use in Zambia.

Table 5.12 Land cover and use in Zambia

Land Cover	Land Use (million ha)					
	Protected Areas		Unprotected areas	Potential extent	Crop land (plus	Actual Extent
	Forest reserve	National parks		Protected+ unprotected	fallow)	
Forest:	**0.63**	**0.30**	**3.75**	**4.68**	**0.52**	**4.16**
Evergreen	0.35	0.23	2.86	3.44	0.34	3.01
Deciduous	0.23	0.07	0.57	0.87	0.09	0.78
Montane	0.00	0.00	0.08	0.08	0.00	0.08
Swamp	0.00	0.00	0.15	0.15	0.00	0.15
Riparian	0.00	0.00	0.09	0.09	0.00	0.09
Plantation	0.05	0.00	0.05	0.05	0.00	0.05
Miombo woodland:	**5.47**	**3.10**	**30.82**	**39.39**	**13.55**	**25.84**
Wet	3.41	0.60	18.42	19.37	6.66	12.71
Dry	1.23	1.80	9.56	11.48	5.91	5.57
Kalahari	0.83	0.70	7.01	8.54	0.98	7.57
Savannah woodland:	**0.40**	**1.33**	**7.49**	9.22	0.34	**8.88**
Mopane	0.23	0.99	2.63	3.85	0.19	3.66
Munga	0.12	0.11	2.72	2.95	0.15	2.80
Termitaria	0.05	0.23	2.14	2.42	0.00	2.42
Grassland:	**0.94**	**1.21**	**18.53**	**20.68**	**1.43**	**19.25**
Wetland	0.01	0.54	12.46	13.01	1.43	11.58
Dambo	0.93	0.67	6.07	7.67	0.00	7.67
Lakes:	**0.00**	**0.00**	**1.29**	**1.29**	0.00	**1.29**
Natural	0.00	0.00	0.66	0.66	0.00	0.66
Man-made	0.00	0.00	0.63	0.63	0.00	0.63
TOTAL	**7.44**	**5.94**	**61.88**	**75.26**	**15.84**	**59.42**

Source:Based on 1:500 000 vegetation map of Zambia (Edmonds, 1976), Schultz (1974), Adeyoju (1991) and Chidumayo (1994).

The hydropower potential is estimated at 4000 MW with an installed capacity of 1795 MW. Coal reserves exceed 30 million tonnes. These energy resources satisfy about 88% total energy demand, the remainder being met by petroleum, all of which is imported.

The energy consumption pattern simply shows the importance of woodfuel in meeting national energy needs.

Woodfuel consists of firewood and charcoal. Firewood is normally burnt in open three-stone stoves while charcoal is burnt in tin stoves with perforated walls. Firewood is the dominant fuel in rural areas while charcoal is predominantly an urban energy source. The average amount of fuelwood, charcoal, and kerosene consumed by an average rural and urban household are estimated as shown in Table 5.13.

Table 5.13 Amounts of fuels used by households (per month)

Fuel type	Rural Households		Urban Households	
	Consumption	%using fuel	Consumption	%using fuel
Charcoal	11.3 kg		92.65 kg	83
Firewood	639.1 kg		80.66 kg	38
Kerosene	-		8.4 ltrs	80

*Source:[***]Data recalculated from DOE Energy Statistics bulletin (1974-1990) and Chidumayo 1993 (Interim report).***DOE/WB Energy Household Survey - 1988*

The changes in the average household sizes in Zambia between 1969 and 1990 are shown in Table 5.14.

Table 5.14: Household size in Zambia between 1969 - 1990[+]

Year	Size	Annual Change (%)
1969	4.65	0.9
1980	5.10	3.5
1990	6.90	

Source: [+]Chidumayo 1993 - Interim report on "Wood used in charcoal production in Zambia."

Woodfuel burning is not releasing carbon dioxide to the atmosphere if the biomass is in balance, the emissions are absorbed under the regrowth. But if the area covered by forest is diminished/increased a net emission/absorption of CO_2 has taken place. This balance has yet to be determined. Aggregate figures on forest resources show that Zambia has enough woodland to meet both energy and non-energy needs. However, there is an imbalance in the spatial distribution of forests and population. For instance, in 1986 the Copperbelt and Lusaka areas where 37% of total population resided had only 8% of the national woodland. This situation has led to the localised deforestation due to combined effects of tree cutting for agricultural expansion and charcoal production.

As indicated earlier, woodfuel, in the form of firewood and charcoal, is the principal source of energy in the country accounting for 68% of total energy supply. When translated into wood, charcoal accounts for 44% of wood consumed for energy and firewood contributes 56%.

The sectoral pattern of woodfuel consumption is dominated by households which consume 86.8% of this energy source. The percentage consumption by other sectors is as follows: Agriculture 3.3% and Commerce and Industry 9.9%.

Petroleum is the only major energy source that is wholly imported. It arrives to Zambia through the 1704 km Tazama pipeline from Dar es Salaam to Ndola and is later refined at the INDENI refinery in Ndola.

The country is self-sufficient in coal reserves. These stand at about 30 million tonnes. The coal is mined at Maamba mine in the Southern Province, in the Zambezi valley. At the present rate of exploitation for both domestic and export markets these reserves can last another 25 years. There are indications that coal deposits exist in other parts of the country. However these are unproven reserves. In the last 5 years, production at Maamba has been declining from a production of over 500,000 tonnes per annum 5 years ago to below 300,000 tonnes in 1994. This is due to reduced performance in plant and machinery which require new investments.

Zambia is also endowed with a variety of renewable energy resources such as solar, mini-hydro and wind. Some of these resources occur in large quantities though they remain largely untapped. Zambia has, on average, 2600 - 3000 hours of sunshine per year. This gives on average annual solar radiation of about 4 kilowatt-hours per square meter per day ($kWh/m^2/day$) with a peak of solar energy being received in October and November. Solar energy is being used on a limited basis for a variety of purposes such as powering telecommunication equipment, water pumping, domestic water heating, refrigeration and drying. There is a wide demand for the increased use of this renewable energy source.

The wind speeds in the country vary between 0.1 - 3.5 meters per second (m/s) with an annual average of 2.5 m/s. The wind regime in Zambia is suitable for water pumping and a limited number of windmills have been installed by individuals for this purpose.

The estimated mini-hydro potential is about 50 MW mainly in the North and Western parts of the country. The exploited proportion of mini-hydros is still low with only 10% of the potential being utilised.

5.9 Energy policy

The energy policy of Zambia is seen against a background of making the energy sector the engine of growth and development in the country. In this vein it is dynamic and responsive to the ever changing developmental needs and goals of the country. The utilisation of energy resources must also contribute to a safe and health environment. The sectoral policy initiatives are outlined below.

Woodfuel

-Ensure management and sustainability of forest resources for woodfuel harvesting.

-Improve technological base of charcoal production and utilisation.

-Minimise seasonal fluctuation in the supply of charcoal in the urban centres.

-Support efforts directed at upward substitution of energy to higher value sources like electricity and New and Renewable Sources of Energy (NRSE).

Electricity

-Restructuring the electricity supply industry (ESI) in order to enhance the delivery of the service.

-Improve accessibility to electricity.

-Promoting electrification of productive and socially viable areas.

-Developing the hydro potential to take advantage of strategic position of Zambia in the sub-region.

-Review the legislation on electricity in order to align it to the new macro-economic dispersion.

Petroleum

-Ensure security of supply of petroleum products in the country by streamlining the procurement and financing of feedstock and holding of strategic reserves.

-Restructuring of the oil industry in order to improve efficiency at procurement, pipeline transportation, refinery, distribution and retail trading levels.

-Encourage petroleum exploration.

Coal

-Promote the exploration of coal

-Promote the use of coal in industry and commercial operations.

-Continue with studies into the viability of coal as a household fuel

-Keep under active consideration the option of coal in electricity generation.

-Ensure that coal mining and utilisation has least impacts on the environment.

New and Renewable Sources of Energy (NRSE)

-Promote NRSE technological development, diffusion and information dissemination so as to gain wider utilisation of NRSE.

Energy conservation

-Promote energy efficient methods in all sectors of the economy.

-Encourage the use of energy efficient equipment and adherence to energy efficient standards.

-Encourage energy substitution, local resources for imported ones, wherever it is feasible.

Energy pricing policies

The Government will encourage pricing of energy resources that meet the following criteria:

-Replacement costs.

-Operational and maintenance cost.

-Incentives for efficiency, reliability, safety and environmental standards.

-Profitability.

5.10 CO_2 emissions from Zambia

One of the purpose of the study is to quantity as far as possible sources of anthropogenic sources of greenhouse gases notably carbon dioxide (CO_2), methane (CH_4) and nitrous oxides (N_2O).

Inventories of sources of greenhouse gases being undertaken include major industrial processes, such as copper and coal mining and processing, cement, lime and ammonia production, brewery and glass making, fuel combustion (both stationary and transportation), forestry (emissions and sinks), agriculture and other sources such as municipal sources (incineration, land fills and sewage).

Initial studies on inventories on some major sources have been undertaken and work continues. Based on specific IPCC/OECD methodologies, preliminary estimates of major greenhouse gases have been calculated and quantities of such emissions are summarised in Table 5.15.

Table 5.15 Summary of preliminary estimates of green house gases emissions (tonnes) for the year 1990

	CO_2	CH_4	N_2O
A. Energy combustion			
1.Combustion in stationary systems			

2.Combustion in transportation systems			
Petrol	442,020	43.0	46.00
Diesel	805,680	17.9	38.69
3.Combustion using Kerosene	89,250	88.0	
4.Boilers and Furnaces (Fuel Oil)	383,360	4.0	17.99
5.Furnaces (Coal)	502,350		
B. Industrial processes			
1.Cement production	200,000		
2.Lime production	182,000		
3.Ammonia production(net)	26,000		
C. Mining			
1.Coal Mining			
D. Agriculture			
1.Livestock manure			
2.Fertiliser use			
3.Land Use Change			
E. Biomass			
1.Prescribed burning			
2.Land fills			
3.Sewage			
4.Sanitary systems			
5.Combustion in traditional stoves using firewood		8798	
6.Combustion in charcoal stoves			

It should be noted that the results shown in Table 5.15 are so far preliminary. These calculations have been based on emission factors from IPCC/OECD methodologies, and no country specific emission factors have so far been determined. Work continues to determine the emission factors wherever possible.

So far preliminary results though estimates are available from industrial and combustion processes as shown in Table 5.15. Similarly work continues on improving the estimates and from other sources notably, agriculture, biomass, and other sources such as fires and sanitary systems.

From the work done so far only carbon dioxide show major contributions of greenhouse gas emissions in Zambia. Both industrial and combustion processes have relatively significant contributions. On the combustion side, furnaces using coal has the largest contribution of CO_2, followed by furnaces and boilers using fuel oil and then followed by cement and lime production.

The emissions from transportation systems are higher than those from individual industrial process, with combustion in diesel engines giving the highest contribution.

5.11 Mitigation options

Although at this stage, is too early to recommend specific mitigation options. It is no doubt apparent that CO_2 is the major target greenhouse gas requiring attention and adoption of preliminary technological options. CH_4 could be a major source from agriculture.

Based on these preliminary and anticipated results and in view of excess hydro-electricity capacity in Zambia most of the technological options from both supply and demand size may include among the following:

Supply side options:

-Afforestation

-Biogas digesters in rural areas

-Use of photovoltaics

-Improved accessibility to electricity

Demand side options:

-Improved charcoal production and utilisation/management techniques

-Improved traditional stoves

-Increased use of electric stoves

-Improved furnace technology

-Substitution of fuel oil and coal fired furnaces

-Substitution of coal fired with oil fired boilers

-Improved cement and lime production processes

-Increased agricultural productivity

-Energy conservation in industry

5.12 References

1.National Environmental Action Plan

2.Energy Statistics Bulletin 1974-1990 Report

3.National Energy Policy, Ministry of Energy and Water Development, Nov. 1993.

4.IPCC - Methodologies

5.Priority Survey I, Report of Central Statistical Office (CSO), 1991.