Climate Change Mitigation in Southern Africa

Botswana Country Study

EECG CONSULTANTS (PTY) LTD.

Ministry of Minerals, Energy and Water Affairs, Botswana

UNEP

**UNEP Collaborating Centre
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CLIMATE CHANGE MITIGATION IN SOUTHERN AFRICA

BOTSWANA COUNTRY STUDY

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Foreword

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

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

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

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

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

The Botswana country study was carried out by EECG Consultants, led by Dr Peter Zhou, on behalf of the Ministry of Mineral Resources and Water Affairs, Botswana. The work is a continuation of a preliminary study (Phase 1) carried out by the UNEP Centre and the Centres and Ministries in the region. This first phase was instrumental in establishing the background for the detailed mitigation studies of the three countries, Botswana, Tanzania and Zambia, as well as for initiating the regional study of the SADC countries which was carried out as a part of the UNEP/GEF project "Economics of GHG Limitations".

The UNEP Centre wishes to acknowledge the productive cooperation and support offered by the Ministry of Minerals, Energy and Water Affairs, Botswana, and in particular its Department of Energy Affairs, in the execution of this study.

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The Government of Botswana through the Ministry of Minerals, Energy and Water Affairs, for whom the project was conducted, gave its full support throughout the project phase. They also organised and officiated in the national workshops.

The Botswana Power Corporation who are the only power utility in the country, provided useful survey data on sectoral electricity consumption, information which was useful for mitigation analysis.

The tireless participation of all the listed members of the project team in making this a successful project can never be ignored.

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Abbreviations and Acronyms

ADB	- African Development bank
AEEI	- Autonomous Energy Efficiency Improvements
AIDS	- Acquired Immuno-Deficiency Syndrome
BCL	- Bamangwato Consolidated Limited
BEMP	- Botswana Energy Master Plan
BHC	- Botswana Housing Corporation
BMC	- Botswana Meat Commission
BOOT	- Build Own Operate and Transfer
BOT	- Build Operate and Transfer
BPC	- Botswana Power Corporation
BWP	- Botswana Pula
CC	- Climate Change
CFC	- Chlorofluorocarbon
CFL	- Compact Fluorescent lamp
CH_4	- Methane
CO_2	- Carbon Dioxide
CSO	- Central Statistical Office
CTO	- Central Transport Organisation - Botswana
DANIDA	- Danish International Development Agency
DEMS	- Department of Electrical and Mechanical Services (MWTC)
DIY	- Do it Yourself
DOC	- Degradable Organic Matter
DSM	- Demand Side Management
EIA	- Environmental Impact Assessment
ESKOM	- Electricity Supply Commission of South Africa
ESMAP	- Energy Sector Management Assistance Programme (World Bank /UNDP)
FLTV	- Framework for Long Term Vision
FOB	- Free on board
GACMO	- **G**reenhouse gas **A**batement **C**osting Model
GEF	- Global Environmental facility
GDP	- Gross domestic Product

Gg	- Gigagrammes
GHG	- Greenhouse gases
GJ	- Gigajoules
GWh	- Gigawatt-hour
GWP	- Global Warming Potential
ha	- hectare
HE	- High efficiency
HH	- Household
IB	- Incandescent Bulb
IPCC	- Intergovernmental Panel on Climate Change
IPP	- Independent Power producer
kg	- kilogram
kl	- kilolitre
km	- kilometre
kV	- kilovolt
kW	- kilowatt
kWh	- Kilowatt- hour
LDV	- Light Duty Vehicle
LEAP	- Long Range Energy Alternative Planning
LPG	- Liquid Petroleum Gas
Ltd	- limited
M	- million
m	- metre
MCI	- Ministry of Commerce and Industry
MEMBOT	- Macro-Economic Model of BOTswana
MJ	- megajoules
MLGLH	- Ministry of Local Government, Lands and Housing
mm	- millimetre
Mt	- million tons
mtoe	- million tonne of oil equivalent
MVA	- Mega volt*ampere
MW	- Megawatts
MWTC	- Ministry of Works, Transport and Communications
NCSA	- National Conservation Strategy Agency
NDP7	- National Development Plan no.7
NE	- North East

NGO	- Non-Governmental Organisation
N_2O	- Nitrous Oxide
P	- Pula
PV	- Photovoltaics
R	- Rand (South African Currency)
RIIC	- Rural Industries Innovation Centre
SADC	- Southern African Development community (formerly SADCC)
SAPP	- Southern African Power Pool
SE	- South East
SHS	- Solar Home Systems
SO_x	- Sulphur Oxides
SWH	- Solar Water Heaters
t	- tonne (metric ton)
TJ	- Terajoule
UCCEE	- UNEP Collaborating Centre for Energy and Environment
UNEP	- United Nations Environment Programme
UNFCCC	- United Nations Framework Convention on Climate Change
USA	- United States of America
USD	- United States Dollar = US$
yr.	- year
ZESA	- Zimbabwe Electricity Supply Authority
ZESCO	- Zambia Electricity Supply Commission

Energy Constants and Conversion Factors

1 kilocalorie (kcal)	= 4.1868 kJ (kilojoule)
1 British Thermal Unit (BTU)	= 1.05 kJ
1 quad (quadrillion BTUs)	= 10^{15} BTU = 1.055 EJ =10^{10} therms
1 terrawatt-hour (TWh)	= 3.6 PJ
1 tonne oil equivalent (toe)	= 10.0 Gcal = 41.9GJ
1 Barrel oil	= 0.136 tonnes of oil
1000 m^3 natural gas equiv.	= 8.6 Gcal =36GJ = 0.86 toe
1 tonne coal equivalent	= 7.0 Gcal = 29.3GJ = 0.70 toe

Heat Values of Fuels

Power station coal	24 GJ/ tonne
Industrial coal	29.3 GJ/tonne- Botswana coal 24GJ/tonne
Diesel	35.52 GJ/kl
Gasoline	31.74 GJ/kl
LPG	46.4 GJ/kl
Paraffin	34.34 GJ/kl
Jet A1	34.34 GJ/kl
Aviation Gas	31.03 GJ/kl
Firewood	16.3 GJ/tonne
Charcoal	30.0 GJ/tonne

Definitions

AEEI - autonomous energy efficiency improvements relate to spontaneous technological improvements outside the framework of mitigation policy. Technologies have been upgraded for reasons other than GHG abatement and they still continue to be upgraded with respect to energy efficiency for example.

Diffusion/penetration rates- the potential for increasing or introducing a technology/product in the market under study.

Discount rates- this is a factor at which money is devalued with time. This could be similar to the interest rate in the case of opportunity cost of capital. In some instances, it also has the effect of inflation.

Transaction costs- The costs which relate to enabling activities like capacity building which however affect the successful implementation of a project.

EXECUTIVE SUMMARY

Overall Project Framework

This study was carried out in Botswana, Tanzania and Zambia as part of the project "Climate Change Mitigation in Southern Africa" funded by the Danish International Development Agency (Danida). The project was conducted parallel to the UNEP/GEF project "Economics of Greenhouse Gas Limitations" which involved 8 other developing countries and 2 regional projects in Latin America and the SADC region.

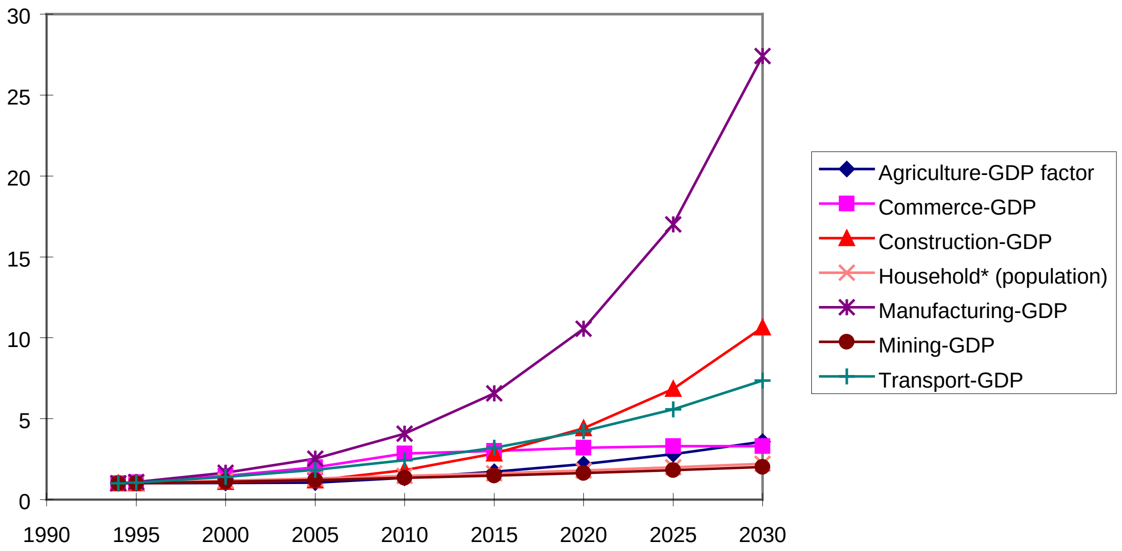
In Botswana, the Danida project focused primarily on the Energy Sector.

Objectives of Project

The project analysed the baseline economic, energy development and greenhouse gas (GHG) scenarios, and abatement costing of plausible greenhouse gas mitigation options in the energy sector of Botswana.

The analysis period for both the baseline and mitigation scenarios is up to 2030 with the short term stretching from 1994 to 2005 and the long term up to 2030. The short-term economic projection was based on Botswana's 7^{th} and 8^{th} National Development Plans which span the periods between 1991-1996/97 and 1996/97-2002/03 respectively. The Long Term economic framework was based on the framework for Botswana's Vision 2016 (Botswana Vision 2016, 1996; 1997) with some modifications (stagnated) for the long term growth rates in the transport and commerce sectors. The sectoral growth patterns in the baseline by assuming the above sectoral growth rates are presented in Fig 1.

Fig 1 Baseline factorial sectoral economic (GDP) growth



Factors are related to 1994/95 base year which has a factor of 1

The economic development as indicated by GDP was then linked to energy intensity in the future energy demand scenario and the related GHG emissions for the economic sectors.

The future domestic energy scenario for the domestic sector was calculated based on demographic projections derived by the Central Statistical Office (1996) of Botswana (Table 1).

Table 1 Projected de-facto national, urban and rural populations

	1991*	1994	2005	2030
Urban-towns	286 779	328 203	524 276	1 209 410
Urban villages & Rural villages	1 040 017	1 097 195	1 439 615	2 480 383
Total	1 326 796	1 425 398	1 963 891	3 689 793

**Census Year*

For the transformation or Power sector, the current power plants and the ones planned in the time horizon were considered in the baseline scenario.

Modelling

The modeling tools from which secondary socioeconomic and energy data were derived are the Macro-Economic Model of Botswana (MEMBOT) and the Botswana Energy Master Plan (BEMP) respectively. The Long Range Alternative Planning (LEAP) and the Greenhouse gas Abatement Costing Model (GACMO) were used in this study to create the baseline scenario and the abatement costing of mitigation options respectively.

The LEAP model was then used to produce the energy and GHG baseline scenarios for the time frame to 2005 and 2030 by assuming the autonomous energy efficiency improvements (AEEI) quoted in Table 2

Table.2 Assumed AEEI values for the various fuel technologies

Fuel	AEEI % per annum
Fuelwood	-0.5
coal	-0.5
paraffin/kerosene (domestic)	-0.5
other petroleum products	-1.0
solar	-1.0
Agriculture diesel	-0.5
All electricity devices	-1.0

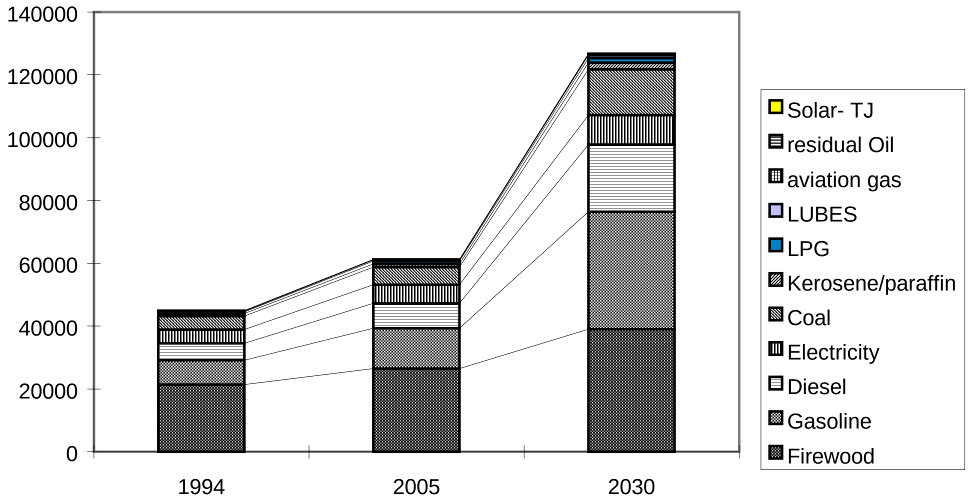
Fuel Demand

The result from the LEAP analysis show that fuelwood is the dominant fuel throughout the time horizon with contribution shares of 43% in 2005 and 31% in 2030.

Gasoline is the second largest fuel in demand in 2005 (21%) and 2030 (30%) but shows faster annual growth rates (4.4-4.7%) in demand than fuelwood (1.6% to 2%). The other important energy source/fuels in the total energy demand are diesel (13-17%), electricity (7-10%) and coal (9-12%) as shown in Fig.2. The other petroleum products consisting of aviation gas, kerosene/jetfuel, fuel oil, lubes and LPG together with solar are expected to contribute the remaining 3 to 4% to the total energy fuel/source demand in the future scenario.

Petroleum products generally will have the highest annual growth rates (>3.5%) in demand especially in the short term. All the fuel/source demand annual growth rates will decline in the long term except for coal, lubes, diesel and aviation gas which show higher annual growth rates between 2005 and 2030.

Fig.2 Projected Energy Fuel demand in the Baseline 1994-2030. (TJ)



The overall annual growth rates in total energy demand for the demand side are 2.9% in the short term and 3% in the long term.

Sectoral Energy Demand

Fig. 3 show that up to 2005, the household sector will still be the largest consumer of energy in Botswana contributing 45% to the total energy demand. Transport (28%), Industry (16%) and Commerce (10%) are the next largest energy contributing sectors.

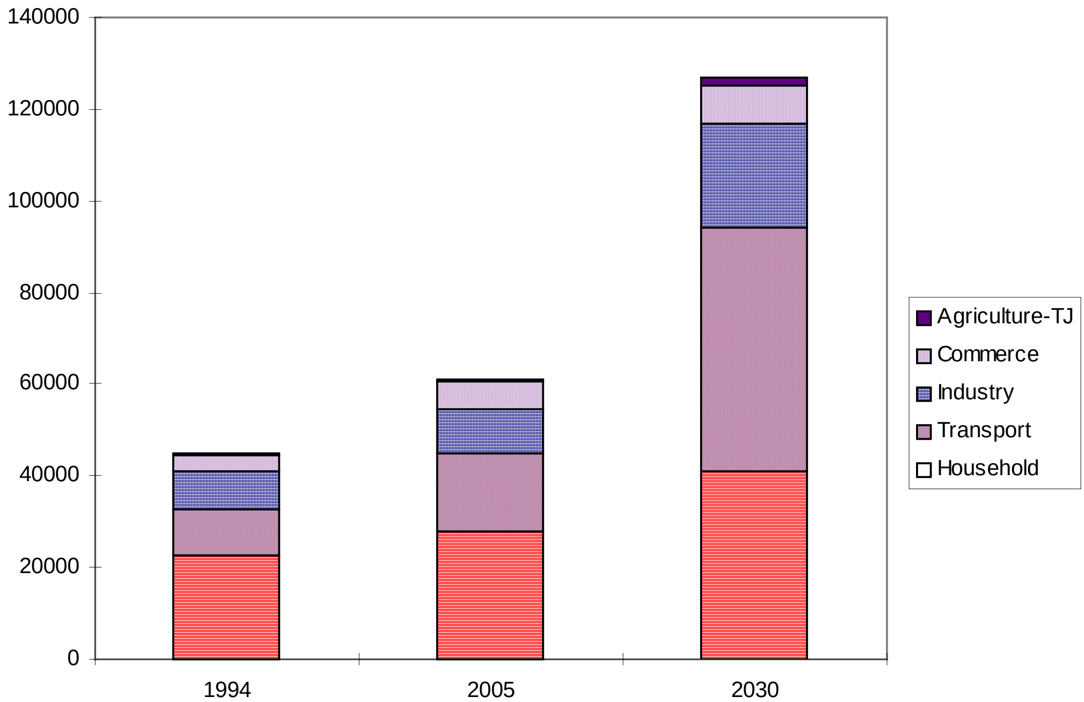
Agriculture will contribute only 1% to the sectoral energy demand.

The household sector is however overtaken by the transport sector in 2030 (Fig 3.2.2) as the sector with the largest contribution to the energy demand with 42% share compared to fuelwood which will contribute 32%.

The transport sector energy demand is expected to grow 5 times between 1994 and 2030 while energy demand in all the other sectors will only increase by at most 3 times.

Transport and industry sectors show an increase in their shares in the long term while the household and commerce sectors shares are reduced. Agricultural energy share remains constant at 1% throughout the time horizon.

Fig 3 Projected Sectoral Energy demand in Baseline 1994-2030 (TJ)



Energy Demand annual growth rates will be highest in the Commerce and Transport sectors in the short term with growth rates of 5.6% and 4.6% respectively. The other sectors have annual growth rates of 2% and below. Transport energy demand growth rate is consistent in the long term while that of Commerce declines to 1.2%. Energy demand annual growth rate of the agricultural and industrial sectors to 4.4% and 3.5 % respectively in the long term. The annual growth rate for the household sector declines in response to decline in the growth of fuelwood demand.

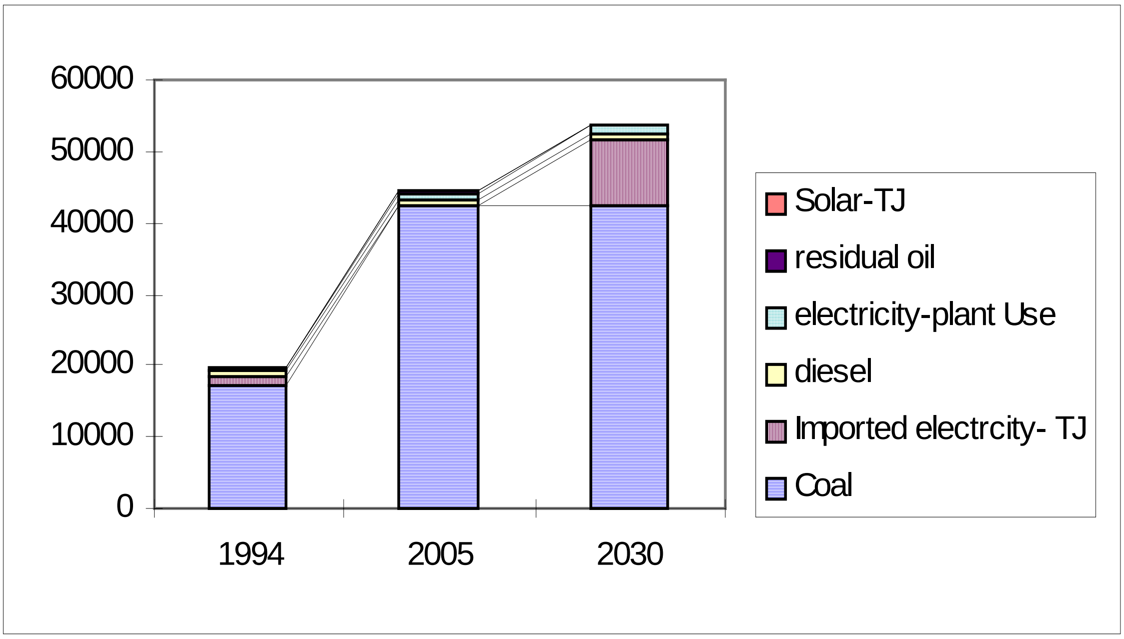
Major energy growth will occur in the transport sector because the sector responds to growth in all the other sectors. Energy demand in Industry will also be increasing in the long term due to expected rapid growth in manufacturing. The energy demand in Industry will significantly be reduced if the BCL mine closes as the mine is the largest consumer of electricity and coal on the Demand Side in Botswana.

Transformation energy

Transformation Input Energy Demand by Fuel

Fig 4.shows the energy fuel/source demand in the transformation/power sector.

Fig 4 Projected fuel demand for electricity generation in baselineby fuel (TJ).



Coal will be the dominant fuel used in the power sector contributing 95% and 78% into the total transformation energy inputs in 2005 and 2030 respectively.

Actual coal demand however will stagnate after 2005 as power imports become increasingly important after 2005. The zero power imports of total energy inputs in 2005 is a reflection of increased local generation capacity at Morupule of 240MW which is expected in 2003. Beyond 2005 imports are the second largest energy input contributing 18% to the total transformation input energy by 2030.

Electricity for plant use and diesel for diesel plants also do not increase after 2005 but together contribute 3 to 5% to the transformation energy input. The highest annual growth rates in fuel demand will be registered in the short term except for imported power which will decline. Plant electricity demand, fuel oil and coal will have high growth rates of 8.3%, 5.5% and 9.8% respectively responding to the upgrade o local generation at Morupule Power Station. Diesel demand will increase slowly (1.1%) in the short term as a result of anticipated growth in demand for DEMS power.

In the long term, growth rates of fuel/source demand are zero for all the energy sources/ fuels except for imported power and solar energy which grow at 4.4% and .8% respectively.

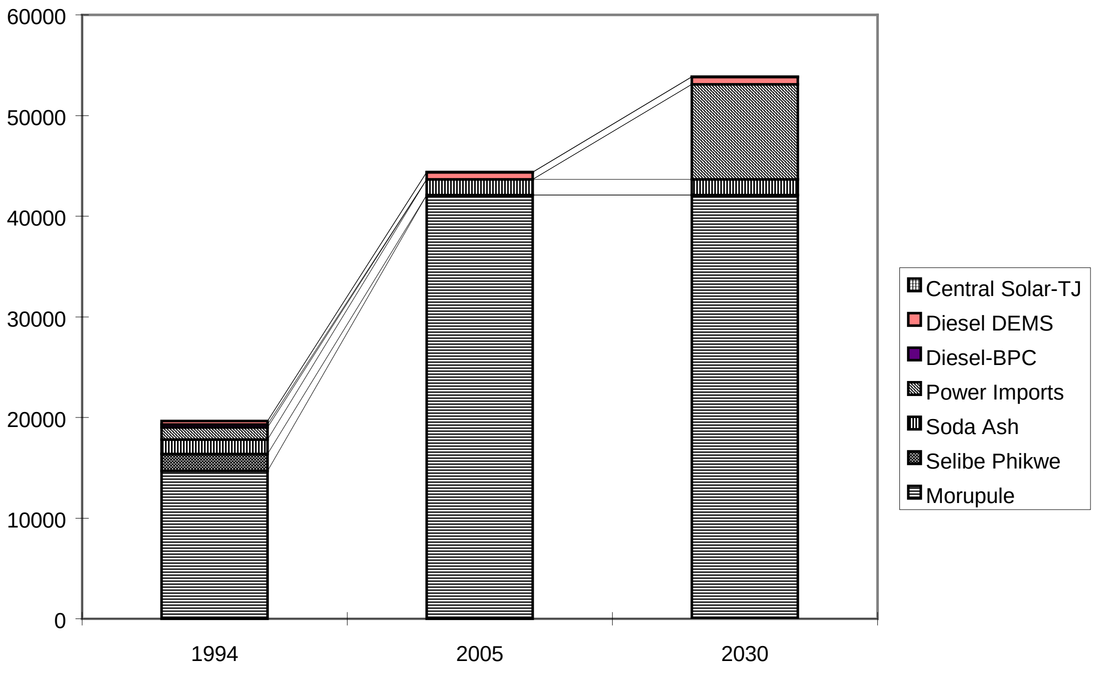
The proportion of imports increases in the long term to meet increasing electricity demand in the absence of additional local generation capacity.

Solar energy input will be increasing but will still be small to make a dent in the power sector.

Energy Demand by Power Plant

Fig 5 sows the transformation energy inputs for the power plants expected to be in operation in the study horizon.

Fig 5 Projected transformation input energy demand in the baseline by power plant (TJ).



Morupule Power Plant will be the main consumer of energy in the Power sector and also the largest local generation plant with a demand of 95% and 78% of the total transformation energy inputs in 2005 and 2030 respectively.

Botswana Soda Ash generation plant will have a constant capacity of 20MW throughout the time horizon hence the constant energy input demand. The plant energy demand share will be about 3 to 4% of the total transformation energy inputs throughout the time horizon.

Diesel plants operated by the Department of Electrical and Mechanical Services (DEMS) will have an energy demand share of about 1% to 2%. Diesel plants operated by the Botswana Power Corporation will be slowly phased out to be negligible in 2005.

Selibe Phikwe energy input demand is only reflected in 1994 since the plant was decommissioned in 1996 but had an energy input share of 8.5% in 1994.

Whilst centralised solar plants are expected to steadily increase in capacity to about 5 MW by 2030, the solar energy input share in the power sector will still be negligible (0.1%).

Baseline GHG Emissions

The total calculated CO2 equivalent emissions in 2005 and 2030 were found to be 7300 Gg and 11700 Gg respectively compared to the base year (1994/95) emissions of 3800 Gg.

Demand and Transformation Side GHG Emissions

The electricity generation sector will release 59% (4318) of the total energy sector CO_2 equivalent emissions (7317 Gg) in 2005. The demand sectors which will release 2426 Gg (33%). Coal production will be responsible for 8% of the emissions in the same year. On the individual gases, the electricity sector will emit 66% of the CO_2, 1% of CH_4 and 59% of N_2O compared to the demand sectors which will emit 34% for CO_2, 17% of CH_4 and 41% of N_2O. The highest CH_4 emissions (82%)of total energy sector CH_4 emissions in Botswana will be due to Coal mining.

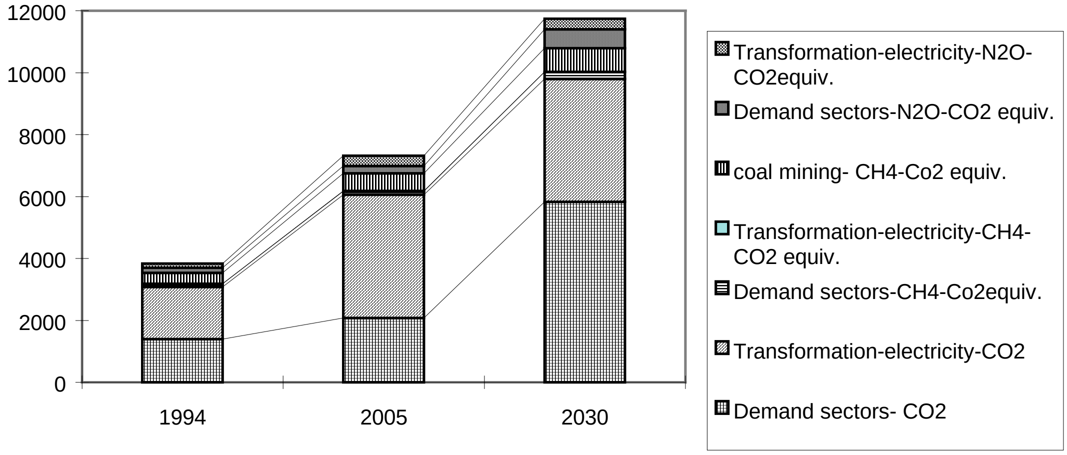
In the long term (2030) the demand side becomes dominant emitting 57% of the total CO_2 equivalent emissions followed by the electricity sector with 41% and coal mining with 7%.

The demand side will also emit 22% of the CH_4 and 65% of the N_2O emissions in 2030. The high CO_2 and N_2O emissions will result from the high petroleum products demand particularly gasoline/petrol and diesel in the transport sector. The electricity or transformation sector will emit 1% of the total energy sector CH_4 in Botswana and 35% of the N_2O in the same year. Coal mining will still dominate the CH_4 emissions with 77% of the total CH_4 emissions. Fig 6 shows the GHG growth pattern in the baseline.

The combination of high petroleum products and coal demand in industry will exceed coal for transformation which will not increase after 2005 hence the higher CO_2 emissions for the demand side. Petroleum products also have a higher N_2O coefficient than coal.

The distribution of CO_2 equivalent emissions in the baseline would suggest placing GHG abatement emphasis on the transformation in the short term and on the demand-sectors in the long term. The selection of mitigation options however depends on the available opportunities in the sectors.

Fig. 6 Baseline GHG emissions from energy demand and supply sectors, by gas type expressed as CO_2 equivalent in Gg.



Sectoral GHG Emissions

In the short term, power generation/transformation sector excluding emissions from coal mining will be responsible for 59% of the total CO_2 equivalent emissions (7317Gg) followed by the transport sectors with 18% (Table 3.5.2-ANNEX). This is not surprising as these are the sectors consuming most of the fossil fuels namely coal, petrol and diesel respectively. Coal mining will emit CH_4 emissions equivalent to 8% of the total CO_2 equivalent emissions.

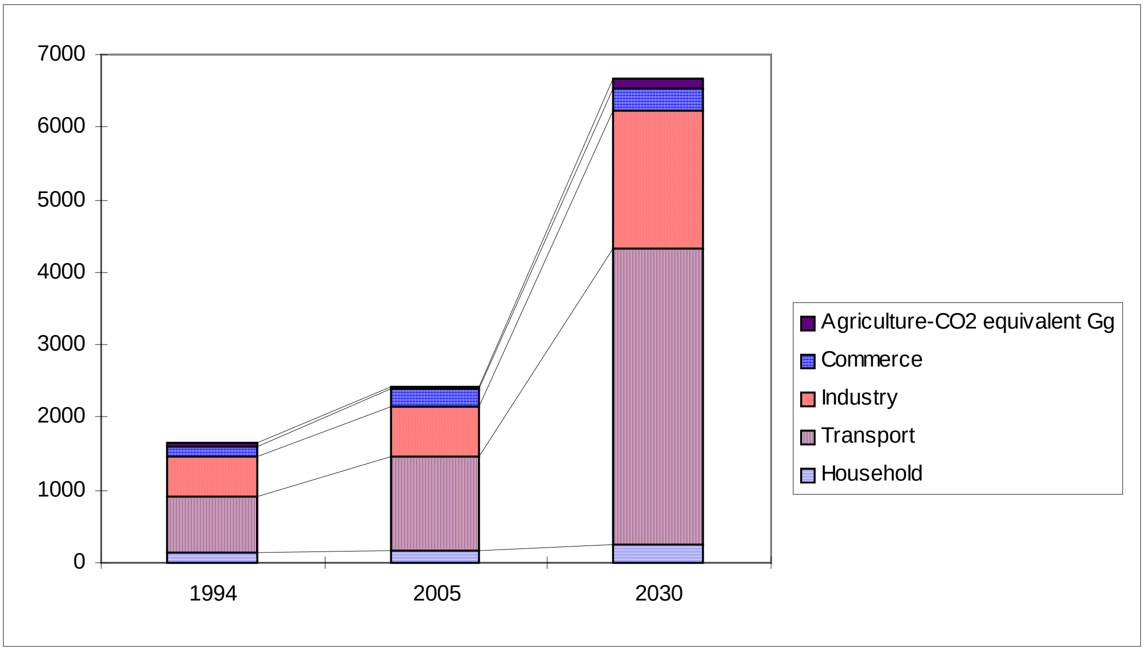
Industry and commerce will contribute 9% and 3% to the total CO_2 equivalent emissions respectively. The household and the agricultural sector will contribute the remaining 3%.

Although in the long term the power /electricity sector remains the dominant emitter (37%) the transport sector emissions will also dramatically increase to 35% of the total CO_2 equivalent emissions (10530 Gg). Industry and coal mining will contribute 16% and 5% to the emissions respectively. The rest of the emissions will be emitted by commerce (3%), households (2%) and agriculture (1%).

Fig 7 shows the anticipated CO_2 equivalent emissions growth pattern by sector.

The sectoral emission distribution would suggest aiming to reduce GHG emissions from the power generation, transport and industry sectors as these are the major emission ones. The determining factors however also include availability of adequate and appropriate data for analysis. In the mitigation analysis, criteria of option selection could also be based more on the impact of an option on the economic and social development even if the level of greenhouse gas is small. Taking into consideration the above issues a portfolio of GHG abatement options was selected from the various sectors as presented in Chapter 4.

Fig 7 CO_2 equivalent emissions by activity/sector type (Gg)



Selection of Mitigation Options

A portfolio of GHG abatement options were identified for the energy sector and GACMO was used to calculate the abatement costs and the potential GHG reduction of these selected mitigation options. In the analysis it was ensured that the penetration rate of each option was a proportion of the total penetration capacity in the baseline produced by LEAP.

The mitigation options presented here are for both energy supply and energy demand sectors. Selection of the options analysed also considered data availability and the importance of the options to Botswana's economy. Table 3 summarises the selected options and their penetration rates used in the analysis of each option.

The cost of GHG reduction/ton and total reduction potential for each option were sequenced in a cost curve. The cost curve coupled with Botswana's development priorities and macro-economic impacts of applying the options formed the basis for suggesting the country's mitigation strategy.

Table 3 Plausible mitigation options for Botswana's energy sector

MITIGATION OPTIONS	PENETRATION 2005	PENETRATION 2030
Supply Options		
1. Power Imports-hydro**	240MW	240MW
2. Reforestation- eucalyptus	9810 ha	9810ha
3. Central Solar PV Plant	2MW	49MW
4. Landfill gas for power	69000 tons waste (1.8MW)	169000 t waste (4.5MW)
5. Biogas home plant	13000 plants	21000 plants
Demand Options		
Household sector		
1. Prepaid meters	35000 meters	136 000 meters
2. Efficient Lighting- CFLs	810000 light points	1820000 light points
3. Geyser Timer	56000 timers	145000 timers
4. solar geysers	1000 geysers	2400 geysers
5. Solar PV home systems	25000 SHS	39000 SHS
Industry		
1. Boiler Efficiency	20 boilers	50 boilers
2. Motor Efficiency	30000kW	56000 kW
3. Power Factor Correction	55 MVAR	55MVAR
Transport		
1. Pipeline for petrol & diesel only	441190 toe	1395980 toe
2. Electrified Railway line	2200 kt	4640 kt
3. Road freight to rail	3700 kt	7700 kt
4. Gasoline to diesel switch-road sector only	11320Petr;4380 diesel TJ	35200 ,13610TJ
5. Vehicle inspection	22760TJ fuel km	62060TJ
6. Paved roads	18409505 v-km	18409505 v-km
Agriculture		
1. Conservative tillage	100000 ha	100000 ha
2. Solar PV pump	7300 boreholes	12400 boreholes

** A regional option not included in Abatement Cost Curve

Implementation Aspects

Analysis of implementation aspects for the mitigation options was based on the following parameters:-

- Institutional capacity
- Difficulty in organising and the lead time required
- Transaction costs not included in the cost analysis which could be a hindrance
- Short and long term effects and sustainability
- Government position or policy on the subject

Macroeconomic Impact Assessment Criteria

Each mitigation option was analysed for macro-economic impact based on the following criteria

- Impact on balance of payments
- Revenue collection e.g. in form of taxes
- Employment loss or creation
- savings on energy consumption and avoided fuel import- bills or deferred investments
- Improvement in economic efficiency/competitiveness
- Cross-sectoral linkages
- Improvement in health aspects
- Improvement of social standards, and
- Land rehabilitation.

Mitigation Strategy for Botswana

Cost Curve Analysis

The cost curve is one way of presenting a GHG abatement strategy for a country. It is a graph showing a possible sequencing of mitigation actions based on their costs of implementation. The cost curve logically suggests that options with the lowest cost are implemented first rising to the expensive ones.

Table 4 shows nine (9) mitigation options which can be implemented at negative costs out of the twenty (20) total options analysed. These relate to both electricity and diesel energy savings. Majority of the options in the household electricity savings have negative costs so these can easily be effected with the limited financial resources available in the households.

Those related to diesel savings are mostly in the transport sector. The cost of diesel savings in the transport sector also depends on the intensity of use. The higher the intensity of use e.g. in terms of t-km carried or toe transported, the lower the costs of reduction. Hence the cost of mitigation actions in the transport responds to economies of scale. Notable changes are in the option involving the pipeline and shifting from diesel to electric locomotives. In the case of the pipeline, the cost shifts from positive cost in 2005 to negative cost in 2030 when the fuel demand has increased to warrant the pipeline. The cost of diesel-electric locomotives drops to less than half that of 2005 in the same period as the freight size increases.

All the renewable mitigation options involving both solar and biogas have positive costs due to the currently high costs of equipment purchase. Reforestation programme also has a positive cost due to high water demand for plants in Botswana as a result of the high temperatures.

In terms of GHG reduction potential, the intensity of use or penetration rate and the unit potential are obviously the determining factors.

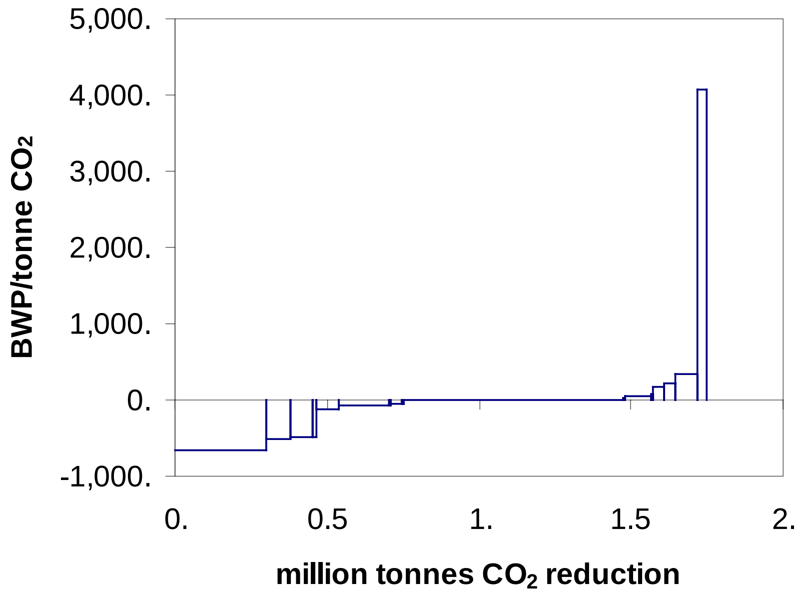
The pattern in the results however shows that in the household sector, a significant GHG reduction can be realised by limiting the geyser/electric water heater consumption.

In the transport sector, pavement of roads and introducing vehicle inspection could result in significant avoided GHG emissions. The expensive options in the transport sector however have relatively low potential for reducing GHG emissions.

Substitution of coal based electricity with hydropower or landfill gas based electricity have significant avoided GHG emissions on the supply side.

The combined effect of all the mitigation options is depicted in Fig. 8 for the short term (2005) and Fig 9 for the long term (2030).

Fig 8 Cost Curve for energy system GHG abatement options 2005



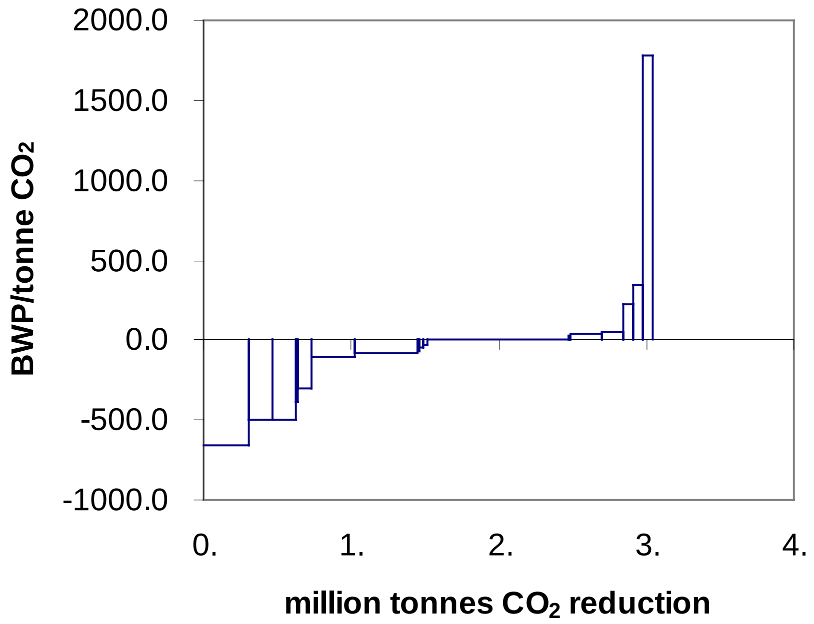
Abatement option	BWP/tonnes CO_2	CO_2 equivalent Cumulative reduction (million tonnes)
1 *paved roads	-660.4	0.30
2 Road freight to rail	-501.7	0.38
3 *Efficient lighting	-495.3	0.45
4 *Tillage	-493.2	0.46
5 *Prepayment meters	-111.2	0.54
6 *Geyser time switches	-84.4	0.71
7 *solar home systems	-67.9	0.71
8 *Power factor correction	-47.6	0.74
9 *Efficient boilers?	-36.7	0.75
10 *Fuel pricing	0.0	0.77
11 *Efficient motors	2.4	0.85
12 *Biogas from landfills	0.0	0.98
13 Vehicle Inspection	8.7	1.48
14 *Solar geysers	27.2	1.48
15 *Biogas for rural households	55.1	1.57
16 Central PV electricity	85.3	1.57
17 *pipeline	178.6	1.61
18 *Solar PV water pumps	223.3	1.65
19 *Reafforestation	342.1	1.72
20 diesel to electric rail	4080.1	1.75

Table4 GHG abatement in the energy sector of Botswana and their costs or reduction and reduction potentials in 2005 and 2030

Mitigation option	**Cost of GHG red. BWP/ton**	**Unit size**	**Driver**	**Fuel used**	**CO_2 equivalent tons/unit**	**Penetration rates 2005**	**Cum. GHG red mt/yr. 2005**	**Penetration rates 2030**	**Cum GHG red. Mt/yr. 2030**
paved roads	-660.4	1	route	petrol/diesel	298950.7	1	0.30	1	0.30
Road freight to rail	-501.7	1	kt-system	diesel	77395.7	1	0.38	1	0.46
Efficient lighting	-495.3	1000	bulb	coal	92.2	810	0.45	1820	0.63
Tillage	-493.2	1	tractors	diesel	26.9	463	0.46	463	0.64
Prepayment meters	-111.2	1	meter	el-coal	2.2	35000	0.54	1	0.73
Geyser time switches	-84.4	1	timer switch	el-coal	3.0	56000	0.71	136000	1.02
solar home systems	-67.9	1	system	paraffin	0.08	25000	0.71	145000	1.45
Power factor correction	-47.6	1	MVAR	el-coal	939.0	39	0.74	39000	1.46
Efficient boilers?	-36.7	1	boiler	coal	475.5	20	0.75	39	1.49
Fuel pricing	0.0	1	fuel system	petrol	15237.0	1	0.77	50	1.52
Efficient motors	2.4	1	kW	el-coal	2.7	30000	0.85	0	1.52
Biogas from landfills	5.4	1	t-waste	el-coal	1.8	69000	0.98	56000	1.67
Vehicle Inspection	8.7	1	fuel system	petrol/diesel	182057.2	1	1.48	1	2.16
Solar geysers	27.2	1	geyser	el-coal	4.9	1000	1.48	169000	2.47
Biogas for rural households	55.1	1	digester	wood	6.6	13000	1.57	2400	2.48
Central PV electricity	85.3	1	MW	el-coal	4374.8	2	1.57	50	2.70
pipeline	178.6 (-307.80)	1	pipeline	diesel	35918.0668	1	1.61	21000	2.84
Solar PV water pumps	223.3	1	pump	diesel	5.5	7300	1.65	12400	2.91
Reforestation	342.1	1	9810 ha	sink	72086.67	1	1.72	1	2.98
diesel to electric rail	4080.1 (1784.50)	1	t-km-system	diesel	26906.6	1	1.75	1	3.04
BASELINE TOTAL EMISSIONS							**7.32**		**11.74**
% GHG REDUCTION							**24%**		**26%**

(1784.50)- 2030 cost/ton as determined by load of freight.

Fig 8 Cost Curve for energy system GHG abatement options in 2030



	Abatement option	BWP/tonne CO_2	CO_2 equivalent cumulative reduction (million tonnes)
1	Road freight to rail	-501.7	0.46
2	*Efficient lighting	-495.3	0.63
3	*Tillage	-381.8	0.64
4	*pipeline	-307.8	0.73
5	*Prepayment meters	-111.2	1.02
6	*Geyser time switches	-84.4	1.45
7	*solar home systems	-67.9	1.46
8	*Power factor correction	-47.6	1.49
9	*Efficient boilers?	-36.7	1.52
10	*Fuel pricing	0.0	1.52
11	*Efficient motors	2.4	1.67
12	Vehicle Inspection	3.2	2.16
13	*Biogas from landfills	0.0	2.47
14	*Solar geysers	27.2	2.48
15	Central PV electricity	44.6	2.70
16	*Biogas for rural households	55.1	2.84
17	*Solar PV water pumps	223.3	2.91
18	*Reafforestation	342.1	2.98

Even if some of the options have small contributions, the overall GHG reduction of these mitigation options is significant at 24%of the total energy sector emissions in 2005 and 26.1% of the emissions in 2030.

Guaranteed hydropower as a mitigation option for Botswana taken in place of the expected expanded capacity in Botswana could alone reduce 2.4 million tons. This option has however not been included in the cost curve as arguments suggest that the option could be more of a regional mitigation option than a national one. The interest should however not be lost to explore how Botswana could benefit from this option.

Sensitivity test with discount rates involved increasing the rate from 6% to 10% and reducing it to 3%. The higher discount rate of 10% resulted in higher costs of reduction but none of the options shifted from negative costs to positive costs. The option of substituting coal power with hydropower was the closest one to shifting in that direction.

Similarly, reducing the discount rate to 3% reduced the costs of mitigation but again none of the options changed sign.

If the cost curve were to be the basis of mitigation strategy in Botswana, then Botswana would initially mop up the opportunities in the household sector which have negative costs and low capital layout followed by the ones with negative costs in the transport sector and power sector since the capital layout is relatively higher. Both the renewables and the expensive transport options would probably be implemented in the long term when it becomes cost-effective to use them.

National Development Priorities and realignment of Mitigation Options

A meaningful GHG abatement strategy in developing countries has to follow the development aspirations of those countries and in this respect, the strategy must take cognisance of the national development policies and possible impacts on the macro economy.

The aspects evaluated in this section included government policy on the mitigation measure/option, ease of implementability and the macroeconomic impacts consisting of impact on balance of payments, employment creation, social benefits like health aspects improvements or income generation, economic efficiency or competitiveness in business, environment enhancement. Consideration was also given where the option accrues benefits in another sector e.g. in form of deferred investments in additional power plants or enhancing agricultural output.

Table 5 is an attempt to rank the analysed mitigation options by considering these aspects. No weights have been allocated to these factors as these are not known but national governments could decide their weighting in the formulation of the GHG abatement strategy.

In this simple approach, only the total number of positive (+) impacts for each mitigation option determined the ranking factor.

Table 5 Ranking of Mitigation Options by national development priorities

No.	Mitigation Option	Cost or GHG Reduction (BWP/ton)	Govt. Policy	Implementability	Impact on balance of payments	employment	social benefits	economic efficiency/ competitiveness	benefits more than one sector	Local environmental enhancement	Ranking
1	paved roads	-660.4	+	+	-/+	+	+	+	+		6
2	Road freight to rail	-501.7	?	?	_/+	_	?	?	?	+	2
3	Efficient lighting	-495.3	+	++	_	0	+	+	+	+	7
4	Tillage	-493.2	?		+	_	?	+	?	+	3
5	Prepayment meters	-111.2	++	++	_	0	+	+	+	+	8
6	Geyser time switches	-84.4	?	+	_	?	+	+	+	+	5
7	solar home systems	-67.9	++	++	_ _	+	++	?	?	+	8
8	Power factor correction	-47.6	+	+	- -	?	?	+	+	+	5
9	Efficient boilers?	-36.7	?	+	_	?	+	+	+	+	5
10	Fuel pricing	0.0	?	++	0	0	_ _	?	0	?	2
11	Efficient motors	2.4	+	+	_ _	?	?	+	+	+	5
12	Biogas from landfills	5.4	?	+	_	++	+	+	+	+	7
13	Vehicle Inspection	8.7	++	+	_	+	++	+	+	+	9
14	Solar geysers	27.2	+	?	_	?	?	+	+	+	4
15	Biogas for rural households	55.1	?	+	0	+	++	?	+	+	6
16	Central PV electricity	85.3	?	?	_ _	+	?	?	?	+	2
17	pipeline	178.6 (-307.80)	?	?	- -	+	?	?	+	?	2
18	Solar PV water pumps	223.3	+	-	_ _	+	+	+	+	+	6
19	Reforestation	342.1	+	_	0	+	+	?	+	+	5
20	diesel to electric rail	4080.1 (1784.50)	?	?	_ _	+	?	+	-	?	2

- = not in favour; + in favour (-- or ++ means more so); ? not known/clear; 0= none

By this type of analysis, the sequencing of the GHG abatement options in Botswana's strategy could resemble the ranking in Table 6

Table 6 Realignment of GHG Abatement Options based on national development interests

Ranking No.	GHG Abatement Description	Cost of Reduction BWP/ton
1	• Vehicle Inspection	8.7 (3.18)
2	• Prepayment meters • Solar Home systems	-111.206 -67.9
3	• Efficient lighting • Landfill gas for power generation	-495.30 5.4
4	• Paved roads • Biogas for rural households • Solar Water Pumps	-660.40 55.10 223.30
5	• Efficient boilers • Geyser time switches • Power factor correction • Efficient motors • Reforestation	-36.7 -84.40 -47.60 2.40 342.1
6	• Solar geysers- Water heaters	27.20
7	• Zero tillage in agriculture	-493.20
8	• Road to rail freight • Fuel switch from petrol to diesel through differential pricing • Central PV plants • Pipeline for petroleum products • Electrifying the railway line	-501.20 0.0 85.30 184.82(-301.50) 4080.10 (1784.80)

This type of ranking would be satisfactory for zero or negative-cost options but the sequence of implementation could be altered where large capital layouts are required for implementation. This may be the case with solar PV pumps which even if government is willing to promote solar technologies, would be slowed down by the cost of the technology. Similarly with reforestation whose cost is higher compared even to solar PV pumps.

Some of the options ranked low could be implemented earlier if the appropriate policies can be put in place e.g. zero tillage in agriculture.

The recommendation is that the mitigation strategy be reviewed from time to time for any necessary amendments.

Conclusions and Recommendations

Conclusions

There is a relatively significant potential to reduce GHG emissions in the energy system of Botswana by applying a number of mitigation options. The potential GHG reduction achievable by applying a set of 20 mitigation options analysed in this study was found to be about 24% in 2005 and 26% in 2030 as in Table 7.

Table 7 GHG emission levels in the baseline and mitigation scenarios

	2005 CO_2 equi. emissions	2030 CO_2 equi. emissions
Baseline scenario	7317 Gg	11739 Gg
GHG reduction in Mitigation scenario	1750 Gg	3070 Gg
Reduction %	24%	26%

** This reduction excludes a potential reduction of hydropower of 1.2 MT*

More GHG reduction could be achieved through additional options that may become available in due course.

With respect to the present analysis, about 44% of the reduced emission could be achieved by implementing zero or negative cost options. The situation may change when more options are added.

Recommendations

Projects to assess in detail the best conditions under which the mitigation measures could be implemented should be the first follow-up activity.

Appropriate government policies directed at implementation of these measures will be necessary. The options should always have some national development benefits but guidance and incentives will be imperative to ensure involvement of the various actors in the economy.

An example of such incentive is practised in South Africa by ESKOM where awards are given annually to consumers of electricity and the suppliers of equipment. The awards are for outstanding achievements in energy efficiency measures or supply of efficient equipment. This is in form of money (up to R 20 million) and trophies but other forms of incentives can be formulated. Successful examples elsewhere could also act as incentives as local actors may also be driven by the aspiration to achieve similar energy and costs savings.

The awareness campaign is a process which takes time for results to be realised. It is therefore recommended that this aspect with respect to energy and cost savings be initiated soon for Botswana’s actors to move towards sustainable development. A dedicated institution for energy efficiency and conservation could be the starting point for implementing of GHG abatement.

In order to have a continued perspective of the mitigation objective, repeated mitigation analysis and refinements of costs probably including some transaction costs need to be made.

1 Introduction

1.1 Overall Project Framework

This study was carried out in Botswana, Tanzania and Zambia as part of the Southern African Greenhouse Gas (GHG) Mitigation exercise and was funded by the Danish International Development Agency (DANIDA). The project was conducted parallel to the UNEP/GEF project which involved 8 other developing countries and 2 regional projects in Latin America and the SADC region.

In Botswana, the DANIDA project focuses primarily on the Economics of GHG Limitation in the Energy Sector.

1.2 Country Background

Botswana is a large landlocked country (582,000 km^2) located in Southern Africa. Over 80% of its land surface is semi-arid to arid, forming part of the Kalahari Desert. Only 20% of the country to the east, NE and SE can support relatively thick tree vegetation and crops and is the most inhabited part of the country carrying 80% of the national population.

1.2.1 Population

The de-facto population of Botswana determined by the 1991 Census was 1 326 796, 41% above the 1981 Census result. The population projected for the base year 1994/95 was 1 425 398 considering a recently derived average growth rate of 2.5% (CSO, 1996) compared to the 3.5% growth rate of the previous decade.

In 1991, 45.7% of Botswana population was living in urban areas and the annual growth rate of urbanisation has been estimated to be 8% (BEMP, 1996). Urban areas are defined as settlements of over 5000 people in which <25% are indulging in agricultural activities. By this definition, the urban population translates into 51% of Botswana's total population. In 1994, the total household population was 297 652 with an average membership of 4.9 people per household.

Both rural and urban settlements are concentrated in the eastern part of the country. This population concentration in 20% of the country creates a localised stress on the natural resources in that region, particularly for water, fuelwood and agricultural land. Over 75% of total farmland (traditional and commercial) is also situated within this area.

The youth (< 15 years) accounting for 43% of the population will create population momentum since the group of child bearing will be increasing. This situation, coupled with an increasing proportion of people living in urban areas, will entail an increasing energy demand, especially at the household level.

1.2.2 Economy

Botswana has a healthy economy and is now rated to be in the Upper Middle-Income group by World Bank standards (World Development Report, 1994). In 1994/95, Botswana had a high per capita income of P8287.00 at current prices (=US$ 2500) or P3206 (US$ 967) at 1985/86 constant prices and the actual GDP was P12.5 billion (=US$3.8 billion) or P4.9 billion (US$1.49 billion) at 1985/86 prices.

The annual GDP growth rate averaged 9.3% between 1975/76 and 1994/95 while the real GDP per capita increased by 6.0% annually in the same period.

The rate of growth of GDP in 1994/95 was 3.1% compared to 4.1% in the previous year. The annual GDP /capita growth rate fell by 0.3% (Table 1.2.1) in the same period. The drop in national GDP was due to the decline of 1.5% in the GDP for the mining sector. The non-mining sectors however increased by 5.5% between 1993/94 and 1994/95.

At independence in 1966, Botswana's economy was dominated by agriculture mainly in form of meat and meat products, which accounted for 40% of GDP. In 1994/95 agriculture only contributed 5.8% (CSO, 1995). The economy of Botswana in the base year 1994/95 was dominated by mining whose contribution to GDP increased from 0% at independence to 50% in 1988/89 and was still the largest single contributor to GDP in 1994/95 with 32% of the national GDP. The large GDP contribution by the mining sector results from export of diamonds which accounts for 75 % of total export trade in Botswana (CSO, 1995). The service-sectors combined contributed 51% to national GDP. The major service-sectors are government (17.2%), Trade, Hotels and Restaurants (16.3%) and Banking, Insurance and Business Services (10.2%) (Table 1.2.1).

The motor vehicle industry is growing fast in Botswana and was the second largest (6% in 1994- CSO, 1995) export trade after diamonds. By the end of 1996, motor vehicles contributed 20% to export trade with South Africa as the major importer of these vehicles. The other important non-mining commodity is textile mainly for export to USA, Europe and regional markets.

The diamond resource is not renewable but Botswana has enough reserves to depend on into the future. Diversification of the economy is now among government's top priority objectives (Midterm Review NDP7, 1994; BEMP, 1996). Alternative engines of growth are limited but tourism and financial services are promising sectors.

The government is however prepared to provide an enabling environment for economic diversification to take place through various financial incentives. In 1995, electricity and telecommunications tariffs were reduced by a minimum rate of 10% each. The Government of Botswana's Financial Assistance Policy to those embarking on viable projects, particularly of manufacturing creates an incentive for investment in the country.

Table 1.2.1 GDP by economic activity (1985/86 constant prices) for 1994/95

SECTOR	GDP (MILLION PULA)	% OF GDP	ANNUAL % INCREASE
agriculture	189.4	5.8	(4.6)
mining	1555.4	47.2	(1.5)
manufacturing	293.4	8.9	4.3
water and electricity	122.4	3.7	6.2
construction	258.3	7.8	1.6
trade, hotels & restaurants	790.5	24.0	7.8
transport	203.5	6.2	6.7
banks, insurance &bus. Services	493.8	15.0	7.6
general government	836.0	25.4	6.1
social & personal services	223.8	6.8	4.3
Dummy sector	(118.8)	(3.6)	5.0
TOTAL (million Pula)	4847.5	100	3.1
Per capita GDP (Pula)	3206	-	(0.3)

(1.5)= negative annual increment

Botswana's sound financial base including its large foreign reserves (higher than GDP) could be deployed to expand the economic base. A diversified economy, the healthy economic situation and the rising per capita income are expected to result in a high demand for commercial energy in the various sectors of the expanding economy. The expanded economy will require an increase in electricity supply and transport facilities, which in the case of Botswana entails more consumption of fossil fuels and consequently higher GHG emissions.

Botswana's inflation rate in 1994/95 was about 10%. The country is however affected by inflationary changes in South Africa from which 80% of the country's imports come. It is indicated that price developments in South Africa exert their impacts on Botswana with a time lag of 6 to 9 months (Annual Economic Report, 1996).

The real interest rates fluctuated between -5% and 5% from 1980 to 1992 (Midterm Review of NDP7, 1994) and the low interest rates are believed to have slowed down 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 the other regional countries (Midterm Review NDP7, 1994).

1.3 Energy structure

1.3.1 Energy Supply and Infrastructure

Botswana is well endowed with three energy carriers namely coal, fuelwood and solar energy. All petroleum products in refined form are imported. Other energy resources in the form of wind and biogas are available in very small proportions.

The energy supply case for Botswana is presented in Table 1.3.1.

Coal reserves in Botswana are estimated to be in the region of 212.8 billion metric tons of which 3.34 billion tonne are measured reserves (BEMP, 1993). The Colliery block and its extension at Morupule mine has 190 million tonnes measured reserves and at the current mining capacity of 1 million tons, the mine alone has a life span of about 190 years.

Electricity generated in Botswana is thermal and is derived from the locally mined coal. The Botswana Power Corporation (BPC), the only power utility in the country has been operating two coal-fired power stations located at Morupule (132MW, the coal mine) and Selibe Phikwe (80MW), but the latter was decommissioned in 1995 as it was highly inefficient incurring high costs of generation. Botswana Ash also generates 20MW for self supply.

The maximum potential for imports from the Zimbabwe Electricity Supply Authority (ZESA) /Zambia Electricity Supply Commission (ZESCO) and the South African Electricity Supply Commission (ESKOM) is 530MW from 1998 [120MW from ZESA/ZESCO and 210MW (+200MW from 1998) from ESKOM].

The national grid in the base year consisted of 920 km of 132 kV and 907 km of 220 kV transmission lines (BPC Annual Report, 1995).

Villages remote from the national grid but close to neighbouring countries are connected to those countries' grids. The SW villages are connected to South Africa, the NW ones to Namibia and those in the north to Zambia.

Isolated diesel generators have a capacity estimated to exceed 20MW throughout the country. BPC operates one large diesel generator at Ghantsi (1.61MW) which is supplying the village. The rest of the generators are relatively smaller and are operated by the Department of Electrical and Mechanical Services (DEMS). The latter generators supply electricity to rural schools, hospitals, police stations and prisons (BEMP, 1993).

All Petroleum products in Botswana are imported in refined form mainly through South Africa. The imports are shipped to the port of Durban in South Africa and are transferred to Pretoria via a pipeline. Transportation to Botswana is by both rail and road freight transport in the proportion 60:40 respectively.

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 MCI keeps strategic reserves equivalent to 50 days supply or 62 000 kilolitres of fuel products. The private sector also keep reserves of about 6000 kilolitres (Zhou/ADB, 1995).

Table 1.3.1 Energy supply by fuel/source for base year 1994/95

FUEL/ENERGY SOURCE	QUANTITY/CAPACITY	INFRASTRUCTURE
electricity	Local Generation -132MW Morupule -45 MW* Selibe Phikwe - 20 MW (Botswana Ash) -up to 20MW centralised and small diesel generation-govt (DEMS) Imports - ZESA/ZESCO 120MW import -ESKOM 210MW import (+200MW from 1998)	907 km 220 kV 920 km 132 kV
coal	-212 billion tonnes total. - 40 million at Morupule mined at 0.9 Mt/year	
biomass-fuelwood	annual increment 50 Mt 1.8 Mt harvested/year	
petroleum (1995 imports)	petrol 251 674 kl diesel 157 253 kl paraffin 19 973 kl	
solar	-3000-3500hrs of 2200kwh/m2/year >10MW Solar Water Heaters >600kW PV-10kW for telecom. systems & 60W for household lighting systems	

** going off stream after 1994:*

source: BEMP, 1996; BPC annual reports;1993).

The actual procurement of petroleum products is done by subsidiaries of the international oil companies. The major petroleum products traded by these companies are petrol, diesel and illuminating paraffin in the proportions shown in Table 1.3.2.

Table 1.3.2 Fuel procurement share by the various oil companies in Botswana -1994

OIL COMPANY	PETROL SHARE KILOLITRES (%)	DIESEL SHARE KILOLITRES (%)	PARAFFIN SHARE KILOLITRES (%)
BP Botswana Pty Ltd	73 284 (29.12)	78 060 (49.64)	6 021 (30.14)
Shell Oil Botswana (Pty) Ltd	68 289 (27.63)	29 496 (18.76)	7 892 (39.51)
Caltex Oil Botswana (Pty) Ltd	51 683 (20.54)	16 973 (10.79)	3 545 (17.75)
Engen Botswana (Pty) Ltd (Formerly Mobil)	33 649 (13.37)	20 530 (13.06)	1 725 (8.63)
Total Botswana (Pty) Ltd	24 769 (9.84)	12 193 (7.75)	791 (3.95)
TOTAL	251 674 (100)	157 253 (100)	19 973 (100)

source: Petroleum Management Unit. Botswana

The oil companies also supply other products but in smaller quantities. Petrochem Pty Ltd trades in lubricants only. LPG is sourced from South Africa by vendors and government does not monitor supply and pricing of the product.

Biomass/fuelwood: The standing biomass stock estimated from remote sensing by ERL Energy Resources (1985) was 16.4 million tonnes (Kgathi, 1992) and about 9.2 million tonnes (air dried weight) were assessed to be of fuelwood species.

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; 1996) which far exceeds the annual national wood demand of about 1.8 million tons. The SE parts of Botswana however have localised over-exploitation due to non-sustainable supply of fuelwood, timber extraction, land clearing for arable agriculture, overstocking and overgrazing. Hence at the local level there is evidence of net tree removal.

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, 1990) where the majority of Batswana are settled.

The regeneration ranges from 0.3 tons/ha in the Kalahari Savannah to 2.1 tons/ha in the dense woodlands of NE Botswana with an average value of 0.93t/ha (ERL, 1985). In densely populated areas where there is high-localised fuelwood demand the regeneration rate is low (0.3 tons/ha/year).

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).

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 the yield is low (5m3 per ha/yr.).

Considering the 650 ha, only 810 tonnes of wood (for all purposes) can be produced from the existing woodlots.

Solar and wind: The renewable energies in use in Botswana are solar and wind.

Botswana is endowed with excellent sunshine and receives 3000 - 3500 hours of sunshine per year with a mean annual insolation of about 2200 kWh/m^2 (6-6.5 $kWh/m^2/day$) compared to European countries with 1000 kWh/m^2. Monitored locations in Botswana receive insolation of about 20MJ/m^2 per day on average with a range 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 about 10MW (BEMP, 1993) with a net annual energy production of 30GWh or 108TJ. PV systems for lighting and water pumping have an estimated total installed capacity of 600kW.

Wind speeds are on the low side (typically <4 ms^{-1}) and wind-power is utilised for water lifting from water levels of ± 50 metres in Botswana.

1.3.2 Energy Demand

Energy Demand by sector in the base year 1994/95 is indicated in Table 1.3.3

Coal: The power sector is the major coal consumer, where it is used for transformation inputs, accounting for 80% of all the coal supplied in 1994/95 of 913 000 tons. The second largest consumer is mining where coal is used for smelting purposes. The other industries use coal for steam raising. Government also uses coal in its urban and rural institutions like schools and hospitals for cooking and steam raising. There is insignificant use of coal currently in the household.

Electricity: The largest consumer of electricity is the mining industry accounting for 58% of the final electricity consumption in 1994/95, 52% of which was taken by the Bamangwato Consolidated Limited (BCL) which is a base metal (copper and nickel) mine. The second largest electricity consumers in the mining sector are the diamond mines with (31%). The other mining operations are Botswana Ash (for soda ash) and Morupule for coal, but the former largely supplies its own electricity.

The second largest single consumer of electricity in the base year was the Trade and Hotels Sector (21% of total final consumption) followed by the household sector (12%) and government (6%). Electricity consumption in urban household sub-sector was about 1.5 times that of the rural sub-sector. However the gap is narrowing as a result of the intensified rural electrification programme.

Petroleum products: The Transport sector consumes 89% of petrol and 57% of diesel, which are the main petroleum products consumed in Botswana. Over 99% of petrol and 87% of diesel used in the transport sector are consumed by the road sector. This makes the road sector the target for fuel consumption reduction and GHG limitation. The high rate of growth of private cars (individual and government) and the size of freight vehicles are the causes for the high petrol and diesel consumption respectively. A considerable share of diesel is also consumed in industry and power generation.

The other notable petroleum fuels used are LPG and paraffin in the household sector. 82% of final LPG consumption in 1994/95 was in the household sector particularly the urban sub-sector, which consumed 96% of the household share. Similarly 95% of the final paraffin consumption was in the household sector and the urban sub-sector used 67% of the household share.

The other petroleum products are consumed in the various sectors but are not significant hence their contribution to GHG emissions is considered minimal.

Fuelwood: Biomass consumption in Botswana is mainly in form of fuelwood, which is mostly obtained through collecting on dead wood hence the rural sub-sector consumes 79% of the fuelwood consumed by the household sector in Botswana. The household sector together consumes 98% of the entire final fuelwood consumed in 1994/95 in Botswana. 55% of urban and 90% of rural household population use fuelwood (BEMP, 1996).

Table 1.3.3 Sectoral energy demand in 1994/95. TJ

Sector	Coal	Fuelwood	Electricity	Petroleum products	Solar	Total
household- TOTAL	50	20940	528	982	31	22531
urban	50	4483	322	800	31	
rural	-	16458	206	182	-	
power generation**	17568			356		17 924
industry-TOTAL	4069	0	2952	1558		8579
- mining	3678		2516	1418		
- manufacturing	158		16	49		
- other industry & construction	233		60	86		
transport-TOTAL	0	0	0	10329	0	10329
commerce-TOTAL	221	481	1243	1366	4	3315
social Services	-	160	46	10		
government	216	320	268	1304	2	
trade and hotels	5	1	929	52	2	
agriculture	0	0	7	520	(+1 wind)	528
TOTAL	4340	21421	4730	14755	36	45282

*** Transformation inputs- not added to demand Totals*

SOURCE: BEMP 1994/95.

The other consumers are government, social and private services. Government institutions in form of the army, schools and hospitals use fuelwood but their proportion is less than 2%. The main end-use in all the above sectors is cooking, which should be the target for fuelwood consumption reduction intervention.

The forest depletion caused by fuelwood collection is not well quantified as over 95% of forest clearance is attributed to agricultural activities (Sekhwela, 1994). Harvested fuelwood may cause localised deforestation around settlements, but is insignificant at the national level.

BEMP (1996) suggests that only 4% of annually regenerated biomass is harvested. It appears therefore that the fuelwood problem is more of its scarcity close to settlements than one for depleting the CO_2 sink.

Solar: 89% of all the final solar energy consumed in 1994/95 was for the urban household sub-sector. Trade and Hotels, and the government institutions consume the rest in equal proportions. The government is promoting further use of solar energy in both urban and rural households. Such a measure would immediately displace fossil fuel based lighting and water heating energy resulting in some GHG reduction and cleaner indoor environments.

1.4 National Energy and Environmental Policies

1.4.1 Energy Policies

The energy policy as stipulated in NDP7 (1991) was 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 to the above, the energy policy also 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.
- electricity, coal and petroleum products are provided at least cost and in sufficient quantities to promote economic growth
- the energy sector planning and management capabilities are improved in order to cope with the increasing requirements and complexities of the sector.

NDP 8 energy policy framework is not any different from that of NDP7 but re-emphasises the following (BEMP, 1996):

a) Economic efficiency where:-

- *energy services are supplied at least cost to the economy by an efficient energy supply industry and no excessive profits are made in energy prices.*
- *energy users & potential ones are to have access to appropriate energy services to enable economic diversification.*
- *there is to be efficient use of energy and*
- *a financially sustainable energy supply industry exists*

b) Social Equity where:-

- *access to adequate and affordable energy services by households and community services exists*.

c) Environmental quality and sustainability where:

- *energy extraction, production, transport and use should not damage the environment and people's health and safety.*

- *long term sustainable use of energy resources is achievable.*

d) Security with respect to:-

- *supply of or access to energy*

1.4.2 Environmental Policies

The National Conservation Strategy Agency (NCSA) is tasked with the overall environmental planning in Botswana. The areas so far identified as of environmental concern under the NCSA are:

- Pressures on water resources
- Degradation of rangelands and pasture resources
- Depletion of wood resources
- Over-exploitation of veld products
- Pollution of air, water, soil and vegetation

The NCS has been in place since 1990 and emphasis in implementation has since been placed on:

- *Improving environmental awareness*
- *Formulating standards and norms on environmental practice and the necessary legislation.*
- *Economic incentives*
- *Preparation of Action Plans, Biennial State of the Environment in Botswana, and bills on Waste Management and Environmental Impact Assessments.*

The issues related to energy in this Strategy conform to wood resources depletion and pollution to air, water and land but not specifically related to GHG emissions.

With regard to wood resources depletion, the strategy places importance in increasing supply either through afforestation programmes or management of natural woodlands which would also create sinks for CO_2 emissions.

1.5 Energy Pricing Policies

The major pricing policy instilled in the energy policies above is that the energy prices would not include excessive profits. The energy prices, particularly of electricity, petroleum products and coal will be lowered to enable economic diversification

Coal prices are determined by both volumes and transport costs and range from P40.00 to P140.00 per tonne depending on the distances from the mine.

Electricity tariffs have already been reduced by 10% in 1995 and this resulted in increased consumption of 7.7% in 1996 (BPC Annual Report, 1996). Tariffs are however based on the utility's long run marginal cost with annual tariff increases not expected to exceed 50% of inflation. There are six tariff categories one for household, three for industry, one for government and water pumping. The household sector pays the least fixed charge of P7.00/month compared to P17.00 for other categories but pays a higher unit price of P0.2403/kWh compared to large industries (P0.1152). BCL, the largest electricity consumer is on a specially negotiated tariff.

Government controls prices of petrol, diesel and illuminating paraffin, the major petroleum products. Paraffin is not taxed as a measure to make it affordable by the majority of low-income households using it. The price of petrol in the base year was P1.04/litre (Zhou, 1994)

Prices of petrol and diesel are similar unlike in other Southern African countries (e.g. Zimbabwe) where the price of diesel is significantly lower than that of petrol as a measure to enable commercial activities. Prices of these fuels in Botswana are mainly dictated by the international prices.

Fuelwood is harvested free of charge in the rural areas where 90% of households use the fuel (BEMP, 1996). It is sold at uncontrolled price in urban areas from traders who use donkey drawn carts or motorised transport. In 1994, the highest price for fuelwood measured in Gaborone (Zhou, 1994) was P0.33/kg but the average was P0.25/kg.

LPG is not price controlled since the fuel is marketed by private vendors. Users however pay a below-cost fixed deposit for all cylinder sizes and this probably encourages uptake of the fuel in the urban households. The cost of LPG in Botswana in the base year was P2.00/kg (Zhou, 1994).

1.6 Project Breakdown

The project comprises of two Phases. Phase 1 was completed in 1994 and its objective was as given below. The current exercise constitutes Phase 2 of the project.

1.6.1 Summary of Phase 1 Study

a) Objectives

The main objective for the Phase 1 study was to present the country's socio-economic, institutional and energy characteristics of relevance to greenhouse gas emissions (GHG) limitation and to identify tentative GHG abatement options in the energy system of Botswana**.** The study was based on 1990 statistical figures.

b) GHG Emission results 1990

Assessment of GHG emissions for Botswana in the Phase 1 study was carried out for CO_2, CH_4 and N_2O gases. The emissions estimated for fuel sources in the energy sector are presented in Table 1.6.1.

Table 1.6.1 Fuel-emission coefficients used in Phase 1 and GHG emission levels 1990

Supply Side

Fuel	**CO_2 (GWP=1)**	**CH_4 (GWP = 11 (21)**	**N_2O (GWP= 270 (310)**	**CO_2 Gg**	**CH_4**	**N_2O**	**CO_2 equivalent**
Coal	92*(92)	0.0062	0.025	1689.0	.114	.459	1814
Gasoline	73(69.3)	0.0965	0.0220	**1028&**	**0.895**	**0.336**	**1129**
Jet Fuel	78(71.5)	0.0114	0.022				
Diesel	74 (74.1)	0.0441	0.026				
Paraffin/kerosene	78 (71.3)	0.0114	0.022				
Fuelwood	0 (109.6)	0.15	0.003	0.0	3.467#	.058	54
TOTAL				**2717**	**4.47**	0.85	**2997**

=coefficient derived for local coal; (71,3) =revised coefficient IPCC 1995; GWP= global warming potential (310- revised)) ; # only final energy consumption; & for all petroleum products.***

c) Fuel and GHG contributions

The major contributing fuels in these sectors are coal, diesel and petrol fuels. In 1990, coal contributed 59% of the CO_2 equivalent emissions followed by diesel with 16% and petrol with 15%. Fuelwood, although with zero CO_2 emissions contribute the fourth largest share of 6% from its CH_4 emissions. The other 4% was contributed by jet fuel and paraffin in similar proportions.

CO_2 is undoubtedly the largest GHG emitted contributing 85% of the CO_2 equivalent emissions in 1990. N_2O contributed 15% of the CO_2 equivalent emissions and CH_4 emission share was comparatively negligible.

d) Sectoral GHG Analysis

Contributions of CO_2 -equivalent by the various economic sectors of Botswana are presented in Table 1.6.4 and the power sector was the largest CO_2 -equivalent emitter in 1990 largely duel to coal combustion. The transport sector, the largest consumer of petroleum products was the second largest emitter of CO_2 -equivalent followed by the mining sub-sector of industry.

Table 1.6.2 Sectoral energy and CO_2 emissions (Gg) for 1990

SECTOR	ENERGY TJ	COAL	PETROLEUM	TOTAL
Agriculture	488		36.1	36.1
Household	20263	3.8	59.5	63.2
Transport	8518		625.4	625.4
Mining-Heavy Industry	7276	349.1	101.6	450.7
Manufacturing-Light Industry	903	20.3	49.7	70
Other industries	291	33.1	56.4	89.5
Commerce	1257	4.4	62.3	66.7
Trade and Hotels	364	4.4	2.8	7.2
Demand side Total	39360	415.1	957.7	1372.7
Power Production	14320	1309	34.5	1342.5
TOTAL	53192	1724.1	992.2	2720

Source UNEP, 1995

The per capita CO_2 emissions from the energy system for 1990 are comparable to those of other regional countries as shown in Table 1.6.3.

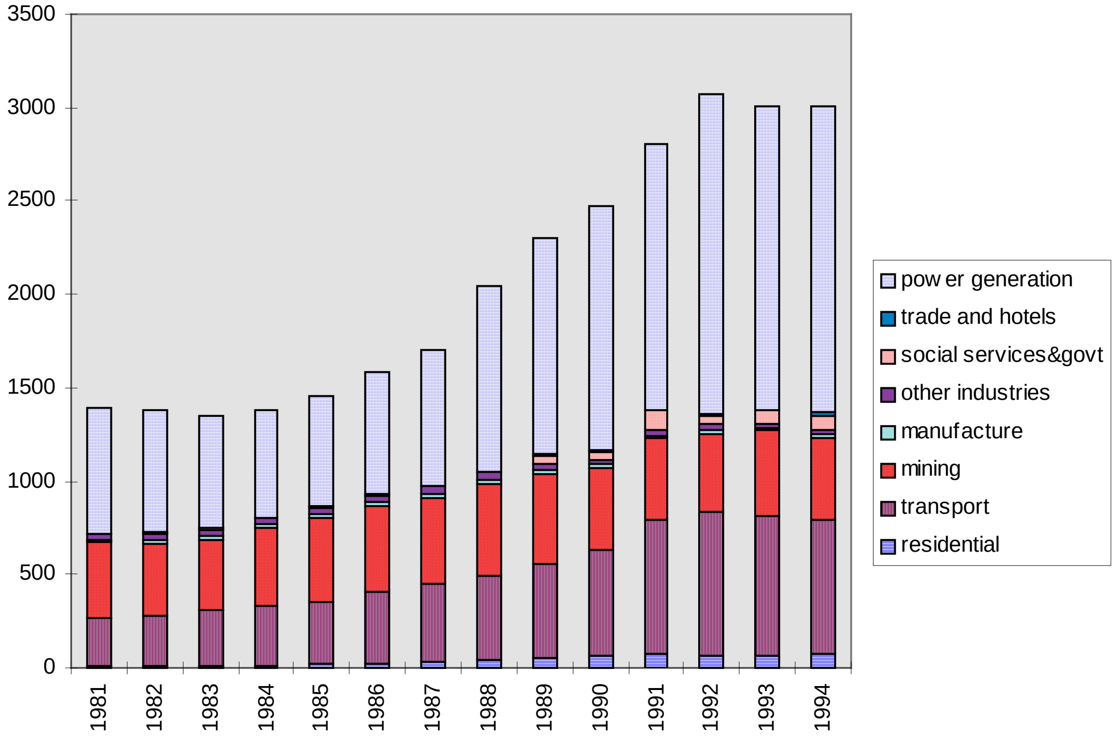
Table 1.6.3 Compared total/yr. and per capita/yr. CO_2 emissions for selected countries 1990.

country	size of country (km^2)	population (m)	total CO_2 emissions (Mt)	emission density (tons/km^2)	per capita CO_2 emissions (tons)	remarks
Botswana	581 764	1.3	2.7	4.6	2.0	energy only
Zimbabwe	390 000	10.4	16.3	41.8	1.6	energy only
Senegal	196 200	6.9	14.5	73.9	2.1	energy +?
Brazil	-	144	680	-	1.9 [4.7]	[4.7]+ energy +deforestation
Denmark	43 093	5.2	56.2	1304.2	11	small IC+high fossil fuel

The historical CO_2 equivalent emissions (Fig. 1.6.1) show that there has been a general increase in CO_2 -equivalent emissions in all sectors since 1981 (Fig 1.6.1) but more so for the three major emitting sectors. These three sectors emit over 90% of the CO_2 emissions from the energy sector in Botswana.

With this GHG emission situation, it will be important to focus the GHG limitation exercise on the power, industrial and transport sectors which are the main fossil fuel consumers. The other sectors like the urban household and commercial sectors are also dependent on electricity generated in the power sector hence the need for identifying mitigation options in these sectors. Certain mitigation options may also be important from a social and economic perspective, for instance those that can provide clean energy, create employment and/or create efficiency of production.

Fig 1.6.1 Historical CO_2 emissions by sector 1981-1994 (Gg)



2 Economics of GHG limitation in the Energy Sector of Botswana

2.1 Objectives of Phase 2

The current phase of the project entails analysis of the baseline economic, energy development and greenhouse gas (GHG) scenarios, and abatement costing of plausible greenhouse gas mitigation options in the energy sector of Botswana.

The analysis period for both the baseline and mitigation scenarios is up to 2030. The short term stretches from 1994 to 2005 and the long term analysis is up to 2030. The short-term projection has been based on Botswana's 7th and 8th National Development Plans, which span the periods between 1991-1996/97 and 1996/97-2002/03 respectively. The Long Term was based on some economic development derived for the framework for Botswana's Vision 2016 (Botswana Vision 2016, 1996; 1997).

The economic development as indicated by GDP was linked to energy intensity in order to forecast future energy demand and the related GHG emissions.

The greenhouse gases targeted in this study are CO_2, CH_4 and N_2O expressed as CO_2 equivalent.

2.2 Data and Modelling Approach

The analysis examines the historical socio-economic development and energy consumption patterns with the view of deriving possible future GHG scenario or baseline. A plausible baseline scenario was derived based on the demographic, economic, energy demand and supply assumptions. Regional and international assumptions are also presented to indicate how they can affect the baseline in Botswana. The derived economic and energy baseline trends were translated into GHG implications for the 2005 and 2030 target years.

The modelling tools from which socioeconomic and energy data have been derived are the Macro-Economic Model of Botswana (MEMBOT) and the Botswana Energy Master Plan (BEMP) respectively. The Long-Range Alternative Planning (LEAP) and the Greenhouse gas Abatement Costing Model (GACMO) have been used in creating the baseline scenario and the abatement costing of mitigation options respectively.

The macro-economic growth rates produced using MEMBOT for the various economic sectors in Botswana for the Plans periods up to 2003 (NDP8, 1997) were used. Base year and future demographic data were obtained from Central Statistical Office (CSO) of Botswana (1996). Similar demographic and economic growth rates have been assumed in the analysis up to 2005 in this study.

For the long term, growth rates derived for government's development aspirations as envisaged in their Vision 2016 were used. The growth rates estimated for Vision 2016 were assumed in this study to be effective up to 2030. Adjustments were however made to some of the estimated growth rates in the Vision period as part of reality check.

The Plan and Vision sectoral GDP growth rates were assumed to be the drivers for the industrial and commercial sectors. Energy demand projections were then calculated using energy intensities of GDP or production. The process assumed the energy intensity of GDP for the base year for each sector which was then adjusted for autonomous energy efficiency intensity improvements (AEEI) before applied to future terms.

For the household sector, energy demand projection was based on population growth rates and per capita or per household energy consumption levels of the various fuels.

For the transformation or Power sector, the current power plants and the ones planned in the time horizon were considered in the baseline scenario.

The LEAP model was then used to produce the energy and GHG baseline scenarios for the time frame to 2005 and 2030.

A portfolio of GHG abatement options was identified and the Greenhouse Gas Abatement Costing Model (GACMO) was used to calculate the abatement costs and the potential GHG reduction of these selected mitigation options. The mitigation options analysed in this study were identified in Phase 1 of the project and were also selected by participants to the first national workshop of the current phase (Phase 2).

2.3 Baseline Data and Assumptions

2.3.1 Demographic Data and Assumptions

Population growth has influence on demand for services and energy and thus will impact on future energy demand as dictated by the population growth rate.

The previous population growth rate for Botswana was quoted as 3.5% in the last decade but the recent growth rate recalculated by CSO (1996) as Medium Variant Single Years Population Projections taking into account the AIDS endemic, shows that the average annual growth rate is 2.5% between 1994 and 2005 and about 2.1% up to 2030 (CSO, 1996; Framework for a Long Term Vision-FLTV, 1996).

The Urban (Towns) population is expected to increase annually by 4.35% to 2005 and 3.4% to 2030. The rural population (inclusive of urban villages) will grow at an average annual rate of 2.5% till 2005 and 2.2% between 2005 and 2030 (*Medium Variant Single Years Population Projections-CSO; 1996).*

The projected populations for Botswana to 2005 and 2030 and their urban-rural breakdowns as determined from these growth rates are presented in Table 2.3.1.

*Table 2.3.1 Projected de-facto national, urban and rural populations (*Census Year)*

	1991*	1994	2005	2030
Urban-towns	286 779	328 203	524 276	1 209 410
Urban villages & Rural villages	1 040 017	1 097 195	1 439 615	2 480 383
Total	1 326 796	1 425 398	1 963 891	3 689 793

If urban village population is considered with urban towns, then the urban population becomes greater than the rural population. The important consideration is however whether urban village-households energy consumption patterns are similar to those in towns or those in the villages. A study conducted for domestic energy consumption (ZHOU, 1994-ADB) shows that large urban villages like Kanye have similar energy fuel consumption patterns like Shoshong and Goodhope villages. In this study, households in urban villages were therefore treated as rural households in line with the population projections given in Table 2.3.1.

The urban-rural divide influences the consumption of the various fuel types especially for the household sector.

Assuming the given population growth rates and the number of households in the base year, the total households for 2005 and 2030 were calculated in the LEAP model. The proportions of urban and rural households as defined above were allowed to vary in the LEAP Model as in Table 2.3.2.

Table 2.3.2 Base Year and Projected urban and rural Households

Household type	1994	2005	2030
Rural	219 879 (74%)	261 695 (67%)	413 671 (63%)
Urban	77 773 (26%)	128 850 (33%)	242 950 (37%)
National Total	297 652 (100%)	390 545 (100%)	656 621 (100%)

2.3.2 Macro-economic Data and Assumptions

The macro-economic assumptions relate to expected growth rates for the various economic sectors. The long-term historical national GDP annual growth rate since 1975 at 1985/86 constant prices, was 9.3% and that for mining, which is the mainstay of Botswana’s economy, averaged 13%. The non-mining GDP annual growth rate averaged 8.1% and government GDP grew at an annual rate of 10.1% (Macroeconomics Outline for NDP8, 1996). Averaged from 1981/82 to 1994/95 (base year), the growth rates have generally declined. In that period the average national GDP growth rate was about 8% and that of mining was 7.85%. The Commercial sector which encompass government however still had a high average growth rate of 10.54% (Table 2.3.3)

The average annual GDP growth rate in NDP7 (1991-1997) was 4.1%, a small divergent from the 4.7% projected for the same period using MEMBOT. The same annual GDP growth rate of 4.7% was projected for NDP8 (1997/98- 2002/2003). Table 2.3.3 presents the short-term sectoral growth rates derived from those of NDP7 (1991) and NDP8 (1997).

In the long term, Botswana's vision is to triple per capita income by 2016 entailing an annual national growth rate of 7.9% (FLTV, 1996). Table A.1in the Annexe (Chapter 9) shows the original Vision 2016 expected growth rates for the various economic sectors of Botswana. Analysis in this study however considered possible achievable potential in this Vision resulting in the growth rates presented in Table 2.3.3.

The sectoral contribution to national GDP in the base year shows that the major contributors are mining, government, trade and hotels and financial services (refer to Table A.1- Annexe.) There is anticipated significant growth in Trade and Hotels and Financial Services as these are the envisaged new engines of economic growth (Midterm Review, 1994). The sectoral rates of growth rates in Table 2.3.3 were used to determine the baseline for energy and CO_2 equivalent emissions to 2005 and 2030.

Table 2.3.3 Sectoral Economic Growth Rates and Factors for 1994/95, 2005 & 2030.

SECTOR	1981/82-1994/95 av. pa GDPG rate % @	short term GDP grate (pa) %1994-2005&	Long Term GDP grate (pa) %2005-2030#	1994 GDP Factor **	2005 GDP Factor **	2030GDP Factor **
Agriculture	3.41	0.8	5.0.	1	1.056	3.576
Mining	7.85	1.7	2.1	1	1.204	2.024
Transport	15.19	5.7	5.7	1	1.840	7.357
Manufacturing	7.53	8.8	10	1	2.529	27.401
Construction	3.26	1.5	9.2	1	1.178	10.634
COMMERCE	10.54	6.54	7.38*	1	1.999	3.30
- Trade and Hotels	7.18	5.6	8.9			
- Social services	10.62	6.5	8.9			
- Water and electricity	11.83	5.8	6.2			
	10.82	8.7	8.9			
- Financial services	12.25	6.1	4.0			
- Government						

** Used 2005 to 2010 there after tapering growth (~1% growth rate to 2025 and 0% to 2030).*

*** factors of 1994/95/base year GDP (see Table A.1 Annexe)*

@ derived from Annual Economic Report 1996

& Macroeconomics Outline for NDP8 (July 1996)

 # Based on Vision 2016

The economic growth rates given for period to 2005 are the likely outcome in NDP8 should government policies be implemented and the underlying assumptions turn out to be correct.

This base case scenario assumed sustained strength of the diamond industry with 3% nominal price increases; and restrained government expenditure. High growth rates are expected in Manufacturing, Trade and Financial Services. Inflation was estimated to fall from 11% to 7% in the Plan period. The current Pula-Rand exchange rate was assumed to remain constant in the period (Macro-economic Outline, 1996).

Government’s optimistic case assumes that real diamond prices increase by 2.5%, hence government can increase development expenditure. The Pessimistic Scenario assumes a fall in real diamond prices by 2.5% causing a fall in government development expenditure. However only the base case growth rates were used in determining the baseline to 2005.

The long term projection or Vision 2016 aspires a growth in manufacturing to a share in GDP similar to that of the Asian (Tiger) Countries. This translates into an annual growth rate of 18.3% for this sector (FLTV, 1996). This scenario was considered to be the High Case.

For the Base Case, a growth rate of 10% was assumed for the sector which is about 30% more than the average per annum growth of 7.53% registered in the period 1981/82 to 1994/95. Even with this adjustment, the manufacturing sector has the largest factor of growth both in the short term and long term (Table 2.3.3). Given the economic stability of Botswana, this assumption of high growth in the manufacturing sector could be achieved but will also depend on labour productivity, capital and resource availability and conducive government policies.

The construction sector although currently in a slump due to past constraints is expected to grow fast in response to the anticipated boom in the manufacturing sector. The FLTV growth rate of 9.2% was retained in the study.

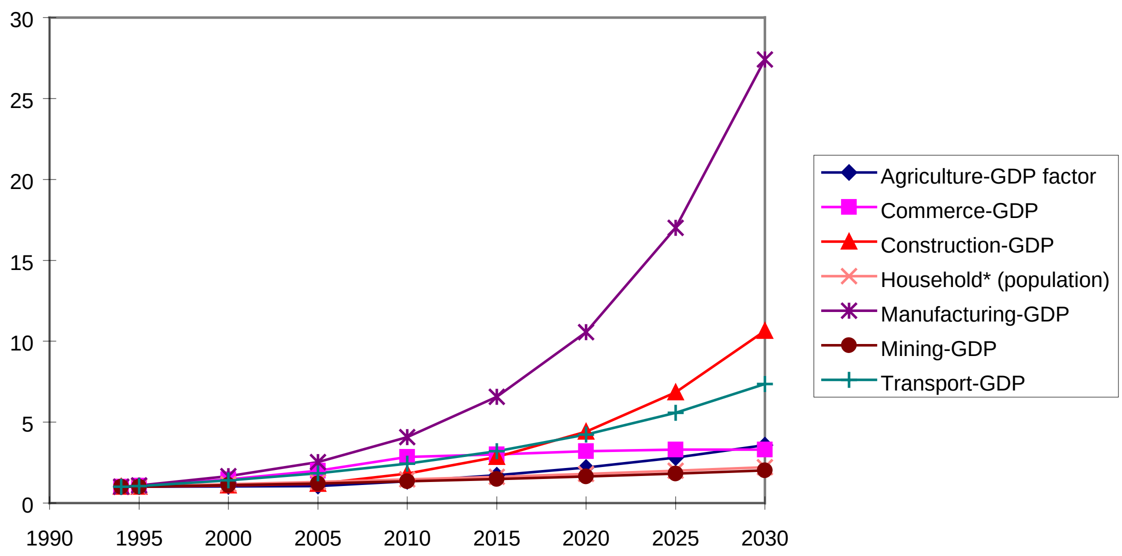
A growth adjustment was made in the transport sector where the FLTV (1996) assigned a growth rate of 8.9% beyond 2005. This growth rate would result in an unparalleled growth by the sectors driving demand in this sector; hence the short-term growth rate of 5.7% was retained for the long-term period as well. In the commercial sector, the long term growth rate (averaged for the sub-sectors) of 7.53% was only used between 2005 and 2010 and thereafter the growth was allowed to taper. This was also to avoid a sectoral energy growth, which could not be comparable with that of the sectors affecting it.

The Mining sector is not expected to grow significantly further, hence the relatively low growth rates for this sector throughout the baseline period. The annual percentage change was even negative (-1.5%) for this sector in 1994/95 (Annual Economic Report, 1996) but will increase slightly due to expansion of diamond mining in the country.

The short term growth rate in Agriculture will be low as a result of poor cereal crop performance and effects of drought on both crop and cattle. Policies to diversify into cash crops and research into drought resistant sorghum varieties and cattle breeds are expected to yield results in the long term hence the expected upturn in sectoral growth rate in the long term period (Table 2.3.3).

The sectoral growth patterns in the baseline by assuming the above sectoral growth rates are presented in Fig 2.3.1.

Fig 2.3.1 Baseline factorial sectoral economic (GDP) growth



Factors are related to 1994/95 base year, which has a factor of 1

Fig 2.3.1 shows that the household sector (based on population growth rates) and the Mining sector will have the lowest factors of growth in the long term, followed by agriculture and commerce. Significant factors of growth will be registered in the Manufacturing, construction and transport sectors in decreasing order.

2.4 Sectoral Energy Demand

To determine sectoral energy growth, the derived sectoral GDP or household population factors were linked with the energy intensities of each sector for each fuel type. For the baseline, some autonomous energy efficiency improvements (AEEI) were assigned to the various fuel-type devices. Table 2.4.1 presents the AEEI values assumed for the various energy fuels/sources-devices based on AEEI values adopted in past studies and the anticipated potential for energy efficiency improvements. Coal, fuelwood and paraffin in the household were assumed to have a lower AEEI of -0.5% as no serious innovations are expected for devices using these fuels in the household sector of Botswana. The industrial coal involving boilers was also assumed to have a similar AEEI as boilers last for decades. This means that boilers bought at today's energy efficiency may last for the whole time frame of this study.

Agricultural diesel devices were assumed to have a -0.5% AEEI also due to the slow scrapping rate in this sector. Both diesel tractors and generators are often retained for long periods.

Significant efficiency improvements were assumed in vehicles, electrical and solar devices hence a larger AEEI of -1% was assumed for devices using these energy fuels/sources.

Table 2.4.1 Assumed AEEI values for the various fuel technologies

FUEL	AEEI % PER ANNUM
Fuelwood	-0.5
coal	-0.5
paraffin/kerosene (domestic)	-0.5
other petroleum products	-1.0
solar	-1.0
Agriculture diesel	-0.5
All electricity devices	-1.0

The link between energy consumption by fuel with the economic sectoral growths and AEEI in the LEAP model enabled projections of fuel demand in the study time frame.

2.4.1 Household Sector-Data and Assumptions

Population growth is the major driver for energy consumption at the household sector level. The urban-rural divide has also influence on the amounts and types of energy fuels consumed at the household sector. In the LEAP model the distinction in energy demand for urban and rural sub-sectors was accounted for. The driving forces for energy fuel/source demand in the future are discussed below.

a) Electricity

There will be an increase in electrified urban housing. 100% of urban high cost houses are electrified but only 20% of low cost houses and Self Help Housing Agency units are electrified. There is anticipation that in the short term, the proportion of electrified low cost houses will rise to 40%. Currently there are 44 800 houses electrified but there are also 280 000 demarcated plots due for building. If only half of those new plots are connected, an estimated additional capacity of 200MW will be required (BPC personal communication).

For rural electrification, 14 villages out of 107 will be electrified every year in the short term. By the end of NDP7, 45 villages had been electrified (NDP8, 1997). Electricity demand assessment assumed that initially 2% of rural households would be connected to the grid and thereafter at 5% annual growth rate for the first ten years. Presently 3% of rural households are connected. After ten years, saturation is expected in the connected villages (BPC personal communication).

b) Fuelwood

The consumption rate will generally decrease as a result of fuelwood scarcity and diffusion of other energy sources e.g. through expansion in the urban and rural electrification and diffusion of LPG and paraffin in rural areas.

c) Paraffin

In urban areas, paraffin demand is expected to fall due to electrification of low cost urban households and adoption of LPG for cooking as the incomes improve.

In rural areas, government is conducting a vigorous campaign for uptake of solar home systems, thus reducing paraffin for lighting, which is the major end-use for paraffin/kerosene in the rural areas.

d) LPG

LPG is a popular cooking fuel in Botswana within even the middle income groups. As incomes improve, the urban low-income group is also expected to adopt the cooking fuel.

e) Coal

At the beginning of NDP7, coal demand was expected to increase as a result of government efforts to promote it. Coal uptake is however hindered by related costs for devices and also that it is an unclean fuel. Government has continued to promote it and thus the assumed growth assumes further scarcity of fuelwood and adopting of coal for cooking by the urban low income and peri-urban dwellers. However the demand growth rate is expected to be low.

2.4.2 Agriculture Sector

The energy consumption in agriculture are related to household chores like water pumping for domestic and livestock consumption using diesel/petrol engines or electric motor pumps, both of which have implications for GHG emissions through consumption of fossil fuels. Diesel followed by fuel oil which are energy fuels used in land tillage and water pumping are the dominant fuels used in the agricultural sector.

2.4.3 Transport Sector

Petrol and diesel are the major petroleum products consumed in Botswana.

Trains and road freight vehicles are major consumers of diesel accounting for almost all the diesel consumption in this sector.

The prevalent use of the private car and high engine capacities is a significant contributor to petrol consumption. There has also been a high increase of cars coming on stream and a high proportion of the road network is unpaved resulting in high vehicle fuel intensity per kilometre travelled.

The rate of private car increase is expected to slow down slightly in the short term as cars become relatively more expensive and opportunities for buying BHC houses override in importance car purchases. There will also be a general shift to small engine vehicles. The vehicle price increases might encourage shift to use of second hand vehicles.

There are also vigorous efforts to pave the road network in Botswana. The more paved roads coming on stream will reduce fuel economy but may be counter-balanced by increased travel.

Consumption by air transport is minimal because Botswana has two small aircraft and there are very few landings by international airlines.

2.4.4 Industry Sector

There is an expected industrial expansion entailing an additional electricity capacity of 102MVA (Orapa mine expansion, 18MVA; Other mines 7MVA; Hyundai, 11MVA and North-South Carrier 32MVA; Algo Industries-14MVA and Lobatse 2000- 20MVA) by 2005. In the Base case, the additional capacity will mostly be met from regional imports plus additional generation capacity planned for Morupule Power station after 2003 of 120MW.

In the manufacturing industry, increased activity and accelerated growth are expected in the long term. The highest energy demand in this sector is expected to be linked to both electricity and coal consumption. Coal consumption in industry is related to steam raising while electricity is mostly to provide motive power. The coal-fired furnace at BCL in Selibe Phikwe is likely to continue being used into the long term even after the mine is closed thus influencing the level of future coal demand.

The demand for other energy sources/fuels in industry will depend on the economic growth of then various industrial sub-sectors.

2.4.5 Commerce Sector

The major energy consumer in the Commerce sector is currently government. The Trade and Hotels and the financial services sectors being expected to be the future engines of economic growth are likely to trigger further energy demand particularly electricity.

The major energy fuels/sources throughout the baseline period are electricity, gasoline, firewood and diesel. Electricity demand will be dictated by lighting, space conditioning and water heating. Gasoline and Diesel consumption is more intensive in government transport. Firewood is used in the government institutions and to a less extent in Hotels.

2.5 Electricity-Transformation Sector

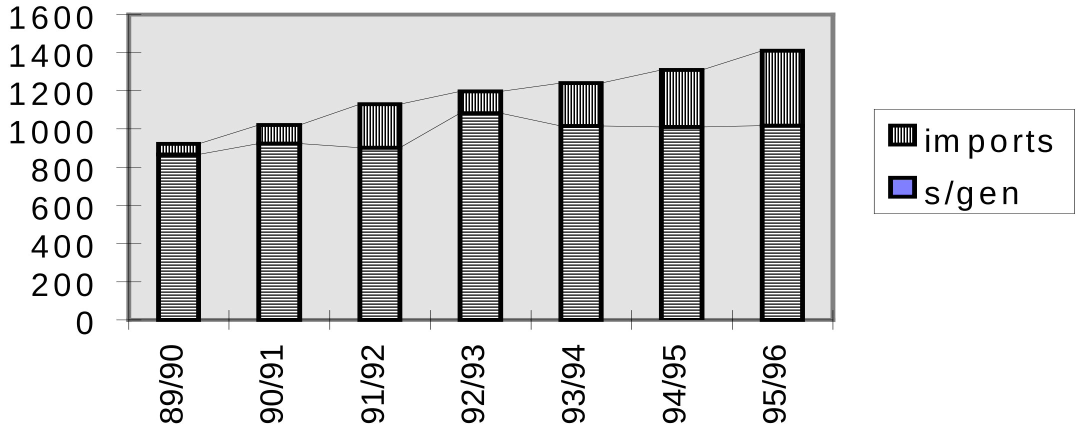
2.5.1 Short Term Assumptions

It is anticipated that all short-term electricity demand will be supplied from regional power imports. The share of imports as shown in Fig 2.5.1 below is increasing significantly as a result of this deliberate power policy. Local generation at Morupule is however also expected to be increased by another 120MW by 2005 and this will result in increased coal consumption.

In the short term, Botswana Power Corporation can attain a maximum capacity of 1014MW and firm capacity of 512MW (Table 2.5.1) (BPC Annual Reports, 1995) from its generation

(132MW + 120 MW in 2003 at Morupule) and from power imports. This is weighed against a minimum expected load of 357MW estimated for Botswana in 2007/2008. This load is about 70% of the firm capacity available at the end of the short-term horizon. There is also additional 20MW capacity at Botswana Ash accounted for in the baseline transformation scenario.

Fig.2.5.1 Local Generation and power imports (GWh)



2.5.2 Long Term Assumptions

In the long term Botswana might increase its local thermal generation capacity but in the base case, Morupule upgrade which is effected by 2005 is the only local additional generation capacity assumed. Diesel generators are assumed to be phased out as from the short term being replaced by the grid and centralised solar.

The high case scenario would assume major additional generation capacity coming on stream from Independent Power Producers (IPPs). IPPs will thrive when major privatisation policies are in place. IPPs will also be attractive since no government expenditure will be required for additional generation capacity. Excess generation capacity can be used by Botswana as a tariff bargaining tool in the regional power trade. The anticipation for an IPP Power Export plant of up to 1200MW was not part of the baseline, as it is becoming increasingly remote that Botswana will go ahead with this project.

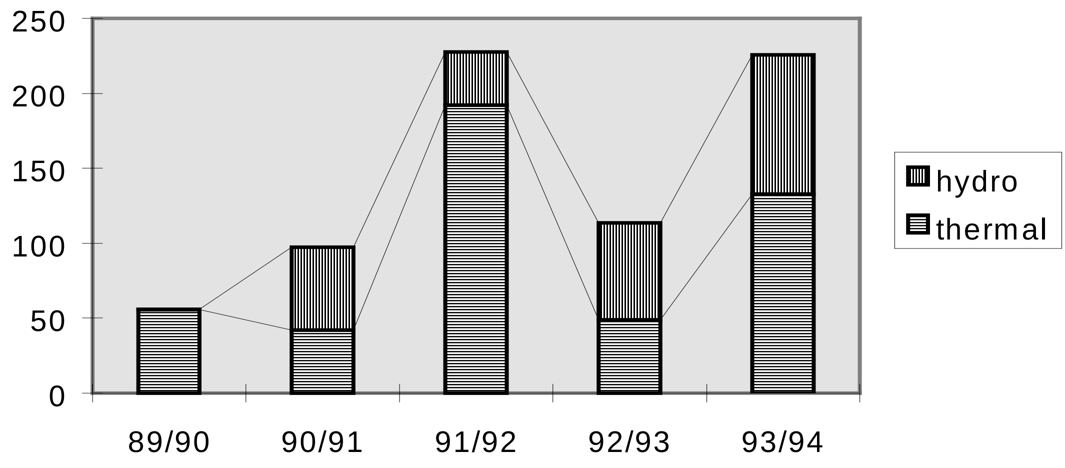
Table2.5.1 Potential Power Capacity Base for Botswana Power Corporation-2007/2008

SUPPLY SOURCE PLANNING		
Max Capacity Firm Capacity	Morupule Power Station (1994/95)* 4x33MW 132MW (gross) 3x33MW 99MW (gross)	117MW net 88MW net
Max Capacity Firm Capacity	Phokoje 400/200KV substation (1997) 2x315MVA 567MW (net) 1x315MVA 284MW (net)	
Max Capacity Firm Capacity	ESKOM 132KV interconnection (1995) 3x70MW 210MW (net) 2x70MW 140MW (net)	
Max Capacity Firm Capacity	ZESA/ZESCO 220KV interconnection (1995) 1x 120 120MW (net) 0 0	
TOTAL Max Capacity Firm Capacity	Net to System (1997) 117+567+210+120 =1014MW 88+284+140 =512MW	

*Source: BPC Annual Report, 1995*This excludes expected additional capacity of 240MW*

In the context of power imports it is also envisaged that hydropower imports will be available from Mozambique, Zambia and Zaire. The hydropower imports from the regional countries however fluctuate (Fig. 2.5.2) due to erratic hydrology in the region.

Fig.2.5.2 Thermal and Hydropower import share (GWh)



In the long term the baseline assumes a steady exploitation of the available capacity and imports from the region.

2.6 Regional Assumptions

Regional assumptions would be relevant where electricity trade is applicable. An option on Botswana depending on guaranteed hydropower imports has been discussed but it is rather more of a regional option than a national one.

For the option to operate, excess hydropower or opportunity to invest in hydropower plants elsewhere in the region would be the prerequisite. Trading and tariff setting would then be done under the Southern African Power Pool (SAPP).

2.7 International Influence - Global Policies and Fuel prices

It is assumed that there will be no major FOB oil shocks in the time horizon in order to retain the recommended IPCC future fuel prices adopted in the mitigation analysis. It is also assumed that other countries in the world will also be conducting GHG abatement so that the effort by Botswana to reduce GHG emissions will be accounted.

There will be a general bias towards using cleaner sources of energy and moving away from fossil fuels for any GHG abatement policy to function.

3 Baseline Scenarios

3.1 Projected Sectoral Energy Demand

Under this section, the sectoral energy baselines as produced in the LEAP Model are presented and discussed.

3.1.1 Household Sector

Table 3.1.1 shows energy demand in the household sector by fuel types.

Table 3.1.1 Projected Household Energy Demand in the baseline and derived growth rates TJ

Fuel Type	1994	2005	2030	1994-2005 growth rate %	2005-2030 growth rate %	BEMP growth rate %-Low to Base case * 1992-2020
Electricity	530	810	1 350	3.9	2.1	3 to 5
Kerosene	490	660	990	2.7	1.6	2.3 to 3.7
LPG	500	730	1 070	3.5	1.5	2.3 to 3.7
Coal	50	80	130	4.4	2.0	2.3 to 3.7
Firewood	20 940	25 570	37 560	1.8	1.5	-1.3 to 2.3
solar	30	50	70	4.8	1.4	
TOTAL	22 530	27 980	41 160	2.0	1.6	

* *where urban and rural; growth rates are given - a weighted average has been worked out. BEMP growth rates of 1992 to 2020*

Firewood remains the most dominant household fuel accounting for about 91% of the total household energy demand in 2005 and 2030. Electricity is the second largest fuel contributing about 3% of the household energy demand. LPG is the third important household fuel contributing 2.6% to the total household energy demand in 2005 and 2030, which is slightly more that the kerosene/paraffin share of 2.3%.

Coal and solar energy demand is expected to be steadily increasing but still contributing the least shares of .3% and .2% respectively to the total household energy.

The household energy will have increased by an additional 20% in 2005 and 80% by 2030 compared to the base year.

The growth rates of the various household fuels/sources represented in the baseline as adopted from the population growth and AEEI for household devices are shown in Table

3.1.1 for both the short term and long term periods. In the short term, the highest growth rates will be in solar (4.8%), Coal (4.4%) and electricity (3.9%). LPG and kerosene will have medium growth rates of 3.5% and 2.7% respectively. The lowest growth rate will be in fuelwood (1.8%), which is the largest household energy fuel and has thus influenced the total household growth rate of 2%.

In the long term the fuel growth rates will generally decline. Relatively high growth rates of about 2% will be in electricity and coal demand, but the rates for all the other fuels will be 1.6% and below (Table 3.1.1).

These derived fuel growth rates were compared with those derived in the Botswana Energy Master Plan (BEMP, 1993) and the growth rates derived in this study were found to lie between the BEMP base case and low case growth rates determined for the period between 1992 and 2020. This implies that our assumptions about the economic growth result in similar results as previously derived by another study, which increases reliability of the current result.

3.1.2 Agricultural Sector

The expected low growth in agricultural GDP between 1994 and 2005 is responsible for the slump in energy demand in 2005. Thereafter the high growth rate of 5% between 2005 and 2030 will result in higher diesel demand for both arable tillage and water pumping for cattle.

Table 3.1.2 shows the energy fuel/source demand in the agricultural sector derived in the LEAP Model.

Table 3.1.2 Projected Agriculture Energy Demand in the baseline (TJ)

Fuel Type	1994	2005	2030	BEMP growth rates: low-base- high cases %
Electricity	7	7	17 (3.6)	3-5-7%
Gasoline	18	17	45 (4)	0-2-5%
Diesel	475	475	1418 (4.5)	3-3-5%
Fuel Oil	27	27	81 (4.5)	
Solar	1	1	2 (2.8)	
TOTAL	528	527	1564 (4.5)	

(4.5) derived fuel growth rates; 3-3-5 low-base-high case BEMP rates as % of 1992-2020

The dominant fuel in the agricultural sector will continue to be diesel contributing about 90% to the total agricultural energy demand in 2005 and 2030. Fuel oil which is often used in conjunction with diesel in tractors and diesel water pumps will contribute 5%. Gasoline is also used to a less extent in water pumping but its share will be lower at nearly 3%.

Electricity and solar Photovoltaics mainly employed in water pumping will make small to the total agricultural energy demand contributions of 1% and 0.2% respectively. (Table 3.1.2).

Due to expected near-stagnant growth of the agricultural sector in NDP8, the energy demand to 2005 will also be stagnant compared to 1994 but after that grows to be 3 times more in 2030.

Energy fuel growth rates derived for this sector show diesel and fuel oil to have the highest rates in the long term of 4.5% each. Gasoline (4%), electricity (3.6%) and solar (2.8%) also have relatively high growth rates but the diesel growth rate will influence the total agricultural energy demand growth rate also of 4.5% (Table 3.1.2).

The agricultural energy fuel growth rates derived in this study also fall within the range of BEMP base case to high case growth rates (Table 3.1.2).

3.1.3 Transport Sector

Table 3.1.3 shows the expected growth in transport energy fuels in the baseline.

Table 3.1.3 Projected Transport Energy Demand in the baseline (TJ)

Fuel Type	1994	2005	2030	BEMP growth rates-low-base-high %
Gasoline/petrol	6 870	11 320 (4.6)	35 200 (4.6)	2-7-9
Aviation gas	70	110 (4.2)	330 (4.5)	3-7-9
Kerosene/Jetfuel	190	320 (4.9)	990 (4.6)	3-6.8-8
Diesel/Gas oil	3 050	5 030 (4.7)	15 650 (4.6)	3-7-9
Other petroleum products	150	240 (4.4)	750 (4.7)	3-7-9
TOTAL	10 330	17 020 (4.6)	52 920 (4.6)	

(4.6) derived energy fuel growth rates (%) versus BEMP low-base-high growth rates (3-7-9)% for 1992-2020.

Gasoline and diesel will each constitute 66% and 30% of the total transport energy demand in 2005 and 2030. Any mitigation analysis in this sector should therefore target reducing consumption of these fuels. Jet fuel (2%), lubes (1.4%) and aviation gas (0.6%) will contribute small shares to the total transport energy demand.

The overall transport energy demand will grow by 65% in 2005 and 5 times in 2030.

The overall transport energy growth rate will be about 4.6% throughout the baseline. This growth rate is less than the 7% estimated for the base case in the BEMP (1993) study (Table 3.1.3). Vision 2016 transport energy growth rate (8.9%) was comparable with the high case BEMP energy fuel growth rate (9%) for this sector. Both BEMP results and Vision 2016 would result in high transport energy demand, which is not paralleled by similar growth in energy in the other sectors. In order not to be dramatic, the short term annual growth rate was kept constant throughout the time horizon of the baseline.

3.1.4 Industry Sector

Table 3.1.4a to 3.1.4c shows the energy demand derived in LEAP for the various segments of Industry namely Mining, Manufacturing and Construction.

Mining

Coal (50%) and electricity (32%) will be the major energy sources/fuels in the mining sector (Table 3.1.4a) both in the short and long term. The same energy sources/fuels are important in smelters and boilers, and motive power supply respectively. Diesel will also contribute a relatively significant share of 16% for driving mining machinery. The other petroleum products consisting of gasoline, fuel oil, lubes, LPG and kerosene/Jet fuel will only constitute about 4% in the future total industry energy demand.

The low energy fuel/source growth rates of about 1% were derived for the Mining Sector (Table 3.1.4a). Due to these low growth rates in the energy source/fuel demand, the total energy demand in the mining industry will grow by an additional 10% in 2005 and 55% in 2030 with respect to the base year demand.

The growth rates derived for the mining sector are close to those for the base case in the BEMP results. The BEMP results suggest lower in energy demand in their lower case, a situation that can only be realised if some major energy consumer- mines like the BCL close. This possibility is not yet envisaged and there is some expansion in the mining sector, particularly diamond which is also a major consumer of electricity. The energy demand growth rate derived in this study is then considered a good balance in the light of the possibilities presented for the BEMP study for this sector.

Table 3.1.4a Projected Mining Energy Demand in the baseline (TJ)

	1994	**2005**	**2030**	BEMP annual growth rates: low-base-high %
Electricity	2515	2711 (0.7)	3545 (1.1)	-10-5-5
gasoline	86	93 (0.7)	121(1.0)	0-2-5
kerosene & Jet fuel	10	11(0.9)	14 (1.0)	
diesel	1215	1310 (0.7)	1713 (1.1)	-5-2-5
Fuel Oil	52	56	73	
Lubes	34	37	48	
LPG	21	23 (0.8)	30 (1.1)	-10-0-2
Coal	3678	4191 (1.2)	6216 (1.6)	-10-0-1
TOTAL	7611	8432 (0.9)	11760(1.3)	

(0.7) *derived energy fuel growth rates in % in this study*

(0.8) *-10-0-1 low (-10%)-base(0%)-high(1%) case BEMP energy fuel growth rates for 1992-2020.*

Manufacturing

Coal (71%), electricity (14%) and diesel (11%) in that order will also be the important energy sources/fuels in the Manufacturing sector (Table 3.1.4b) both in the short and long term. LPG, gasoline and lubes will together constitute 4% of the total energy demand in the manufacturing sector.

Table 3.1.4b Projected manufacturing (+Meat products) Energy Demand in the baseline (TJ)

Fuel Type	1994	2005	2030	BEMP annual growth rates low-base-high %
Electricity	76	172 (7.7)	1450 (8.9)	3-5-7
gasoline	8	18 (7.7)	153 (8.9)	0-2-5
diesel	61	138 (7.7)	1164 (8.9)	3-3-5
LPG	12	27 (7.7)	229 (8.9)	2-5-6
Coal	391	892 (7.8)	7661 (9.0)	-10-0-1
Lubes	1	2 (6.5)	19 (.9.4)	
TOTAL	549	1249 (7.8)	10676(9.0)	

(7.7) derived energy fuel/source growth rates as % in this study

-10-0-1 low-base-high case growth rates for BEMP study (period 1992-2020)

The expected high growth in manufacturing will result in doubling of fuels in 2005 and an energy growth in 2030 which is about 20 times that of the base year. Although the growth rate in manufacturing energy demand is high, the absolute demand is not comparable to that of the transport and commercial sectors.

The energy fuel/source growth rates derived in this study of 8 to 9% are higher than those derived for the high case in the BEMP study (1993) (Table 3.1.4b) this difference may be explained by the fact that the BEMP study was conducted before Vision 2016. Vision 2016 aspires for an even higher growth rate in the manufacturing sector than envisaged during BEMP study.

Construction

Construction only consumes gasoline and diesel in the proportion of 45% and 55% respectively. Both fuels will grow by seven times in 2030. Growth in the short term will however be minimal (less than 6% by 2005). (Table 3.1.4c).

Table 3.1.4c Projected Construction Energy Demand in the baseline (TJ)

Fuel Type	**1994**	**2005**	**2030**	**BEMP annual growth rates** **low-base-high**
Gasoline	24	25 (0.4)	178 (8.2)	3-3-5
Diesel	29	31 (0.6)	215 (8.1)	3-3-5
TOTAL	53	56 (0.5)	393 (8.1)	

(7.7) derived energy fuel/source growth rates as % in this study

-10-0-1 low-base-high case growth rates for BEMP study- period 1992-2020

The energy fuel growth rates in the short term will average 0.5% but will increase to 8.1% in the long term probably in response to the expected manufacturing expansion.

The energy fuel growth rates in the construction sector in the long term are significantly higher than those estimated in the BEMP (<5%) (Table 3.1.4c).

3.1.5 Commercial Sector

Table 3.1.5 shows the energy fuel/source demand in the collective Commercial Sector in the baseline period.

Electricity will continue to be the most important energy source in the Commercial sector contributing about 37% to the total sector energy demand. Gasoline (22%), diesel (16%) and fuelwood (16%) are the other important energy fuels in this sector. Coal will contribute about 7% to the sector energy demand throughout the time horizon. Kerosene/Jet fuel, LPG and solar will together only contribute 2% to the sector’s total energy demand.

Table 3.1.5 Projected Commercial Sector Energy Demand in the baseline (TJ)

Fuel Type	1994	2005	2030	BEMP annual growth rates: low-base-high %
Electricity	1243	2245 (5.5)	2968 (1.1)	4-5-7
gasoline	739	1323 (5.4)	1698 (1.0)	3-7-9
Kerosene/Jet Fuel	26	49 (5.9)	72 (1.6)	1-3-5
Diesel/gas Oil	534	956 (5.4)	1227 (1.0)	3-7-9
LPG	67	124(5.8)	176 (1.4)	2-5-6
Coal	221	418 (6.0)	609 (1.5)	
Firewood	481	945 (6.3)	1516 (1.9)	-10-0.5-2
Solar	4	7 (5.2)	9 (1.0)	
TOTAL	3315	6067 (5.6)	8275 (1.2)	

(7.7) derived energy fuel/source growth rates as %: BEMP growth rates 1992-2020.

-10-0-1 low-base-high case growth rates for BEMP study

Energy demand in this sector will grow by an additional 83% in the short term but between 2005 and 2030 energy demand will only grow by an additional 36%. The long term additional energy demand growth with respect to the base year is about 150%.

The average energy demand growth rate in the short term is high (5.6%) but after 2005, the growth rate drops to an average of 1.2%.

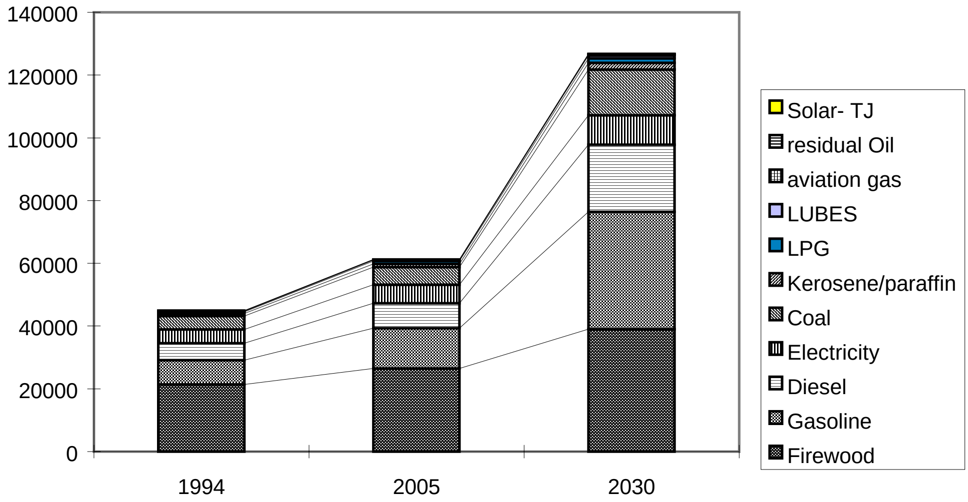
The short-term energy growth rate for this sector falls within the base case-high case range of the BEMP rates. The long-term growth rate is however lower than the BEMP low case for most fuels except kerosene and fuelwood. This is a result of the assumption made in this study that opportunities for rapid growth in the Commercial sector will have been captured by 2010- a consideration which was not probably made in the BEMP study.

The overall energy baseline for the energy sector of Botswana is presented below.

3.2 Total Demand-Side Energy

Fig 3.2.1 and Table A.2 (Annexe) show the general energy fuel/source growth pattern in the baseline for the whole energy sector.

Fig 3.2.1 Projected Energy Fuel demand in the Baseline 1994-2030. (TJ)



3.2.1 Fuel Demand

Fuelwood is the dominant fuel throughout the time horizon with contribution shares of 43% in 2005 and 31% in 2030. Gasoline is the second largest fuel in demand in 2005 (21%) and 2030 (30%) but shows faster growth (4.4-4.7%) in demand than fuelwood (1.6% to 2%) (Table 3.2.1). The other important energy source/fuels in the total energy demand are diesel (13-17%), electricity (7-10%) and coal (9-12%) as shown in Table 3.2.1. The other petroleum products consisting of aviation gas, kerosene/jetfuel, fuel oil, lubes and LPG together with solar are expected to contribute the remaining 3 to 4% to the total energy fuel/source demand.

Petroleum products generally will have the highest growth rates (>3.5%) in demand especially in the short term. All the fuel/source demand growth rates will decline in the long term except for coal, lubes, diesel and aviation gas which show higher growth rates between 2005 and 2030 (Table 3.2.1).

The overall growth rates in total energy demand for the demand side are 2.9% in the short term and 3% in the long term.

Table 3.2.1 Demand Side energy demand by fuel type and fuel growth rates (derived)

FUEL TYPE	1994- Energy Demand **TJ**	2005- energy demand TJ	2030- energy Demand TJ	annual growth rate 2005	annual growth rate 2030
Electricity	4370	5950 (10%)	9330 (7%)	2.8	1.8
gasoline	7750	12800 (21%)	37400 (30%)	4.7	4.4
aviation gas	70	110	330	4.2	4.5
kerosene/Jet fuel	720	1040	2060	3.4	2.8
Diesel	5370	7940 (13%)	21380 (17%)	3.6	4.0
Fuel Oil	50	60	70	1.7	0.6
LPG	600	910	1500	3.9	2.0
Lubes	210	310	900	3.6	4.4
Coal	4340	5580 (9%)	14620 (12%)	2.3	3.9
Fuelwood	21420	26510 (43%)	39070 (31%)	2.0	1.6
Solar	40	50	80	2.0	1.9
TOTAL	**44920**	**61240**	**126750**	**2.9**	**3.0**

(12%) percentage contribution by fuel to total energy demand

3.2.2 Sectoral Energy Demand

Up to 2005, the household sector will still be the largest consumer of energy in Botswana contributing 45% to the total energy demand. Transport (28%), Industry (16%) and Commerce (10%) are the next largest energy contributing sectors. Agriculture will contribute only 1% to the sectoral energy demand.

The household sector is however overtaken by the transport sector in 2030 (Fig 3.2.2) as the sector with the largest contribution to the energy demand with 42% share compared to fuelwood which will contribute 32%. The transport sector energy demand is expected to grow 5 times between 1994 and 2030 while energy demand in all the other sectors will only increase by at most 3 times.

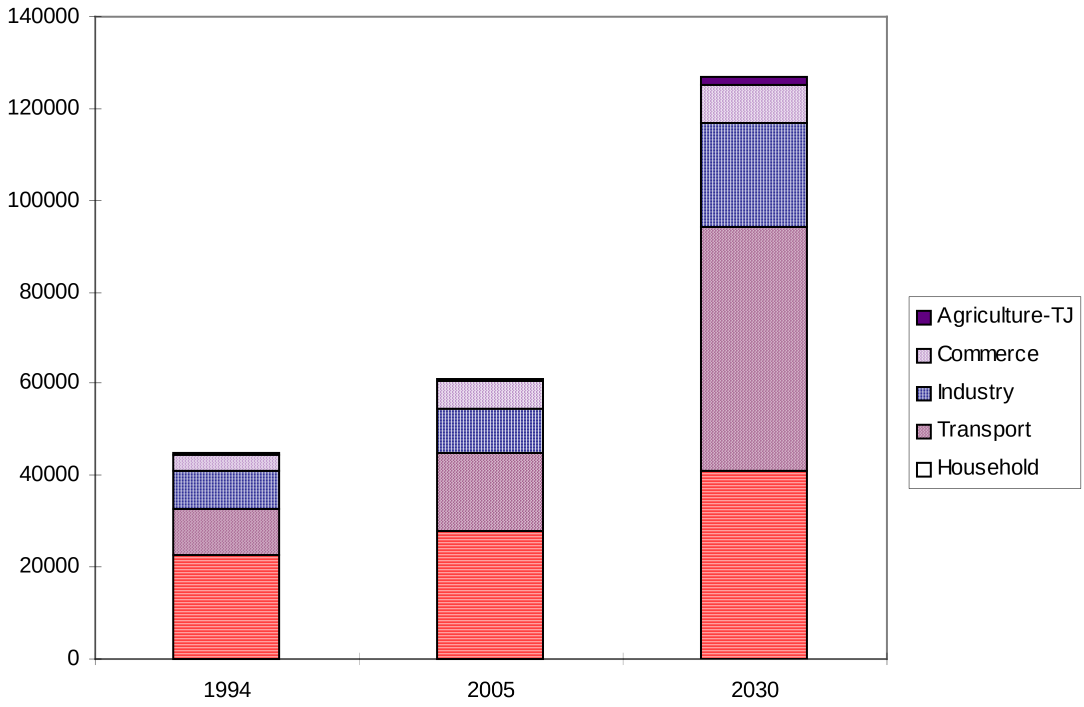
Table 3.2.2 Sectoral energy demand and fuel growth rates (derived)

SECTOR	1994 energy demand TJ	2005 Energy Demand TJ	2030 Energy Demand TJ	1994-2005 annual growth rates	2005-2030 annual growth rates
Household	22530	27900 (45%)	41160m (32%)	2.0	1.6
Transport	10330	17020 (28%)	52920 (42%)	4.6	4.6
Industry	8210	9740 (16%)	22830 (18%)	1.6	3.5
Commerce	3320	6070 (10%)	8280 (7%)	5.6	1.2
Agriculture	530	530 (1%)	1560 (1%)	0	4.4
TOTAL	44920	61240 (100%)	126750 (100%)	2.9	3.0

(42%) Sector energy contribution/share

Transport and industry sectors show an increase in their shares in the long term while the household and commerce sectors shares are reduced. Agricultural energy share remains constant at 1% throughout the time horizon.

Fig 3.2.2 Projected sectoral energy demand in baseline 1994-2030. TJ



Energy Demand growth rates will be highest in the Commerce and Transport sectors in the short term with growth rates of 5.6% and 4.6% respectively. The other sectors have growth rates of 2% and below. Transport energy demand growth rate is consistent in the long term while that of Commerce declines to 1.2%. Energy demand growth rate of the agricultural and industrial sectors to 4.4% and 3.5 respectively in the long term. The growth rate for the household sector declines in response to decline in the growth of fuelwood demand.

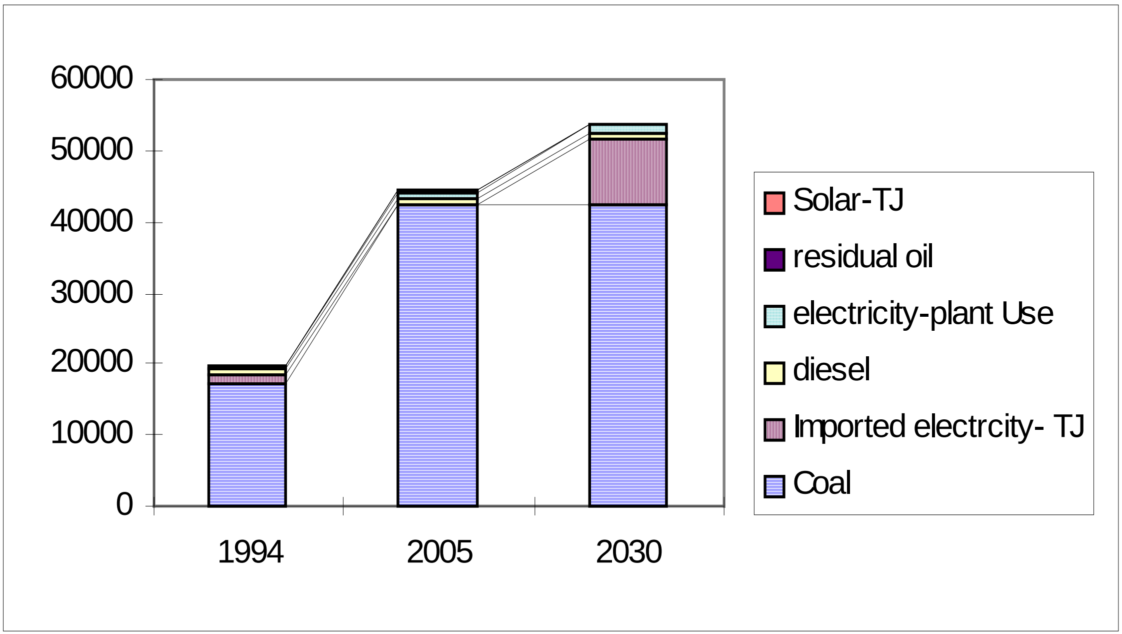
Major energy growth will occur in the transport sector because the sector responds to growth in all the other sectors. Energy demand in Industry will also be increasing in the long term due to expected rapid growth in manufacturing. The energy demand in Industry will significantly be reduced if the BCL mine closes, as the mine is the largest consumer of electricity and coal on the Demand Side in Botswana.

3.3 Transformation energy

3.3.1 Transformation Input Energy Demand by Fuel

Fig 3.3.1 shows the energy fuel/source demand in the transformation/power sector.

Fig 3.3.1 Projected fuel demand for electricity generation in baseline (TJ) by fuel



Coal will be the dominant fuel used in the power sector contributing 95 and 78% in to the total transformation energy inputs in 2005 and 2030 respectively. Actual coal demand however will stagnate after 2005, as power imports become increasingly important after 2005. The zero power imports of total energy inputs in 2005 is a reflection of increased local generation capacity at Morupule of 372MW (present 132MW and additional 240MW) which is expected in 2003. Beyond 2005 imports are the second largest energy input contributing 18% to the total transformation input energy by 2030.

Electricity for plant use and diesel for diesel plants also do not increase after 2005 but together contribute 3 to 5% to the transformation energy input.

The various transformation energy inputs and the related fuel/source growth rates are presented in Table 3.3.1.

Table 3.3.1 Transformation energy inputs for Botswana in the baseline 1994-2030

FUEL	1994	2005	2030	growth rates 1994-2005	growth rates 2005-2030
Electricity	489	1170 (2.6)	790	8.3	0
diesel	640	1170 (1.6%)	720	1.1	0
fuel oil	50	140 (0.3)	140	5.5	0
coal	17560	42350 (95.4%)	42350 (78.4%)	9.8	0
solar	0	20	40	-	2.8
imported electricity	1190	0	9460 (17.6%)	-9	4.2
TOTAL	19640	44390 (100%)	53870 (100%)	7.7	4.1

(93.6%) - percentage contribution to total transformation energy input in that year

Imported power, in this analysis, has been treated as an input energy source in a plant with 100% efficiency; hence the input is similar to the output electricity.

The highest growth rates in fuel demand will be registered in the short term except for imported power which will decline to zero if the Morupule upgraded plant operates a full capacity. Plant electricity demand, fuel oil and coal will have high growth rates of 8.3%, 5.5% and 9.8% respectively responding to the upgrade of local generation at the Morupule Power Station. Diesel demand will increase slowly (1.1%) in the short term as a result of anticipated growth in demand for DEMS power.

In the long term growth rates of fuel/source demand are zero for all the energy sources/ fuels except for imported power and solar energy which grow at 4.4% and 2.8% respectively.

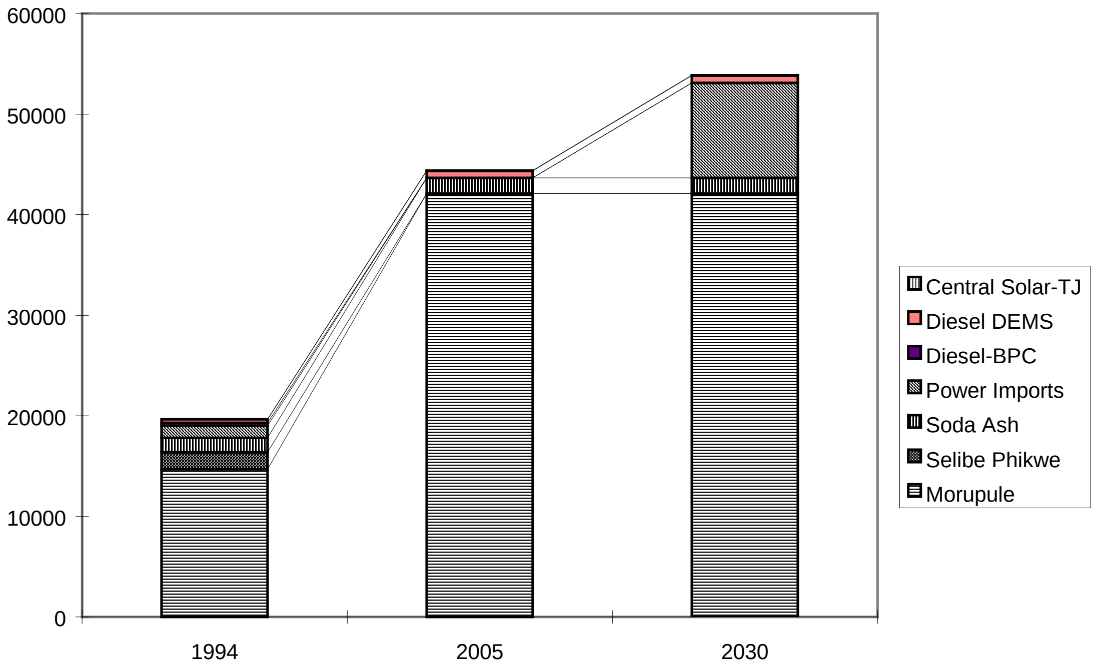
The proportion of imports increases in the long term to meet increasing electricity demand in the absence of additional local generation capacity.

Solar energy input will be increasing but will still be small to make a dent in the power sector.

3.3.2 Energy Demand by Power Plant

Fig 3.3.2 shows the transformation energy inputs for the power plants expected to be in operation in the study horizon.

Fig 3.3.2 Projected transformation input energy demand in the baseline by power plant (TJ)



Morupule Power Plant will be the main consumer of energy in the Power sector and also the largest local generation plant with a demand of 95% and 78% of the total transformation energy inputs in 2005 and 2030 respectively.

Botswana Soda Ash generation plant will have a constant capacity of 20MW throughout the time horizon hence the constant energy input demand. The plant energy demand share will be about 3 to 4% of the total transformation energy inputs throughout the time horizon.

Diesel plants operated by the Department of Electrical and Mechanical Services (DEMS) will have an energy demand share of about 1 to 2%. Diesel plants operated by the Botswana Power Corporation will be slowly phased out to be negligible in 2005.

Selibe Phikwe energy input demand is only reflected in 1994 since the plant was decommissioned in 1996 but had an energy input share of 8.5% in 1994.

Whilst centralised solar plants are expected to steadily increase in capacity to about 5 MW by 2030, the solar energy input share in the power sector will still be negligible (nearly 0.1%).

3.4 Primary Energy Fuel Supplies

The primary energy supplies derived in LEAP are presented in Table 3.4.1, which also shows the indigenous and imported fuels. There are no fuel exports from Botswana under the assumed baseline.

Table 3.4.1 Projected Primary Energy Supply in the baseline (TJ)

Fuel Type	**1994**	**2005**	**2030**
Gasoline	7750	12800	37400
aviation gas	70	110	330
Kerosene/Jet fuel	900	1040	2060
diesel	6010	8660	22100
Fuel Oil	160	210	320
LPG	620	910	1500
Other petroleum products	150	240	750
coal*	21910	47960	56970
Imported electricity	1190	0	9460
firewood*	49260**	26510	39070
solar*	40	70	120
TOTAL	**88060**	**98510**	**170080**
Indigenous fuels*	**71210**	**74540**	**96160**
Imported Fuels	**16850**	**23970**	**73920**
Indigenous share %	**81**	**76**	**57**
Import share %	**19**	**24**	**43**

*** includes a high statistical difference of about 28000 TJ*

Imported fuels are the petroleum products and imported electricity. There is an increase in the proportion of these commercial fuels in Botswana in the long term. This is not unusual, as there is a general shift from indigenous to commercial energy demand as economic development of a country is advanced.

The main commercial energy fuels imported into Botswana are the petroleum products. While coal is a major indigenous commercial fuel in Botswana, stagnation of local power generation will keep coal supply almost constant.

3.5 Baseline GHG Emissions

The total calculated CO_2 equivalent emissions in 2005 and 2030 were found to be 7317 Gg and 11739 Gg respectively compared to the base year emissions of 3786 Gg.

Table 3.5.1 shows the individual GHGs and their level of emissions in the short and long term.

Table 3.5.1 Baseline GHG emissions for Botswana Gg (CH_4=21 GWP and N_2O= 310GWP)

GHG type	**1994**	**2005**	**2030**
CO_2	3050	6052	9802
CH_4	20.75	33.2	47.23
N_2O	0.97	1.83	3.05
CO_2 equivalent	**3786**	**7317**	**11739**

3.5.1 Demand and Transformation Side GHG Emissions

The electricity generation sector will release 59% (4318) of the total energy sector CO_2 equivalent emissions (7317 Gg) in 2005. The demand sectors which will release 2426 Gg (33%) (Table A.4- Annexe) while coal production will be responsible for 8% of the emissions in the same year. On the individual gases, the electricity sector will emit 66% of the CO_2, 1% of CH_4 and 59% of N_2O compared to the demand sectors which will emit 34% for CO_2, 17% of CH_4 and 41% of N_2O. The highest CH_4 emissions (82%) of total energy sector CH_4 emissions in Botswana will be due to Coal mining.

In the long term (2030) the demand side becomes dominant emitting 57% of the total CO_2 equivalent emissions followed by the electricity sector with 41% and coal mining with 7%.

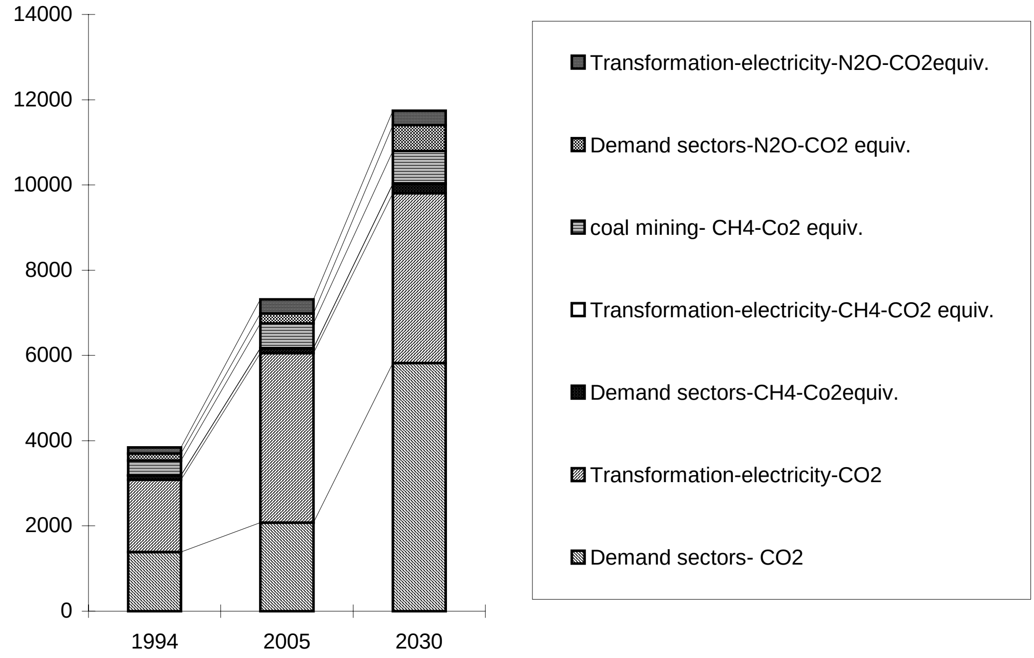
The demand side will also emit 22% of the CH_4 and 65% of the N_2O emissions in 2030. The high CO_2 and N_2O emissions will result from the high petroleum products demand particularly gasoline/petrol and diesel in the transport sector. The electricity or transformation sector will emit 1% of the total energy sector CH_4 in Botswana and 35% of the N_2O in the same year. Coal mining will still dominate the CH_4 emissions with 77% of the total CH_4 emissions.

Fig 3.5.1 shows the GHG growth pattern in the baseline.

The combination of high petroleum products and coal demand in industry will exceed coal for transformation, which will not increase after 2005 hence the higher CO_2 emissions for the demand side. Petroleum products also have a higher N_2O coefficient than coal.

The distribution of CO_2 equivalent emissions in the baseline would suggest placing GHG abatement emphasis on the transformation in the short term and on the demand-sectors in the long term. The selection of mitigation options however depends on the available opportunities in the sectors.

Fig.3.5.1 Baseline GHG emissions by gas type expressed as CO_2 equivalent (Energy demand and supply sectors)



3.5.2 Sectoral GHG Emissions

In the short term, power generation/transformation sector excluding emissions from coal mining will be responsible for 59% of the total CO_2 equivalent emissions (7317Gg) followed by the transport sectors with 18% (Table A.5 - Annexe). This is not surprising, as these are the sectors consuming most of the fossil fuels namely coal, petrol and diesel respectively. Coal mining will emit CH_4 emissions equivalent to 8% of the total CO_2 equivalent emissions.

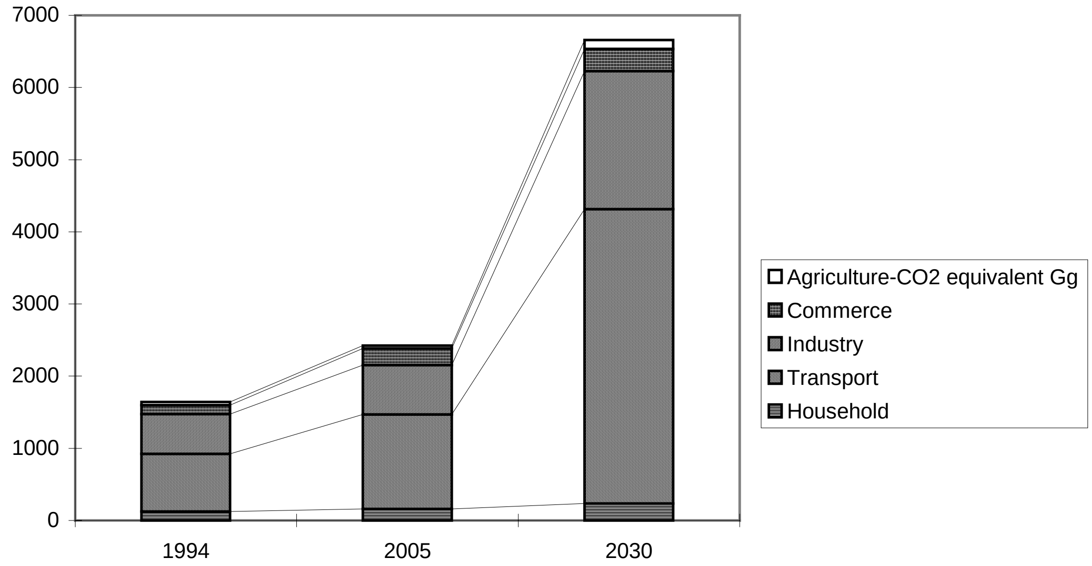
Industry and commerce will contribute 9% and 3% to the total CO_2 equivalent emissions respectively. The household and the agricultural sector will contribute the remaining 3%.

Although in the long term the power /electricity sector remains the dominant emitter (37%) the transport sector emissions will also dramatically increase to 35% of the total CO_2 equivalent emissions (10530 Gg). Industry and coal mining will contribute 16% and 5% to the emissions respectively. The rest of the emissions will be emitted by commerce (3%), household (2%) and agriculture (1%).

Fig 3.5.2 shows the anticipated CO_2 equivalent emissions growth pattern by sector.

The sectoral emission distribution would suggest aiming to reduce GHG emissions from the power generation, transport and industry sectors, as these are the major emission ones. The determining factors however also include availability of adequate and appropriate data for analysis. In the mitigation analysis, criteria of option selection could also be based more on the impact of an option on the economic and social development even if the level of greenhouse gas is small. Taking into consideration the above issues a portfolio of GHG abatement options was selected from the various sectors as presented in Chapter 4.

Fig 3.5.2 CO_2 equivalent emissions by activity/sector type



4 Analysis

4.1 Parameter Analysis

4.1.1 Discount Rates

Costs of mitigation options e.g. introducing a new technology need to be discounted to the present value and thus a discount rate is required for the purpose.

Selection of a discount rate is not a straightforward process. There are three discount rates that might be used namely:

a) The opportunity cost of capital. This appears to be the best discount rate to use but difficult to apply. This is the profitability of the last possible investment in an economy given the available capital. In the developing countries it is assumed to be somewhere between 8 and 15% (Gittinger, 1974).

b) The borrowing rate for the project which is financed i.e. if capital is borrowed at 12% rate of return, then the discount rate assumed becomes 12%.

c) The social rate of return which, it is suggested, adequately reflects the time preference of society as a whole than does the opportunity cost of capital. Although it is a more realistic rate to use for mitigation analysis, it is difficult to determine.

Some previous studies on Abatement costing like the chapter on Zimbabwe Country Study (Risø/UNEP, 1995) assumed the social discount rate as the government lending rate.

Botswana with a prime lending rate is 14% and an inflation rate of 8% was allocated a discount rate of 6% (Prime lending rate- inflation rate) in this study.

This discount rate of 6% was used to discount costs only but the emissions were not discounted, as the analysis is not yet widely used.

4.1.2 Costs and Prices

In mitigation analysis, the preferred costs/prices are the factor costs i.e. which exclude taxes and subsidies. It is however difficult to relate local prices to factor costs. The costs derived inside the country provide the consumer perspective and in this study no attempts were made to change the prices/costs to factor costs/prices.

In Botswana, there are no major subsidies and the import tax is about 10% and another 10% for products originating outside the South African Customs Union, hence if factor costs are required, the final costs of GHG reduction per tonne could be adjusted downwards by a maximum of 20% otherwise 10%.

4.1.3 Data Reliability and perspective

Data used for the analysis has been verified with the related consumers or suppliers as much as possible and thus reflect local industrial/economic perspective.

Technology performance e.g. fuel consumption and efficiency, was also verified where possible but in cases where this was not possible, the default values were used. Surveys were conducted for most electricity-based technologies in the household (i.e. appliances) and industry (e.g. motors) through the BPC and the data is taken to be considerably reliable. Information on renewables like solar and biogas technologies were also available to a reasonable accuracy.

Boiler information was obtained only from one major supplier of coal based boilers located in South Africa (John Thompson- Africa) but the performance data of boilers from elsewhere were not available. Electricity based boilers were not even considered due to lack of information. Follow -up surveys may be needed in the future.

Generally efforts could be made in the future through surveys to improve the costs and technology data. Some of these surveys have been recommended in this report as possible projects for the future.

The data used here are however accurate enough to have reliably given the right magnitude of costs and technology performance adequate for future national development planning.

4.2 Selection of Mitigation Options

The mitigation options presented here are for both energy supply and energy demand sectors.

The presented mitigation options are by no means exhaustive. Selection for analysis was also based on data availability and the importance of the options to Botswana’s economy.

The penetration potential of the mitigation options in both the short term and long term reflect trends in the growth of activities in the energy sector. The baseline activity defined in the LEAP analysis was the reference from which the penetration of these options was based to avoid overlap as the option analysis was conducted separately (from the baseline) using the spreadsheet model Greenhouse gas Abatement Costing Model (GACMO).

Whilst the LEAP Model would in as much as possible avoid overlap of mitigation option penetration and the baseline penetration, the model is not directly capable of providing individual option data for construction of the cost curve. GACMO allows partial analysis of individual mitigation options and display of cost curve data and the curve itself.

Table 4.2.1 summarises the selected options and their penetration rates used in the analysis of each option. The selected mitigation options are discussed in detail in Chapter 5.

Table 4.2.1 Plausible Mitigation Options for Botswana's Energy Sector

MITIGATION OPTIONS	PENETRATION 2005	PENETRATION 2030
Supply Options		
1. Power Imports-hydro**	240MW	240MW
2. Reforestation- eucalyptus	9810 ha (=1 case)	9810ha (=1case)
3. Central Solar PV Plant	2MW	49MW
4. Landfill gas for power	69000 tonnes waste (1.8MW)	169000 t waste (4.5MW)
5. Biogas home plant	13000 plants	21000 plants
Demand Options		
<u>Household sector</u>		
1. Prepaid meters	35000 meters	136 000 meters
2. Efficient Lighting- CFLs	810000 light points	1820000 light points
3. Geyser Timer	56000 timers	145000 timers
4. solar geysers	1000 geysers	2400 geysers
5. Solar PV home systems	25000 SHS	39000 SHS
<u>Industry</u>		
1. Boiler Efficiency	20 boilers	50 boilers
2. Motor Efficiency	30000kW	56000 kW
3. Power Factor Correction	55 MVAR	55MVAR
<u>Transport</u>		
1. Pipeline for petrol & diesel only	441190 toe (=1case)	1395980 toe (=1 case)
2. Electrified Railway line	2200 kt (=1case)	4640 kt (=1 case)
3. Road freight to rail	3700 kt (=1 case)	7700 kt (=1 case)
4. Gasoline to diesel switch-road sector only	11320Pe; 4380dies TJ (=1 case)	35200 ,13610TJ (=1 case)
5. Vehicle inspection	22760TJ fuel km (=1case)	62060TJ (= 1 case
6. Paved roads	18409505 v-km (=1case)	18409505 v-km (=1 case)
<u>Agriculture</u>		
1. Conservative tillage	100000 ha (=463 tractors)	100000 ha (=463tractors)
2. Solar PV pump	7300 boreholes	12400 boreholes

** A regional option not included in Abatement Cost Curve

4.3 Option Analysis Layout

Each option was analysed giving the background information on the activities pertaining to the policy framework under which the option could be implemented.

The baseline and mitigation scenario of the option was defined and this guided the calculation of costs of reduction and potential GHG reduction. The cost of GHG (expressed as CO_2 equivalent emissions) reduction and the reduction potential per activity (e.g. boiler) were calculated using GACMO.

The calculation of the total GHG reduction potential in 2005 and 2030 were also given based on the penetration/diffusion rates of the activities in each option.

The cost of GHG reduction/tonne and total reduction potential for each option were sequenced in a cost curve. The cost curve coupled with Botswana's development priorities and macro-economic impacts of applying the options formed the basis for suggesting the country's mitigation strategy.

4.4 Implementation Aspects

Analysis of implementation aspects for the mitigation options was based on the following parameters:

a) Institutional capacity

b) difficulty in organising and the lead time required

c) Transaction costs not included in the cost analysis which could be a hindrance

d) Short and long term effects and sustainability

e) Government position or policy on the subject

4.5 Macro-economic Impact Assessment Criteria

a) Each mitigation option was analysed for macro-economic impact based on the following criteria:

b) Impact on balance of payments

c) Revenue collection e.g. in form of taxes

d) Employment loss or creation

e) savings on energy consumption and avoided fuel import- bills or deferred investments

f) Improvement in economic efficiency/competitiveness

g) Cross-sectoral linkages

h) Improvement in health aspects

i) Improvement of social standards, and

j) Land rehabilitation.

5 Option by Option Analysis

5.1 Demand Side Options

5.1.1 Household sector

A) Prepaid meters

Use of prepaid meters is considered an electricity conservation measure, as consumers tap electricity already paid for and indicated on a magnetic card or in form of a numeric code. Consumers thus become conscious that in the event of the amount of electricity running out, they have to pay for further consumption. Total current electrified households are 46341 consisting of low cost, medium cost and high cost households.

Policy Framework

The policy of installing prepaid meters has already been adopted by BPC as a cost recovery measure. The installation will target all electrified households except about the 2-3% of the high cost ones. To date about 9000 prepaid meters have been installed (BPC personal communication).

Baseline case

The BPC targets the 37000 household installations and at the expected current rate of installation of 5500 meters per year these will be met by 2005.

Mitigation scenario

The mitigation policy can increase capacity to deal with the expected additional electrified 35000 households and 136 000 households expected in 2005 and 2030 respectively.

Cost and CO_2 Reduction Potential

The use of prepaid meters as an electricity conservation measure results in about 25% savings. A domestic prepaid meter is estimated to cost P110.00 (BPC personal communication) with a life span quoted between 6 and 15 years depending on usage. The average life span has been taken as 10 years. The cost per tonne of avoided CO_2 equivalent and the CO_2 reduction levels were calculated using GACMO. The cost of CO_2 equivalent reduction was found to be P –111.20 /tonne and each meter has a potential of reducing 2.2 tonnes annually.

At this rate the mitigation policy applied to this option could achieve a total CO_2 equivalent reduction of 77000 tonnes and 299200 tonnes in 2005 and 2030 respectively with cost savings of P2million and P18 million savings. The savings would accrue from avoided power plant capacity increase and fuel (coal) costs. In the life span of the prepaid meters, GHG reduction of 0.77Mt and 2.99Mt will have been realised.

Implementation Aspects

This option is implemented through the power utility and the policy has already been adopted. The only crucial element is to increase the rate of installations. The future strategy will be to install the meter as new consumers are being connected. Electricity consumers could also be made aware to check their card balance so that they become conscious of the need to conserve electricity.

Macroeconomics Impacts

The prepaid meters are presently imported which will affect the country's balance of payment. At the present cost of P110, the country will pay about P9 million and P20 million in 2005 and 2030 for the total 81000 and 182 000 meters required for the potential electrified household consumers. This expenditure is equivalent to 7% and 16% of the 1994/95 Water and Electricity GDP contribution.

The reduction in electricity demand will result in reduced coal demand at the power plant. The effect contributes to a better healthy environment due to avoided local pollution from the power plant and reduced land deformation from coal mining.

Potential Project

a) Appropriate management of prepaid meters

The project is best conducted by the BPC

B) Efficient Lighting- Compact Fluorescent Lamp (CFL)

This technology is targeted for the household sector where incandescent bulbs are used. A survey conducted by BPC (1996) shows that there are about 6 lighting points in low cost houses, 12 points in medium cost and up to 23 points in high cost. Each bulb is ON for 4 hours per night. The outside bulbs may be on for longer but that balances with some indoor bulbs that are lit for less than 4 hours. The weighted average power points per electrified household is then 15 lighting points. In the analysis the potential points were reduced to 10 lighting points per household after considering that consumers may only replace those bulbs used for long periods at night.

Policy framework

There is not yet a national or utility policy to promote the use of CFLs in households in Botswana. The CFLs are mostly used by hotels in the lobbies and other areas where light is required for longer periods.

Baseline scenario

The baseline assumption is that no significant use of CFLs in households is realised due to the cost disparities and lack of knowledge on the cost effectiveness of CFLs.

Mitigation Scenario

The mitigation policy aims to encourage use of CFLs in electrified urban households in 2005 and 2030. The total urban households using electricity lighting in 2005 and 2030 are estimated to be 81 000 and 182 000 respectively each with a potential for replacing 10 IBs with 10 CFLs.

Cost and CO_2 Reduction Potential

The local cost of a CFL and its housing is P40.00 with a power rating of 11W while that of an incandescent bulb is about P3.00 with an average power rating of 60W. The CFL lasts for 9 000 hours and the incandescent bulb (IB) for 730 hours. Hence 12 IBs are required during the life span of one CFL which is about 6.2 years.

The cost and CO_2 equivalent reduction potentials derived in GACMO Model for this option were P-495.30/tonne and 92.20 tonnes per 1000 bulbs respectively.

The total CO_2 equivalent reduction potential when all the electrified urban households adopt use of CFLs in place of IBs, is about 75 000 tonnes in 2005 and 168 000 tonnes in 2030. In the life span of the CFLs the reduction potential is 465000 tonnes and 1.05 million tonnes which is considerably significant.

Implementation Aspects

Electricity consumers have to be made aware of the cost-effectiveness of CFLs as this is the major cause for slow uptake of the CFLs is the price disparity with the IBs. This was also found to be the case in the GEF project in Mexico (Friedmann et al., 1995)

For easy of uptake, CFLs could also initially be introduced through the power utility and paid up as part of the electricity bill. Alternatively, a credit facility for efficient technologies could be introduced through commercial banks as what is being considered for the purchase of solar home systems in the country.

Macroeconomic Impact

Electricity demand for lighting is at peak times in most countries and reduction in power demand through the use of CFLs will save the countries additional expense of either importing the peak power or running additional power plants.

The reduced power demand as a result of using the CFLs also result in a cleaner local environment due to reduced pollution from coal combustion and coal mining. In the case where peak power is imported, the country saves revenue.

All CFLs are imported while some of the IBS are manufactured locally. In the case where IBs are considered to be imported, the extra cost of the CFLs (after accounting for equivalent IBs) of about P4 is the extra external expenditure for the country when comparing the baseline and mitigation scenarios. The extra external payment could be as much as P3.24million in 2005 and P7.28million in 2030.

Potential Project

a) Assessing the potential market for CFLs in Botswana

b) Awareness programme on the cost-effectiveness of CFLs

C) Geyser Timer

The geyser timer will allow the geyser to be ON at specified times when hot water is required hence resulting in a significant electricity saving. Although the electric geyser can be switched ON and OFF manually, the geyser timer ensures consistency. The option can be coupled with appropriate setting of the geyser thermostats.

Policy framework

Implementation of a technology like this one would best be conducted for both medium and high cost houses where electric geysers are used. The national policy could be that timers become a requirement for a housing electrical installation standard. Government could also facilitate supply of the geyser timer in Botswana through reduced import duty/taxes or promotion of local manufacture.

Baseline Scenario

The baseline case is that all future medium and high cost houses in Botswana will still be equipped with an electric geysers without geyser timers.

Our LEAP analysis puts potential urban households with electrical geysers at 56000 in 2005 and 145 000 in 2030.

Mitigation scenario

The total medium-high cost houses available in 2005 and 2030 will be fitted with geyser time switches. The option however excludes the second geyser in 3% high cost households, which was analysed for replacement with solar water heaters.

The Cost and CO_2 Reduction Potential

The geyser timer cost P435.00 in 1994 inclusive of installation costs in Botswana. The life span of the timer is assumed to be 5 years although the period depends on the level of proper handling.

On average, electricity consumed by the geyser in the medium and high cost housing categories is about 250-450 kWh/month (BPC, 1996). Assuming 4 hours of geyser-timer switch operating as ON, the option has a potential of an annual CO_2 equivalent emission saving of 3.0 tons/timer at a cost of P-84.40/ton. When considering the penetration rate of the timers, the option can reduce 168000 tonnes in 2005 and 435000 tonnes in 2030.

Implementation Aspects

The price of the geyser timer could be affordable by the targeted market but it seems that awareness is lacking. The introduction of this option could also be promoted through the power utility.

A supply of the timers is required from a reliable source and installation through DIY could make the option easily implementable. The quality of the timer has to be monitored to maintain the customer confidence in the technology.

Macroeconomic Impact

The external procurement of geyser timers is estimated to be about P24 million and P63million in 2005 and 2030 respectively which will affect the balance of payments. Considering such external expenditure, it might make better sense to encourage production of the timer in Botswana realising the much-needed employment as well. Apart from the existing electrified households, additional power demand in 2005 could be 3.6MW in 2005 and 36MW in 2030 to supply geysers only. The timer therefore will be important in postponing investments in power generation or imports.

Potential Project

a) Assess market for geyser timer

b) Assess the possibility of making the timer in Botswana

c) Conduct a Do it Yourself geyser timer installation training

D) Solar Geysers or Water Heaters

Solar water heaters depend on the inexhaustible solar energy for heating water. In that respect water heating could be achieved in Botswana where sunlight is abundant 2200 MJ/m2 through solar energy thus saving on coal based electricity. The solar technology is sometimes hindered by cloudy conditions.

BPC survey (BPC, 1996) showed that about 3% of the high cost houses have 2 or more bathroom geysers. SWHs could be installed in those of the high cost households owning two/more geysers. It is envisaged that the high cost households are the ones which can afford the cost of a solar water heater as additional geysers.

Policy Framework

The installation of SWHs could still be encouraged to continue in BHC constructed high cost houses. A policy requiring houses with more than one geyser to install SWHs could be considered. The SWH could also be purchased through a credit facility as long as the cost-effectiveness is well demonstrated to the potential users.

Base Case

In 3% of the high cost houses the two or more geysers remain of electric type.

Mitigation scenario

All additional geysers in the high cost households become of solar type with electricity backup. The estimated required SWHs will be about 1000 in 2005 and 2400 in 2030.

Cost and CO_2 Reduction Potential

The calculations considered 150L electric versus 150L solar water heated geysers. The cost of CO_2 equivalent emission reduction calculated with GACMO was P27.20 /tonne with an annual potential reduction of 5 tons/SWH when the solar fraction is 75% with the 25% backed-up by electricity.

The option has thus a potential of reducing 5000 tonnes and 12000 tonnes in 2005 and 2030 respectively. This reduction is comparatively small but the SWHs have however a CO_2 equivalent reduction potential of 75000 tonnes and 180 000 tonnes in their life span of about 15 years.

Implementation Aspects

The industry for SWHs is in place in Botswana and a code of conduct for solar products tries to ensure that suppliers supply good quality products. SWHs are more expensive (about 4 times) compared to the electric geyser of the same size. The reaction of the customers would be to buy the cheaper heater. There is need to demonstrate the potential energy savings and hence cost savings to the potential consumers for the technology to be more attractive. A credit facility and tax refund on the cost of the SWHs could be incentives for procuring the SWHs.

Macroeconomic Impact

This mitigation option involves a cleaner free energy source and eventually saves on the country investments on coal mining and combustion at the power station. The option can save about 0.5MW and 1.2MW of electricity capacity in 2005 and 2030 respectively. This electricity demand will be met from imports in the baseline and such a saving will translate into a cost saving for the country in avoided power imports.

Potential Projects

a) Potential market for SWHs in Botswana

b) Creation of credit facility for SWHs and other renewable products

E) Solar home systems

There has been no significant uptake of solar home systems in Botswana. The technology can be used in rural households to substitute use of paraffin for lighting. The systems could be used mainly for lighting and powering of light electrical appliances like radios. The scope for introducing the technology in rural households is large allowing a reduction of GHG emissions and other pollutants from the use of paraffin.

Policy Framework

A policy to promote sustainable uptake of solar home systems is necessary e.g. in form of credit facilities and promotion of local manufacturing of devices as a measure to reduce the capital costs of the systems.

Baseline Scenario

Rural households predominantly continue to use paraffin as a lighting fuel.

Mitigation Scenario

Use of solar home systems is adopted by 10% of the rural households which is the likely ready market for SHSs based on past surveys in the country and elsewhere. Based on this proportion, about 25 000 and 39000 rural households could be the available market for SHSs in 2005 and 2030 respectively.

Cost and CO_2 Reduction Potential

A rural household was found to be using about 2litres of paraffin per month (Zhou, 1994) for lighting. This was compared with a 55Wp panel supplying 4 lights and possibly a radio. The paraffin lanterns equivalent to 20 years of the panel's life span constituted the baseline cost.

The output in GACMO indicated a cost of P-67.90/tonne of CO_2 equivalent emissions reduced. Each SHS has a potential of reducing 0.08 tonnes of CO_2 per year equivalent emissions. Considering the potential rural households constituting the potential market for SHS, a GHG reduction of 2000 tonnes and 3120 tonnes in 2005 and 2030 respectively is realised. In the 20-year life span of the SHSs, the reduction becomes considerable at 38400 tonnes and 62400 tonnes respectively.

Implementation Aspects

SHSs are already starting to be commercialised in Botswana through government efforts hence the lead time for the introduction of the option is immediate. Effort is needed in creation of credit facilities for the purchase of the systems. The local solar industry is also able to supply the market although panels are imported. There might be a need to provide DIY training to potential users so as to reduce the full cost of the systems.

Macroeconomic Impact

Apart from the GHG reduction, SHSs can provide a social benefit through cleaner indoor environments and creating income-generating activities that require light at night like hair platting. The systems also provide opportunities for rural school going children to read at night. Evaluation of a pilot project in Botswana has already indicated these benefits.

The project has potential for employment creation for the installation companies. There about are about 20 companies registered with government so far for installation of SHSs under the National PV programme.

The savings on balance of payments as the avoided annual paraffin imports of about 600kl in 2005 and 940 kl in 2030 which translate to cost savings of about P660000.00 and P1.045 million respectively. In the 20-year period the paraffin savings amount to P13.2 million in 2005 and P20.90 million in 2030 compared to the capital costs of the SHS which amount to P75 million and P117million for the systems required in 2005 and 2030 respectively.

Potential Projects

a) Conduct a Do It Yourself installation and maintenance training course

b) Assess potential for creation of credit facilities

5.1.2 Industry Sector

A) Boiler Efficiency

Boilers and furnaces in Botswana accounted for about 22% of the coal supplied in 1994. John Thompson, one of the major suppliers of boilers to Botswana quotes a typical boiler efficiency of 79%, which can be improved to 85% by installing an economiser.

Policy Framework

Consideration is given to targeting small coal-fired boilers in government institutions and small industries who are not likely to be implementing efficiency measures or retrofitting. The majority of these boilers are about 10 tonnes and below in size. Only large industries and the BPC have larger sizes.

The cost of these boiler ranges from R 800000 for a 5t to R 1 100000 for a 10 t boiler (R1.27=1BWP) and the economiser costs about 10% of the boiler price.

Baseline scenario

Boilers given in Table 4.2.1 of 79% continue to be used through to 2005 and 2030. There are obviously more boilers in operation in Botswana but in the absence of correct figures, these known ones have been used for the option. More boilers will only mean more GHG reduction potential but at the same cost of reduction as given here.

Mitigation Scenario

The Boilers are fitted with economisers to raise efficiency to 85%. The current deterrent is the cost implications.

Cost and CO_2 Reduction Potential

The cost of reducing 1 tonne of CO_2 equivalent emissions using this option would cost P-36.57 and each boiler has a potential of reducing 475.50 tonnes annually. The actual number of boilers in industry by 2005 and 2030 are not well known. The potential reduction was considered for 20 boilers in 2005 and 50 boilers in 2030 which amounted to about 9500 tonnes and 23800 tonnes of CO_2 equivalent emissions respectively. In the life span of the boilers, the emission reduction potential will be 0.35Mt in 2005 and 0.84Mt in 2030.

Implementation Aspects

This option could be organised through the Factory Inspection Department in the Ministry of Labour, which is mandated to inspect boilers in industry. A comprehensive inventory of the boilers does not exist and needs to be created for proper targeting of the option

Macroeconomic Impact

The use of economisers on the boilers would reduce coal consumption by about 6% and the coal for boilers in Botswana is imported thus also saving on import costs.

The initial capital layout for the economisers for the boilers however would costly (about P1.5million for 20 boilers; P3.75 million for 50 boilers).

Potential Projects

a) making an inventory of boilers in industry and government institutions

b) assessing energy efficiency of the boilers and potential improvements

<u>B) Motor Efficiency</u>

None of the high efficiency motors have been imported into Botswana yet.

Botswana is using motors of efficiency range of 70% for 0.75kW units to 93.5% for the 250 kW and operation efficiencies can be improved to 85.4% and 96.2% respectively (Marbek, 1995).

The motors considered for this option are of the capacity range 0.75kW to 5.5 kW whose life span is about 3 years and the average cost/kW is about P500.00. These motors have an efficiency of about 78%. High efficiency motors (89%) at a higher cost (P965), which can be used for the same purpose but saving on electricity consumption.

Policy Framework

The motor efficiency improvements can be made under a demand side management scheme implemented by the BPC. The policy could be of incentive type where industrial consumers who can achieve a certain electricity saving could be given a special tariff code. It will be difficult to enforce use of efficient motors, as monitoring will be difficult unless if higher tariffs are introduced as a fiscal measure for industrialists to consider energy saving measures.

Baseline Scenario

The present types of motors continue to be used through to 2005 and 2030.

Mitigation scenario

The ordinary motors are replaced by high efficiency motors at replacement in 2005 and 2030 and the diffusion/penetration of the high efficiency motors in those spot years is determined by the current rate of motors coming on stream. BPC conducted a survey of motors available in some industries and concluded that there could be about 10000 such motors in 2005 and nearly double in 2030.

Cost and CO_2 Reduction Potential

The GACMO calculations considered a kW as a unit of activity and the number of motors in use in 2005 and 2030 were translated into kW equivalent of 30000kW and 56000 kW in 2005 and 2030 respectively.

The cost of reducing CO_2 equivalent with this option was found to be P2.40/tonne and each 1 kW motor replaced with a high efficient one would result in a reduction of 2.7 tonnes of CO_2 equivalent emissions.

The total diffusion in 2005 and 2030 could result in 81 000 tonnes and 151200 tonnes of CO_2 equivalent emission reduction.

Implementation Aspects

Demand side management is being considered by BPC and other utilities in the region and implementation of this option forms part of an important DSM process in industry. What is however required is the actual potential to justify its implementation. The availability of high efficient (HE) motors systems on the market have also to be assessed. Industrialists will have to be educated on the cost effectiveness of HEs and where they can get the HE motors.

Macroeconomic Impact

The capacity reduction in power production when the option is implemented will be about 4.5MW in 2005 and 8.5MW in 2030. In energy terms, the savings could amount to 5% and 9% of the electricity consumed in the whole mining industry in 1994. The money equivalent for imports from the region is about P1million in 2005 and P2million in 2030. The cost gets to P3.8 million and P7.7 million if the electricity is locally generated at present costs.

Potential Projects

a) Inventory of motors in Botswana

b) Market potential for HE motors

c) Suppliers of HE motors and characteristics

d) Awareness programme for industrialists on HE motors

C) Power factor Correction

The application of power factor correction results in reduction of power loss. The level of loss reduction is dependent on the power factor correction capacitors, the length and design of the circuits in question.

In the baseline the expected local generation will be about 372MW in 2005 and 2030 hence the option analysis has assumed the same capacity.

Policy Framework

The incentive for industrialists who get bulk supply of power to conduct power factor correction is when BPC sells MVA and not the actual power (MW) as is the case now.

Baseline scenario ***and*** **Mitigation Scenario**

Baseline scenario assumes a power factor of 0.90 and the mitigation scenario a power factor of .95. This capacity is equivalent to 413MVA in the baseline and 392MVA in the mitigation scenario. The related reactive power will be 179MVAR in the baseline and 124MVAR in the mitigation scenario. The actual reduction in Reactive Power is then 55MVAR.

Cost and CO_2 Reduction Potential

The estimated cost of the power factor correction capacitors in Botswana's experience is P 8200.00/MVAR. The cost of reducing CO_2 equivalent emissions by this option amount to P-47.60/tonne and each MVAR in reduction has the potential of limiting CO_2 equivalent emissions by 939 tons.

The total mitigation potential of the option is then about 51 600 tonnes in both 2005 and 2030.

Implementation Aspects

The option can be implemented by the BPC and certain earmarked industries that draw a significant amount of bulk power. Some lead-time is required to educate the industrialists and obtain their cooperation in the exercise. Introduction of the MVA tariff will also level the playing field for those willing and unwilling to implement the option.

Macroeconomic Impact

At the given cost of P8200/MVAR, the impact on balance of payments would not be significant (about P320 000) compared to the long term savings on power production and the related environmental consequences.

Of importance in this option is the savings on the input resources like water and coal. Water is a scarce commodity in Botswana. Whilst coal is abundant at Morupule, its mining and combustion in the power plant result in air pollution and undesirable effluents both of which could impact on human and livestock health in the surrounding areas.

Potential Projects

a) Identification of industries amenable for power factor correction and the potential reduction in power production and related input resources like water and coal.

b) Testing effectiveness of the various capacity circuits and the sources of supply

5.1.3 Transport Sector

A) Pipeline for Petroleum products

Petroleum products are currently transported by road and rail from Pretoria in South Africa in the proportion of about 40:60% respectively. Road freight transport has energy intensity, which is about 4 times that of rail freight per t-km, and the pipeline takes about 10% of the rail consumption. In that respect, shifting to pipeline for transporting petroleum products could result in diesel savings.

Policy Framework

The pipeline is constructed after a satisfactory Environment Impact Assessment is acceptable for the option to be environmentally competitive with the other means of transport. In order not to disrupt current activities in this area, the pipeline can be targeted for additional petroleum products required in 2005 and 2030. This will enable the eventual smooth phase-out of the road and rail freight for petroleum products.

The Petroleum Management Unit in the Ministry of Commerce and Industry would be the policy making body for the project.

Base case scenario.

As demand for petrol and diesel increases, the proportion of liquid transport is consistent for road and rail. The demand for these petroleum products estimated for 2005 (441190 toe) and 2030 (1395980 toe) continue to be ferried by road and rail from Pretoria in South Africa.

Mitigation Case.

The transportation of petrol and diesel supplied in 2005 and 2030 is substituted by a pipeline.

Costs and CO_2 Reduction Potential

The costs of constructing pipelines were provided by Tractebel Engineering, a large Belgian multi-disciplinary engineering firm.

Cost of pipeline depends on diameter and wall thickness but ranges from US$84/m for 114mm diameter to US$644/metre for 914 mm diameter. The diameter (among other things) determines (among other factors) the volume of the liquid to be transported per unit time Operation and maintenance costs given were of the order 1-2% of investment. Life span is taken as 40 years.

The following other information was considered for the road and rail transport costs and capacity.

- A liquid freight tanker of capacity 34 toe and empty weight of 20 toe
- The cost of truck and tanker is about US$ 150 000.
- Fuel consumption for an average truck 0.85 MJ/tonne-km
- The truck's maintenance cost/yr. is about 10% of investment.
- The life span of truck and tanker was assumed to be 12 years hence trucks for 40 years are required.
- The estimated supply of petrol and diesel products demand in 2005 and 2030 in Botswana, were estimated from LEAP.

GACMO output shows that the pipeline option would cost P184.82 per tonne in 2005 and –P301.50/tonne in 2030 as a CO_2 equivalent emission mitigation option. The cost for this option is therefore dependent on the level of traffic involved. This means that the option accrues a net benefit when the oil freight becomes significant in 2030 (over 1.4Mtoe) i.e. 3 times that of 2005 (0.44Mtoe).

The petroleum products will result in CO_2 equivalent reduction of about 36000 tonnes in 2005 and about 90 000 tonnes in 2030. In the life span of the pipeline CO_2 equivalent reduction can be between 1.40 Mt and 3.60 Mt; the latter being nearly equal to the 1994 base year total emissions from the energy sector of 3.86Mt.

Implementation Aspects

The construction of a pipeline is expensive at about USD1000/m of distance and such investment could possibly only be made by the private sector if the venture is profitable. The option has positive cost of CO_2 reduction in the short term hence the option may qualify for global funding under the UNFCCC except that the level of emissions when the pipeline serves Botswana's petroleum demand only is not significant and GEF may not be keen to finance the project especially when it eventually becomes of net benefit in the long term.

It is the task of the Petroleum Management Unit to investigate the need for such a pipeline and the further benefits that might accrue from it.

Macroeconomic Impact

The reduction of road and rail transport reduces maintenance costs on the roads and rail infrastructure.

It is not envisaged that the construction of the pipeline will be made by Botswana hence the impact on balance of payment is not likely to be a problem. If either GEF or a private sector investment is made, the country will actually benefit from the inflow of funds and creation of employment for the period of construction.

The pipeline does not take much space and hence will not take much of the useful land on its path. There might however be danger when accidents do happen in terms of possible forest destruction and water contamination.

Potential Projects

a) Investigate the need for a pipeline in the long term when demand increases.

b) Investigate investment opportunities by private sector as either BOT or BOOT type of projects for such a pipeline.

c) Investigate GEF type project for such an option.

B) Electrified Rail system

Electric locomotives have a higher carrying capacity than diesel locomotives and the former would be desirable where large freight traffic exists. The diesel locomotive however consumes slightly less energy/t-km (0.23MJ) than the electric one (0.27MJ/t-km).

The option of shifting to electric locomotives from diesel for Botswana is only based on the premise that hydropower imports will be available from the northern countries of Zambia and Zaire.

Policy Framework

The option requires a long-term contract for buying hydropower imports from the region for such electricity demand. Botswana Railways, BPC and the central government would all be involved in implementing the electrification process and securing the hydropower imports.

Baseline case.

The option is considered for the railway line running between Zimbabwe border in the north and the South African border in the south. In the baseline, this route continues to be serviced by diesel locomotives through to 2005 and 2030.

Mitigation Case.

In the mitigation scenario, the railway line is electrified and electric locomotives replace the diesel ones. The freight size (which is the driver for the option) expected for the rail transport in 2005 and 2030 are 2200kt and 4640 kt respectively.

Cost and CO_2 Reduction Potential

The cost of an electric engine is in the range of US$ 1.8- 5 million while that for a diesel train ranges between US$ 1.8-3.2 million as provided by Tractebel of Belgium.

The cost of electrifying an existing railway line is estimated to be between US$ 0.3-1 million/km and an average of US$0.5 million was used.

CO_2 emissions for the electric engine is taken to be zero if the source of electricity is hydropower.

The cost of reducing CO_2 equivalent emissions with this option was found to be P4080.10/tonne in 2005 and P1784.50/tonne in 2030. The cost is also dependent on the level of traffic volume such that as the volume increases, the cost of CO_2 equivalent emission reduction decreases.

The potential level of emission reduction in 2005 and 2030 based on projected freight sizes are 26 900 tonnes and 56 700 tonnes respectively.

This analysis has slightly overestimated the cost and underestimated the emission reduction level since it has not accounted for passenger traffic. The electrified rail will also serve the passenger traffic, which will save more diesel. The cost of diesel that can be saved is however small compared to the capital cost of electrifying the rail and acquiring the locomotives.

Implementation Aspects

This option also requires a long lead-time in order to verify the need for an electrified rail. The need will arise when traffic volumes increase significantly; hence the option is a long-term option. The capital layout in the case of electrifying the rail is also high (over p1.4

billion), such that Botswana may not be in a position to invest that kind of money in the short term.

This is also more than half of the last GEF budget for projects and thus may not also be attractive to GEF for funding.

The project however may be implemented under a Joint Implementation project where by the country of investment will benefit both from emission reduction and selling of their technologies to Botswana. It could also be introduced as a BOT or BOOT project.

Guaranteeing hydropower for such a project from an outside source could also be difficult. If hydropower and coal based electricity are used alternatively, the GHG reduction potential of the option obviously decreases.

Cooperative investment with other regional countries on new hydropower plants could be a way of guaranteeing access to hydropower imports.

Macroeconomic Impact

If the railway line were to be electrified and powered by hydropower imports, the country will save on imported diesel, which also costs about P25.3/GJ compared to about P26.91/MWh (P7.48/GJ) of hydropower imports.

The rail electrification process will create significant employment during construction, which will benefit the country.

This option has cross-sectoral linkages between the energy sector and the transport sector in that electrification will depend on whether hydropower imports will be available. The service also becomes beneficial when the economy is booming creating high freight traffic volumes.

The use of hydropower imports will also result in improved air quality due to avoided emissions from diesel combustion.

Potential Projects

a) Botswana railways projected freight volumes

b) Potential for hydropower imports in the region

c) Potential investors for electrified rail in Botswana.

<u>C) Road Freight to Rail Freight</u>

Road freight transport has energy intensity, which is about 4 times that of rail freight per t-km

Road freight in particular has also an extra cost in road maintenance even where the roads exist. The road wear increases where heavy traffic like freight trucks move. It will therefore be important to move in-country- road- freight to rail transport as this will save energy imports and reduce costs of road maintenance.

Policy and Institutional Framework

This option can be applied where road license for freight vehicles reflects true cost of road maintenance. The Departments of Roads, National Transport Control and the Botswana Railways can both be involved in the implementation of the measure.

Baseline Scenario

An assumption has been made that 40% of the cargo between the north border and south border is carried by road freight, which is about the case presently.

Mitigation Scenario

In the mitigation scenario the ratio of rail to road freight is increased to 80% and 20% respectively. The total expected freight in 2005 and 2030 are 3700kt and 7700kt respectively.

Cost and CO_2 Reduction Potential

The cost of trucks and locomotives and wagons required for the two scenarios constituted the main capital layout. The fuel costs in the life span of the rail and road equipment were also taken into consideration.

The cost of reducing CO_2 equivalent emissions with this option was found to be P-501.70/ton. The potential GHG reduction will be 77000 tonnes in 2005 and 161000 tonnes in 2030. In the life span of the equipment (30 years), the total CO_2 equivalent emissions that can be avoided by this mitigation option are 2.31 million tonnes for the 2005 case and 4.80 million tonnes for the 2030 case.

Implementation Aspects

Dry-land ports already exist in both the north at Francistown and south in Gaborone, so efficiency rail freight service competitive with road transport can be realised.

The turn around time for Gaborone to Francistown between road and rail is not significant to make road freight significantly more competitive but the railways need to be efficient in delivery of goods at destination.

Road transport will however remain competitive on carrying food staff due to the need for quick delivery especially the perishables

Hence the option will be amenable to bulk cargo like timber, minerals, cement, machinery, petrol and diesel, and grain. By considering these types of cargo, the option CO_2 equivalent reduction potential remains above 75%.

The option can be taken up if the playing filed is levelled in form of charging road transporters for overloading which can be monitored at weigh bridges.

Macroeconomic Impact

The reduction in road activity may result in loss of jobs. The impact on the balance of payment will be minimal and negative cost for CO_2 reduction indicates that the country will actually benefit than it would in the baseline case but the transaction costs will have to be borne by the country itself. GEF will not finance the implementation of this measure since it has negative costs. The increase of road tariff will increase revenue for government

Potential Projects

a) Determine road and rail traffic levels

b) Assess capacity of the railway system and required adjustments to achieve efficiency

<u>D) Gasoline to diesel Switch</u>

Preferential increase of petrol prices through taxes compared to diesel can result in a shift towards diesel cars and LDVs. Botswana’s fleet of cars and LDVs is dominated by petrol engines.

In neighbouring Zimbabwe where the price of diesel is about half that of petrol, 40% of the vehicle fleet is now of diesel type. Diesel vehicles have lower fuel intensity than petrol vehicles to the tune of 15-20% energy savings.

Policy Framework

This a measure operating on fuel taxes and government would have to make the price tax changes. A 25% increase on petrol is assumed.

Baseline Scenario

The projected petrol and diesel demand of 11320TJ petrol and 4380TJ diesel in 2005, and 35200 TJ petrol and 13610TJ diesel in 2030 are for road fuel demand only (LEAP-output) in the baseline.

Mitigation scenario

In this scenario the 25% increase in petrol price results in 10% decrease in petrol consumption. For road transport only. 80% of the reduction in petrol consumption becomes the increase on diesel consumption since diesel vehicles are about 20% more efficient than petrol.

Cost and CO_2 Reduction Potential

The introduction of fuel prices is considered fiscal-free hence the cost for implementing this option is zero. Transaction costs might be involved in coordinating the fuel increases and pump adjustments but these are considered small.

The fuel price increase and consumption adjustments for petrol and diesel have potential for reducing CO_2 equivalent emissions by about 15237 tonnes in 2005 and 41 000 tonnes in 2030.

Implementation Aspects

This option can be implemented immediately with little impact on the economy. The option would be implemented by the Petroleum Management Unit. The process can start in the short term and the market eventually adjusts itself in favour of diesel vehicles.

Macroeconomic Impact

Reduction in petrol consumption will save the country some foreign currency since the petroleum products are imported.

The use of diesel without converters can result in air pollution, but the converter increases N_2O emissions 5-fold and reduces the fuel efficiency of vehicles.

The increased fuel tax will provide government with revenue for maintenance of transport infrastructure like roads.

Potential Projects

a) Analyse scope for shifting fuel preference from petrol to diesel.

E) Vehicle Inspection

The government of Botswana is considering introducing vehicle inspection for road-worthiness. The exercise is expected to encourage motorists to regularly service their vehicles.

Garage owners estimate that regularly serviced vehicles have about 10% better fuel efficiency than otherwise apart from the fact that they give a long service to their owners.

Baseline Scenario

The baseline scenario assumes status quo with respect to management of vehicles. Presently there is a large population of newer vehicles on the road but this is likely to change as prices of vehicles increase.

Mitigation Scenario

Vehicle inspection is introduced in the short term through to the long term.

Cost and CO_2 Reduction Potential

By considering that the Ministry spends 5% of their annual budget in NDP8 for setting up the vehicle inspection system countrywide and realising the 10% savings on fuel consumption as assumed here, this option can reduce CO_2 equivalent emissions by 132000 tonnes at a cost of P8.70/tonne in 2005. There is a higher GHG reduction of 496 000 tonnes at a cheaper price of P3.20/tonne in 2030.

Implementation Aspects

The option will just ride on an already government-planned system but there is need to inspect for parameters that affect fuel consumption like tyres, exhaust fumes and oil leaks.

The Ministry of Transport may not effectively implement the inspection in the current NDP8 due to budget constraints if it were not budgeted for.

Macroeconomic Impact

Vehicle inspection apart from reducing emissions will ensure safety on the roads as accidents will be reduced. The air quality will also improve due to proper servicing of vehicles.

The inspectorate departments will expand in order to provide the service countrywide thereby creating more employment for the country.

For the business fleets, inspection will increase economic efficiency and competitiveness in the regional freight transport business in form of reliability of transport vehicles.

Potential Projects

a) tailoring the planned Vehicle Inspection to realise GHG and air pollution reduction in addition to achieving safety on the roads.

F) Paved Roads

Fuel consumption on unpaved roads was found in Botswana (Botswana Transport Plan, 1983) to be about one and half times that on paved roads for the same type of car and speed.

In 1993 about 41% of the main road network were paved compared to over 90% in South Africa and Mauritius, which are countries of similar economic ranking as Botswana. Gravel roads were 34% and sand/earth roads were 25% of the National road network.

Road improvement is slowly increasing, as in 1989 the proportion was 30% and in 1980 15%.

Speeding up road paving could result in a significant fuel saving and emission reduction for Botswana, assuming similar frequency of vehicle travel.

Policy Framework

The government of Botswana could aim to reach a target proportion of about 70% by 2005 and 95% by 2030.

In this case we have only examined impact of paving segments of road network between Toteng - Ghantsi (217km) and Shorobe-Kasane (314 km) each with traffic of 53 vehicles and 124 vehicles per day respectively.

Baseline and Mitigation Scenarios

Ghantsi- Toteng and Shorobe (after Maun) to Kasane road segments remain sandy roads in the baseline while in the mitigation scenario the portions of the road network are paved and retaining the same number of vehicles-km throughout the study time horizon of 18 409 505 v-km.

Cost and CO_2 Reduction Potential

Road paving is an expensive exercise particularly in Botswana (at about US$70 000/km and maintenance of US$ 2300/km) with sandy conditions but fuel consumption is also very high in sandy roads here assumed to be 6km/litre or 16l/100km.

The paved road option can save a significant amount of fuel such that the cost of CO_2 equivalent emission reduction is negative (P-660.40/ton). Just this route with the level of traffic given can reduce about 299 000 tonnes annually. In the life span of the road of 20 years, the road can avoid CO_2 equivalent emissions of 6 million tons, which is equivalent to all the expected CO_2 equivalent emissions in 2005 from the energy sector.

The v-km will obviously increase when the roads have improved hence the GHG reduction potential derived here is the minimum.

The initial investment to pave the two road segments is about P141million.

Implementation Aspects

The road segments considered are important routes for Botswana linking Zambia/Zimbabwe with Namibia. They are also busy routes for tourists interested in wild life and can thus open up to more traffic and more revenue for Botswana.

Implementation of the road paving would only depend on the budget allocation for the routes.

Macroeconomic Impact

Road pavement in this region will create revenue for Botswana through increased tourism and road license charges improving on both GDP and balance of payments as most tourists are from outside the country. The option will link up transport, energy and tourism sectors.

The road pavement option will save fuel imports avoiding erosion of foreign earnings and pollution resulting from fuel combustion. Fuel consumption may however not be reduced if traffic increases responding to good roads.

The road construction itself will create the much-needed employment for Batswana and the local contractors.

Potential Projects

a) Potential for speeding up paving of the routes and finance sources

b) Potential fuel savings by paving roads in Botswana.

5.1.4 Agriculture Sector

A) Zero Tillage

The option assumes avoiding the use of diesel tractors in the country as a result of adopting zero tillage. Zero tillage is direct planting where seed and fertiliser are broadcast without soil disturbance. The practice was found in Zimbabwe to be amenable to red clays and granite sandy soils and can be adopted for maize, beans, groundnut and cotton. Land planted with these crops in Botswana is about 100 000 ha (1/3 of total land cultivated).

Zero tillage has been found to result in better soil management and better yields up to 15% higher). In Zimbabwe about 10% of the commercial farmers practised this type of farming in 1993 and got better yields. 45% of them practised conservative farming i.e. leaving about 30% of crop residue cover on the soil surface after planting.

Ploughing demands a large diesel share in the agricultural sector. Botswana also has prevalent use of tractors for ploughing.

Policy Framework

The most serious barrier so far to this technique is lack of information. In Botswana the Ministry of Agriculture could conduct trials with various soil types and crops to be able to make a recommendation on what land or crops are amenable to zero tillage.

In the case where ploughing is paid for by government those who manage zero tillage can transfer their ploughing grant/loan to some other stage in the farming process.

Baseline scenario

The cultivated land (about 100 000ha in Botswana) for maize, bean and groundnut is ploughed prior to planting and tractors are used to conduct the ploughing process.

Mitigation Scenario

The 100000ha cultivated for maize, beans and groundnuts is put under zero tillage thus eliminating the ploughing component only. The rest of tractor operations like harrowing continue as in the baseline.

Cost and CO_2 Reduction Potential

Tractor costs range between P100 000 and P180 000 plus P10 000 for the plough. Diesel consumption for each tractor for each hectare ploughed was taken to be 42 litres, hence the avoided diesel consumption and GHG emissions could be worked out.

The cost of CO_2 equivalent emission reduction with this option is -P493/tonne assuming that existing tractors are used. Each tractor is capable of reducing 27 tonnes per year and in the 20 year life span can reduce 540 tonnes. The estimated required tractors to plough the 100 000 ha amenable to zero tillage are 463 tractors and the total CO_2 equivalent reduction potential is 11 960 tonnes in both 2005 and 2030 and after 20 years is 249 000 tonnes. The land under cultivation is not expected to increase in the long-term hence similar emission reduction potential for 2005 and 2030.

Implementation Aspects

Proper research with Botswana soils is necessary before the option can be implemented. The research aspects would have to be funded by government as service to farmers. This could still be a short-term option if research starts in NDP8 but it is possible that it cannot be accommodated in the Plan budget and in that case it will only be implemented in the next plan period extending beyond 2005.

Macroeconomic Impact

The macro-economic benefits are in form of improved crop yield and soil conservation. The imported diesel will also be saved thereby limiting erosion of foreign earnings.

This is a typical cross-sectoral option linking agriculture, transport and energy sectors.

Owners of tractors may lose income that normally accrues from ploughing for other landowners.

Potential Projects

a) Assessing applicability of zero tillage to Botswana

B) Solar PV Pumps

The potential for using solar pumps for water lifting in Botswana is high considering that the large proportion of water supplies come from groundwater. The cost of solar pumping systems is however still too high. The technology cost is coming down and by comparison with diesel water pumps, will be competitive in the future. Over 85% of the 15000 boreholes in Botswana are equipped with diesel pumps. 600 boreholes are drilled every year in Botswana but solar pumps can pump water from depths of about ±50 m (Hodgkin, 1988) at about $10m^3/h$. About 34% of drilled boreholes have depths below 60m and these could be equipped with solar pumps saving on the imported and polluting diesel.

Policy Framework

Solar PV water pumps are only used at some village water supply boreholes but the extent of use is very limited mainly due to cost. A credit scheme will be required to increase the uptake.

Baseline Scenario

The 34% boreholes that qualify for solar PV pumps continue to use diesel pumps. I.e. 7300 boreholes in 2005 and an additional 5100 boreholes in 2030 (potential for 2030 in therefore 12400 boreholes).

Mitigation Scenario

The 34% boreholes with an appropriate pressure head (60m) expected in 2005 and 2030 are equipped with solar PV pumps

Cost and CO_2 Reduction Potential

The solar PV pump is capable of reducing 5.5 tonnes of CO_2 equivalent emissions annually at a cost of P223.30/ton. Estimated boreholes with the right head for solar PV pumps available in 2005 and 2030 will be 7300 and 12400 boreholes. When considering these boreholes equipped with solar PV pumps, the potential reduction in emissions is 40150 tonnes in 2005 and 68200 tonnes in 2030. In their life span, the solar PV pumps can reduce 0.803Mt from 2005 and 1.364Mt from 2030.

Implementation Aspects

It is likely that the rate of solar PV pump uptake will still be small by 2005 due to high costs and the estimated potential for application may not be fully exploited by then. Solar PV modules are imported and mark-up is the largest price addition although some government tax is attached. Government may have to create wholesale of modules under their national PV programme to reduce prices through lower mark-ups.

The capital layout required for investment into solar PV systems may also be prohibitive unless a local solar PV module industry is set up in Botswana.

Macroeconomic Impact

The capital layout for acquisition of solar PV modules of about P 462million in 2005 and P 785 million in 2030 can affect the balance of payment. Diesel pumps although imported to the tune of P85 million and P144 million in 2005 and 2030 respectively are only about 20% of the cost of solar PV pumps.

Use of solar PV pumps however will save diesel imports of about P13 million in 2005 and P23 million in 2030.

Solar PV pumps will eliminate the noise made by diesel engines and the possible contamination of groundwater by diesel and oil leaks from diesel pumps.

There is a cross-sectoral linkage between the energy sector and the agriculture sector as the borehole water is mainly used for livestock watering. In 1994, the livestock industry through sale of beef to Europe was the 3rd largest foreign currency earner after minerals and vehicles making it an important sector for Botswana. The social status of Batswana is centred on cattle ownership and hence supply of water through use of inexhaustible solar energy will ensure sustainability of the industry.

Potential Projects

a) Assess potential boreholes that can be equipped with solar PV pumps in the country.

b) The willingness of borehole owners to uptake solar PV pumps- at construction time and as replacement of diesel pumps on expiry the latter.

c) Assess the financing opportunities for solar PV pumps in the country and at GEF.

5.2 Supply Side Options

<u>A) Hydropower Imports</u>

This option is more of a regional type than a national one. It has been discussed here to reflect how it can be implemented but it has not been included in the Abatement Cost Curve.

In the baseline, Botswana's electricity import demand in 2005 and 2030 was accounted in LEAP to be about 200MW and 300MW. Imports currently are from South Africa and Zimbabwe/Zambia.

Imports from Zambia are mainly of hydropower but in the short term South Africa will be the main supplier of coal-based electricity to Botswana. The hydrology in the region can also be unreliable and hydropower imports become limited.

Joint investment in new projects like Batoka Gorge, other sites in Zambia and the Inga Dam will ensure that Botswana gets a guaranteed supply of hydropower from the region.

This therefore is an option whereby Botswana would invest for hydropower outside its borders instead of a coal power plant within its borders.

Before the investment is due, Botswana can depend on prearranged imports from South Africa and Zambia/Zimbabwe.

Policy Framework

It will be important for BPC to make a policy of capital contributions where a hydropower plant is built to guarantee supply. The Southern African Power Pool will probably offer opportunities for joint investments.

Baseline Case

Botswana will upgrade Morupule by 240 MW in 2005 and depend on imports, mainly coal based from South Africa, in the long term.

Mitigation Scenario

Botswana will jointly invest in hydropower generated in the region under the Southern African Power Pool instead of upgrading the Morupule Power Station by 240 MW. The long-term effect of reducing GHG emissions by importing guaranteed hydropower will be significant compared to a 35 year coal plant.

Cost and CO_2 Reduction Potential

The cost of reducing CO_2 equivalent emissions by this option was found to be P-10.25/tonne and each kW of imported hydropower can reduce 10 tonnes of the emissions annually.

Considering a power capacity of 240MW, the potential reduction per year will be 2.4Mt of CO_2 equivalent emissions. In the life span of the plant the option will have reduced about 84 Mt of CO_2 equivalent emissions which is about 4 times the emissions expected in 2030 from the energy sector.

This shows that if the option can be implemented, it holds a large potential to reduce GHG emissions.

Implementation Aspects

This option would couple up with the shifting of diesel trains to electric trains powered from hydropower.

The option will only be implementable if the SAPP provides opportunities for joint investments in the region.

This is a project for global funding but the fact that it is at negative cost will not be fundable by GEF. It may be considered under future emission trading. Botswana may consider external investment unattractive in terms of insecurity of supply and creating development and employment in another country.

Macroeconomic Impact

Investment in another country will obviously deprive Botswana of some development and employment opportunities but the avoided air pollution will also be important.

External investment will thus negatively affect the balance of payments and may not be politically acceptable.

Potential Projects

a) Potential joint investment opportunities in hydropower plants in the region

b) Potential funding options for joint investments in power plants.

<u>B) Reforestation</u> - Eucalyptus

Re-afforestation is an option to replenish depleted wood but the cost of plant care is high and suitable land for re-afforestation is limited in Botswana. The cost of is increased by dry arid conditions aggravated by limited water resources for plant irrigation. The cost of fencing, land preparation, implements, water, chemicals and fertilisers was P14000/ha in 1992 (FAB, personal communication) excluding labour.

However there is significant deforestation in the country through various agricultural and energy activities. Fuelwood equivalent to about 50 000 ha is consumed per year in Botswana and 9831ha of this by deliberate tree cutting (Zhou, 1994).

That land from which trees are cut for fuelwood could be planted with trees for both fuelwood and sale of timber.

Policy Framework

Permits to cut trees are needed in order to oblige those cutting trees to replace cut trees with new plants. Incentive is also required whereby communities/traders involved in cutting trees for fuelwood for sale are advised on how to make it a sustainable venture.

Baseline Case: Fuelwood harvesting in Botswana continues unabated resulting in a deforestation rate of 9831ha/year.

Mitigation scenario: At least the area from which fuelwood is harvested by cutting is replanted with trees.

Cost and CO_2 Reduction Potential

Seven years for growth of a tree to maturity was assumed. The cost of abatement also assumed a cost per hectare of P14000.00 (Forest Association of Botswana- personal communication) for the seven years and 9831 ha (Zhou, 1994) as being the area depleted by fuelwood cutting annually. Annual labour costs per ha was taken as P4800.00 for two people at P200/month. The sequestration rate assumed was 2 t carbon /ha which is within the range of default values for sinks of forest types elsewhere. The information on sink coefficients for the eucalyptus in Botswana is not known.

The cost of CO_2 reduction by re-afforestation calculated in this study was P342.05/tonne of CO_2 equivalent emissions reduced. The potential GHG reduction is 72 000 tonnes of CO_2 equivalent emissions.

Costing for this option however requires more accurate sink capacity of the different types of growing trees and indigenous forests.

Implementation Aspects

This could be successfully achieved involving community participation provided the benefits can be realised. The Ministry of Agriculture would need to be active together with involved NGOs in order to make an impact.

Previous attempts to create woodlots have not been very successful, as the total area under forest plantations has stagnated at 650 woodlots.

Rather than planting where trees are cut, new plants can be planted in favourable conditions as long as they do not interfere with other important land use activities.

Macroeconomic Impact

Where tree planting is conducted for fuelwood supply, the option offers sustainability of energy supply to rural households. If the venture results in saleable timber for household construction then this will create income generation in addition to providing building material.

Planting of trees in degraded areas will also assist in rehabilitating the deforested land. This has been successful in Lesotho where planting of trees in gullies has improved the land value.

Potential Projects

a) Assessing potential land for tree planting

b) Assessing market for saleable timber

c) Assessing possibilities for reducing forestry costs

C) Central Solar PV plant

Exploiting solar energy could relieve the use of fossil fuels in power generation but is not expected to substitute the coal-fired power plants in the foreseeable future

The use of centralised solar power plants is expected to come on stream in Botswana by 2005 and this source could replace equivalent coal based electricity thus reducing GHG emissions from the power sector.

Policy Framework

The BPC need a policy to compliment grid electricity with solar PV systems particularly in villages remote from the grid. This approach is being considered by the utility and other involved institutions like the Botswana Technology Centre.

Baseline Scenario

In LEAP, about 2MW of solar power plants is expected in 2005 and 5MW in 2030 at P14600-22000/kW.

Mitigation Scenario

The mitigation scenario assumes putting up a 2MW per annum of solar PV manufacturing capacity in Botswana at P6300/kW as from 2003 thus achieving 50MW in 2030. Thus the option only considers the additional 2MW in 2005 and 49MW by 2030 as reducing from the baseline GHG emissions. The cost is for setting up the plant only to supply the market and excludes the cost of PV kits paid by individual consumers.

Cost and CO_2 Reduction Potential

By this option, the cost of GHG reduction is P85.30/tonne and each MW is capable of reducing 4375 tonnes of CO_2 equivalent emissions annually. The potential GHG reduction is 8750 tonnes in 2005 and 219 000 tonnes in 2030. In the 20 year life span of the solar plants, the potential reduction is 175 000 tonnes for the 2005 plant and 4.4 million tonnes in 2030.

Implementation Aspects

Solar is a popular source of energy in Botswana and government is making its efforts to introduce solar home systems. The Botswana Technology Centre is creating a budget to pilot a centralised solar PV plant in a village to be selected. These efforts indicate that the potential for centralised solar will be possible in the lead times indicated above.

The setting up of a local solar PV industry will however depend on the market potential. This could be achieved through private investment. This could also be a project for global funding.

Macroeconomic Impact

If the solar PV industry is set in Botswana, this will increase the national GDP and employment capacity. The option will have also localised part of the costs of importing solar PV modules.

The annual levelled net cost for the project is about P395145 per MW of capacity, which amounts to about P21.34 million for the 27 years from 2003 to 2030. The current market value of putting up 49MW of solar PV plants is however very significant at P309 million.

The solar PV power plants are more sustainable than the fossil fuel based ones and thus will contribute to economic sustainability and a cleaner environment.

Potential Projects

a) Scope for cooperation in solar PV power plants between BPC and external investors

b) Scope for GEF funding for the project

c) Infrastructure requirements for setting up a solar PV manufacturing plant in Botswana

D) Biogas- Landfill Plants

Waste management is a problem in developing countries and incurs substantial amounts of money in collection and disposal of waste. In Botswana, a waste management act is being passed to ensure proper disposal of waste.

It is possible to turn the waste into an asset as fuel for electricity production. The waste produced in the urban centres can easily be assembled to generate some electricity. In so doing, the CH_4 another strong greenhouse gas, released on waste dumps can be used for energy production before turned into CO_2, which has a lower global warming potential than CH_4.

This option therefore examines the potential of reducing CO_2 equivalent emissions through use of CH_4 for energy production.

Policy Framework

A waste management act to be in place needs to be monitored to ensure that there is proper waste collection and disposal. The cost of waste management may create incentive to utilise waste for energy production.

Baseline Scenario

Waste in Gaborone continues to be dumped in dumpsites as in the past through to 2005 and 2030. About 69 000 tonnes and 169 000 tonnes of waste is expected to be generated in 2005 and 2030 in Gaborone.

Mitigation scenario

The waste generated in Gaborone is exploited for power generation via CH_4 generation instead of releasing CH_4 into the atmosphere.

Cost and CO_2 Reduction Potential

The cost of reducing CO_2 equivalent emissions with this option was found to be P6.71/tonne and with each tonne of waste landfill having the potential to reduce 2.1 tons. This is a tonne with degradable organic content (DOC) of 15% and fraction of DOC to CH_4 of 75%. The content of CH_4 in the biogas is known to be about 50-60%. The GHG avoided is in form of CH_4.

With the potential waste for Gaborone reaching 68920 tonnes in 2005 and 168920 tonnes in 2030, the option can reduce 124 000 tonnes in 2005 and 304 000 in 2030 of CO_2 equivalent emissions.

Investment for all the waste in 2005 and 2030 will cost about P14 million in 2005 and P34 million in 2030 at current prices. The levelised costs are P0.97million in 2005 and P2.4 million in 2030.

Implementation Aspects

The option requires knowledge of proper dump designs and harnessing of generated biogas. The power plant also has to be located close to the dumps to avoid transportation pipelines for the gas.

The principle of exploiting landfill gas for power generation is straight forward but the actual implementation has some lead time. The option is best exploited by an independent power producer or initiated as a GEF Project since it has positive costs/tonne of CO_2 equivalent emissions. GEF has financed a similar project in Tanzania with Municipal Solid Waste generated in Dar es Salaam (*Inforse* no 17, May, 1997). GEF provided USD 2.5 million (P9.54 million) for the project.

The monopolistic tendencies of utilities could hamper such initiatives by independent power producers. Even if the utility may want to buy power from IPP, the price setting becomes the sticking point.

Macro-economic Impact

Utilising waste for productive use will turn a waste into a gain. There will be a return on the cost of waste collection and disposal. Waste management will improve creating an attractive environment even for tourists. The health aspects associated with indiscriminate dumping of waste will also improve.

The process will create further employment at the power plant and by construction and management of waste dumps.

Producing energy from waste is sustainable as the waste continues to be generated. Revenue can also be collected from marketing of the gas with government getting tax on it.

The measure has potential to replace power imports thus improving the balance of payments for the country.

Potential Projects

a) Evaluate waste generation levels and waste quality in Botswana

b) Scope and costs and infrastructure design for tapping landfill gas and expected generation capacity.

c) Potential revenue deriving from sale of landfill gas.

E) Biogas Home Plants

Rural households in Botswana are experiencing fuelwood scarcity such that women spend up to 2 hours fetching fuelwood from long distances of up to 20 km.

Previously biogas for household use has not been widely used in Botswana due to dispersed manure as cattle are on rangeland grazing practice. If it takes 2 hours to fetch fuelwood whereby the sources are even retreating, it might be worthwhile considering collecting cow dung for a biogas plant. The benefits go beyond energy provided by fuelwood. Biogas can be used for cooking, lighting and water heating. The manure accruing from the plant can be used for gardening, which can turn out to be an income generating activity.

Policy Framework

Biogas technology has not received similar government support like solar technologies in Botswana. It will therefore be useful for the government to support acquisition of appropriate biogas technologies for Botswana and also create credit facilities for the potential market.

Baseline Scenario

All rural households continue to use fuelwood through to 2005 and 2030 resulting in forest depletion.

Mitigation Scenario

5% of the rural households resort to using biogas in place of fuelwood for cooking. The total such (5%) households (a proportion of rural households derived from LEAP) in 2005 and 2030 will be 13000 and 21000 households respectively.

Cost and CO_2 Reduction Potential

It costs P55.10 to reduce a tonne of CO_2 equivalent with this option and each household type biogas plant has the potential to reduce 6.6 tonnes annually. For the 5% of households in 2005 and 2030, the potential GHG reduction will be 86 000 tonnes in 2005 and 138600 tonnes in 2030. In the life span of 10 years assigned to the plants, the potential for CO_2 equivalent emission reduction can be -.86Mt and 1.39 Mt.

Implementation Aspects

The cost of putting up a biogas plant is relatively high for rural households hence the proportion of 5% for the technology market which is lower than the 10%, the proportion expected for solar PV systems for the same market of rural households.

Cost of gas equipment for cooking and lighting is further cost that is not included in the option and may further hamper uptake of the biogas technology at household level.

Interest in biogas technology in Botswana has to be revived through demonstration and training in plant installations.

Macro-economic Impact

Biogas technology will reduce land degradation through deforestation by woodcutting. The technology is made mainly from local materials and will not affect balance of payments. It also has cross-sectoral linkages between energy and agriculture sectors as the manure from biogas plants can be used to improve agricultural yield.

Installation of biogas plants will create employment for those trained in the art.

All in all, the standard of living of the rural people will be upgraded through sustainable supply of cleaner energy than fuelwood. Biogas as a cleaner energy will reduce indoor air pollution caused by fuelwood fires.

Potential Projects

a) R & D on biogas plant types and sizes

b) Pilot biogas plants for rural households

c) Demonstration of appropriate biogas plants and benefits

6 Mitigation Strategy for Botswana

6.1 Cost Curve Analysis

The cost curve is one way of presenting a GHG abatement strategy for a country. It is a graph showing a possible sequencing of mitigation actions based on their costs of implementation. The cost curve logically suggests that options with the lowest cost are implemented first rising to the expensive ones. Table 6.1.1 shows the mitigation options analysed in this study and their data for the cost curve (Fig 6.1.1 and Fig 6.1.2).

Table 6.1.1 shows 9 mitigation options that can be implemented at negative costs out of the 20 total options analysed. These relate to both electricity and diesel energy savings. The majority of the options in the household electricity savings have negative costs so these can easily be effected with the limited financial resources available in the households.

Those related to diesel savings are mostly in the transport sector. The cost of diesel savings in the transport sector also depends on the intensity of use. The higher the intensity of use e.g. in terms of t-km carried or toe transported, the lower the costs of reduction. Hence the cost of mitigation actions in the transport hence responds to economies of scale. Notable changes are in the option involving the pipeline and shifting from diesel to electric locomotives. In the case of the pipeline, the cost shifts from positive cost in 2005 to negative cost in 2030 when the fuel demand has increased to warrant the pipeline. The cost of diesel-electric locomotives drops to less than half that of 2005 in the same period as the freight size increases.

All the renewable mitigation options involving both solar and biogas have positive costs due to the currently high costs of equipment purchase. Reforestation programme also has a positive cost due to high water demand for plants in Botswana due to the high temperatures.

In terms of GHG reduction potential, the intensity of use or penetration rate and the unit potential are obviously the determining factors. The pattern in the results however shows that in the household sector, a significant GHG reduction can be realised by limiting the geyser/electric water heater consumption. In the transport sector, pavement of roads and introducing vehicle inspection could result in significant avoided GHG emissions. The expensive options in this sector have relatively low potential for reducing GHG emissions. Substitution of coal based electricity with hydropower or landfill gas based electricity has significant avoided GHG emissions on the supply side.

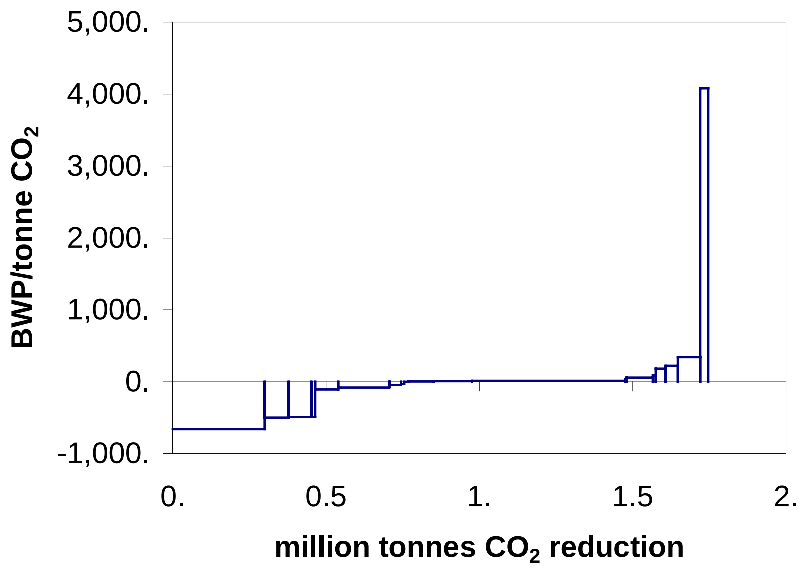
The cumulative GHG reduction effect of all the mitigation options is depicted in Fig 6.1.1 and Fig. 6.1.2 for the short term (2005) and for the long term (2030) respectively.

Table 6.1.1 GHG abatement in the energy sector of Botswana and their costs and potential of reduction

Mitigation option	Cost of GHG red. BWP/ton	Unit size	Driver	Fuel used	CO_2 equiv. tons/unit	Penetration rates 2005	Cum. GHG red Mt/yr. 2005	Penetration rates 2030	Cum GHG red. Mt/yr. 2030
paved roads	-660.4	1	route	petrol/diesel	298950.7	1	0.30	1	0.30
Road freight to rail	-501.7	1	kt-system	diesel	77395.7	1	0.38	1	0.46
Efficient lighting	-495.3	1000	bulb	coal	92.2	810	0.45	1820	0.63
Tillage	-493.2	1	tractors	diesel	26.9	463	0.46	463	0.64
Prepayment meters	-111.2	1	meter	el-coal	2.2	35000	0.54	1	0.73
Geyser time switches	-84.4	1	timer switch	el-coal	3.0	56000	0.71	136000	1.02
solar home systems	-67.9	1	system	paraffin	0.08	25000	0.71	145000	1.45
Power factor correction	-47.6	1	MVAR	el-coal	939.0	39	0.74	39000	1.46
Efficient boilers?	-36.7	1	boiler	coal	475.5	20	0.75	39	1.49
Fuel pricing	0.0	1	fuel system	petrol	15237.0	1	0.77	50	1.52
Efficient motors	2.4	1	kW	el-coal	2.7	30000	0.85	0	1.52
Biogas from landfills	5.4	1	t-waste	el-coal	1.8	69000	0.98	56000	1.67
Vehicle Inspection	8.7	1	fuel system	petrol/diesel	182057.2	1	1.48	1	2.16
Solar geysers	27.2	1	geyser	el-coal	4.9	1000	1.48	169000	2.47
Biogas for rural households	55.1	1	digester	wood	6.6	13000	1.57	2400	2.48
Central PV electricity	85.3	1	MW	el-coal	4374.8	2	1.57	50	2.70
pipeline	184.82 (-301.50)	1	pipeline	diesel	35918.0668	1	1.61	21000	2.84
Solar PV water pumps	223.3	1	pump	diesel	5.5	7300	1.65	12400	2.91
Reforestation	342.1	1	9810 ha	sink	72086.67	1	1.72	1	2.98
diesel to electric rail	4080.1 (1784.50)	1	t-km-system	diesel	26906.6	1	1.75	1	3.04
BASELINE TOTAL EMISSIONS							7.32		11.74
% GHG REDUCTION							24%		26%

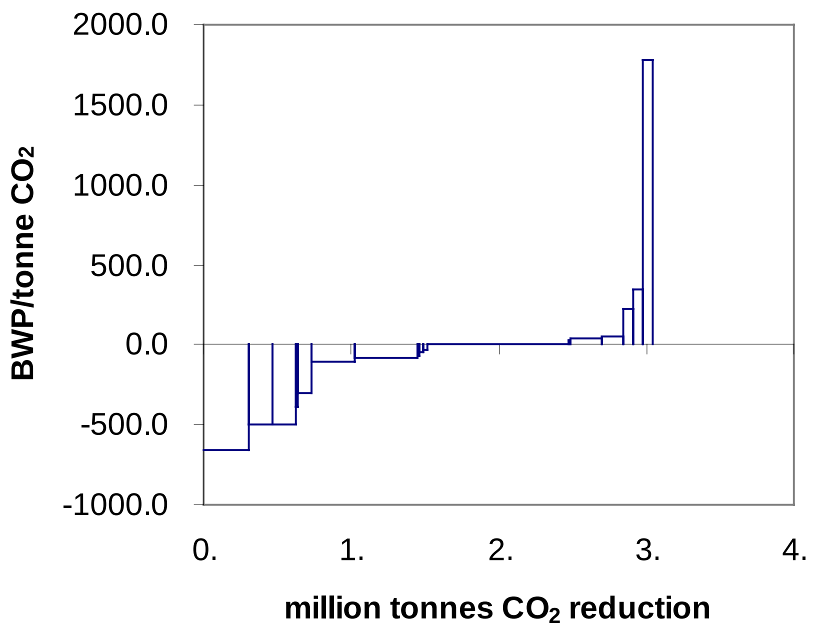
(1784.50)- 2030 COST/TONNE AS DETERMINED BY LOAD OF FREIGHT.

Fig 6.1.1 Cost curve for energy system GHG abatement options 2005



Abatement option	BWP/tonnes CO_2	CO_2 equivalent Cumulative reduction (million tonnes)
1 *paved roads	-660.4	0.30
2 Road freight to rail	-501.7	0.38
3 *Efficient lighting	-495.3	0.45
4 *Tillage	-493.2	0.46
5 *Prepayment meters	-111.2	0.54
6 *Geyser time switches	-84.4	0.71
7 *solar home systems	-67.9	0.71
8 *Power factor correction	-47.6	0.74
9 *Efficient boilers?	-36.7	0.75
10 *Fuel pricing	0.0	0.77
11 *Efficient motors	2.4	0.85
12 *Biogas from landfills	0.0	0.98
13 Vehicle Inspection	8.7	1.48
14 *Solar geysers	27.2	1.48
15 *Biogas for rural households	55.1	1.57
16 Central PV electricity	85.3	1.57
17 *pipeline	184.82	1.61
18 *Solar PV water pumps	223.3	1.65
19 *Reafforestation	342.1	1.72
20 diesel to electric rail	4080.1	1.75

Fig 6.1.2 Cost curve for energy systems GHG abatement options 2030



	Abatement option	BWP/tonne CO_2	CO_2 equivalent cumulative reduction (million tonnes)
1	Road freight to rail	-501.7	0.46
2	*Efficient lighting	-495.3	0.63
3	*Tillage	-493.2	0.64
4	*pipeline	-301.5	0.73
5	*Prepayment meters	-111.2	1.02
6	*Geyser time switches	-84.4	1.45
7	*solar home systems	-67.9	1.46
8	*Power factor correction	-47.6	1.51
9	*Efficient boilers?	-36.7	1.53
10	*Fuel pricing	0.0	1.55
11	*Efficient motors	2.4	1.70
12	Vehicle Inspection	3.2	2.19
13	*Biogas from landfills	0.0	2.50
14	*Solar geysers	27.2	2.52
15	Central PV electricity	44.6	2.73
16	*Biogas for rural households	55.1	2.87
17	*Solar PV water pumps	223.3	2.94
18	*Reafforestation	342.1	3.01
19	diesel to electric rail	1784.5	3.07

Even if some of the options have small contributions, the overall GHG reduction of these mitigation options is significant at 24% of the total energy sector emissions in 2005 and 26% of the emissions in 2030.

Guaranteed hydropower as a mitigation option for Botswana taken in place of the expected expanded capacity in Botswana could alone reduce 2.4 million tons. This option has however not been included in the cost curve as arguments suggest that the option could be more of a regional mitigation option than a national one. The interest should however not be lost to explore how Botswana could benefit from this option.

Sensitivity test with discount rates involved increasing the rate from 6% to 10% and reducing it to 3%. The higher discount rate of 10% resulted in higher costs of reduction but none of the options shifted from negative costs to positive costs. The option of substituting coal power with hydropower was the closest one to shifting in that direction.

Similarly, reducing the discount rate to 3% reduced the costs of mitigation but again none of the options changed sign.

If the cost curve were to be the basis of mitigation strategy in Botswana, then Botswana would initially mop up the opportunities in the household sector which have negative costs and low capital layout followed by the ones with negative costs in the transport sector and power sector since the capital layout is relatively higher. Both the renewables and the expensive transport options would probably be implemented in the long term when it becomes cost-effective to use them.

6.2 National Development Priorities and Realignment of Mitigation Options

A meaningful *GHG abatement* strategy in developing countries has to follow the development aspirations of those countries and in this respect, the strategy must take cognisance of the national development policies and possible impacts on the macro economy.

The aspects evaluated in this section included government policy on the measures, ease of implementation and the macro-economic impacts consisting of impact on Balance of Payments, employment creation, social benefits like health aspects improvements or income generation, economic efficiency or competitiveness in business, environment enhancement. Consideration was also given where the option accrues benefits in another sector e.g. in form of deferred investments in additional power plants or enhancing agricultural output.

Table 6.2.1 is an attempt to rank the analysed mitigation options by considering these aspects. No weights have been allocated to these factors as these are not known but national governments could decide that in the formulation of the *GHG abatement* strategy.

In this simple approach, only the total number of positive (+) impacts for each mitigation option determined the ranking factor.

By this type of analysis, the sequencing of the GHG abatement options in Botswana’s strategy could resemble the ranking in Table 6.2.2.

This type of ranking would be satisfactory for zero or negative-cost options but the sequence of implementation could be altered where large capital layouts are required for implementation. This may be the case with solar PV pumps, which even if government were willing to promote solar technologies, would be slowed down by the cost of the technology. Similarly with reforestation whose cost is higher compared even to solar PV pumps.

Some of the options ranked low could be implemented earlier if the appropriate policies can be put in place e.g. zero tillage in agriculture.

The recommendation is that the mitigation strategy be reviewed from time to time for any necessary amendments.

Table 6.2.1 Ranking of mitigation options by national development priorities

No.	Mitigation Option	Cost or GHG Reduction (BWP/ton)	Govt. Policy	Implementability	Impact on balance of payments	employment	social benefits	economic efficiency/ competitiveness	benefits more than one sector	Local environmental enhancement	Ranking
1	paved roads	-660.4	+	+	-/+	+	+	+	+		6
2	Road freight to rail	-501.7	?	?	_/+	_	?	?	?	+	2
3	Efficient lighting	-495.3	+	++	_	0	+	+	+	+	7
4	Tillage	-493.2	?		+	_	?	+	?	+	3
5	Prepayment meters	-111.2	++	++	_	0	+	+	+	+	8
6	Geyser time switches	-84.4	?	+	_	?	+	+	+	+	5
7	solar home systems	-67.9	++	++	_ _	+	++	?	?	+	8
8	Power factor correction	-47.6	+	+	- -	?	?	+	+	+	5
9	Efficient boilers?	-36.7	?	+	_	?	+	+	+	+	5
10	Fuel pricing	0.0	?	++	0	0	_ _	?	0	?	2
11	Efficient motors	2.4	+	+	_ _	?	?	+	+	+	5
12	Biogas from landfills	5.4	?	+	_	++	+	+	+	+	7
13	Vehicle Inspection	8.7	++	+	_	+	++	+	+	+	9
14	Solar geysers	27.2	+	?	_	?	?	+	+	+	4
15	Biogas for rural households	55.1	?	+	0	+	++	?	+	+	6
16	Central PV electricity	85.3	?	?	_ _	+	?	?	?	+	2
17	pipeline	184.82 (-301.5)	?	?	_ _	+	?	?	+	?	2
18	Solar PV water pumps	223.3	+	-	_ _	+	+	+	+	+	6
19	Reforestation	342.1	+	_	0	+	+	?	+	+	5
20	diesel to electric rail	4080.1 (1784.50)	?	?	_ _	+	?	+	-	?	2

- = not in favour; + in favour (-- or ++ means more so); ? not known/clear; 0= none

Table 6.2.2 Realignment of GHG Abatement Options based on national development interests

Ranking No.	GHG Abatement Description	Cost of reduction BWP/ton
1	Vehicle Inspection	8.7 (3.18)
2	Prepayment meters Solar Home systems	-111.206 -67.9
3	Efficient lighting Landfill gas for power generation	-495.30 5.4
4	Paved roads Biogas for rural households Solar PV pumps	-660.40 55.10 342.1
5	Efficient boilers Geyser time switches Power factor correction Efficient motors Reforestation	-36.7 -84.40 -47.60 2.40 223.30
6	Solar geysers- Water heaters	27.20
7	Zero tillage in agriculture	-493.20
8	Road to rail freight Fuel switch from petrol to diesel through differential pricing Central PV plants Pipeline for petroleum products Electrifying the railway line	-501.20 0.0 85.30 184.82(-301.50) 4080.10 (1784.80)

7 Conclusions and Recommendations

7.1 Conclusions

There is a relatively significant potential to reduce GHG emissions in the energy system of Botswana by applying a number of mitigation options. The potential GHG reduction achievable by applying a set of 20 mitigation options analysed in this study was found to be about 24% in 2005 and 26% in 2030 as in Table 7.1.1

Table 7.1.1 GHG emission levels in the baseline and mitigation scenarios

	2005 CO_2 equiv. Emissions	2030 CO_2 equiv. emissions
Baseline scenario	7317 Gg	11739 Gg
GHG reduction in mitigation scenario	1750 Gg	3070 Gg
Reduction %	24%	26%

** This reduction excludes a potential reduction of hydropower of 1.2 Mt*

More GHG reduction could be achieved through additional options that may avail themselves in due course.

With respect to the present analysis, about 44% of the reduced emission could be achieved by implementing zero or negative cost options. The situation may change when more options are added.

7.2 Recommendations

Projects recommended in this study for the various presented mitigation measures should be the starting point for assessing in detail the best conditions under which the measures could be implemented.

Appropriate government policies directed at implementation of these measures will be necessary. The options should always some national development benefits but guidance and incentives will be imperative to ensure involvement of the various actors in the economy.

An example of such incentive is practised in South Africa by ESKOM where awards are given annually to consumers of electricity and the suppliers of equipment. The awards are for outstanding achievements in energy efficiency measures or supply of efficient equipment.

This is in form of money (up to R 20 million) and trophies but other forms of incentives can be formulated. Successful examples elsewhere could also act as incentives as local actors may also be driven by the aspiration to achieve similar energy and costs savings.

The awareness campaign is a process that takes time for results to be realised. It is therefore recommended that this aspect with respect to energy and cost savings be initiated soon for Botswana's actors to move towards sustainable development. A dedicated institution for energy efficiency and conservation could be the starting point for implementing of this GHG abatement.

In order to have a continued perspective of the mitigation objective, repeated mitigation analysis and refinements of costs probably including some transaction costs need to be made.

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Annexe

Table A.1 NDP7, NDP8 (1994/95-2005) and Vision 2016 (2005-2030) estimated economic (GDP) growth rates for Botswana.

SECTOR	1994 GDP contributi ons	1981/82-1994/95 av. pa GDP-Growth Rate %	short term GDP g. rate %1994-2005 **	Long Term GDP g. rate %2005-2030#	1994 GDP P million	2005 GDP P million	2030 GDP P million
Agriculture	5.8	3.41	0.8	5.0.	189.4	206.8	700.3
Mining	47.2	7.85	1.7	2.1	1555.4	1872.3	3147.9
Transport	8.9	15.19	5.7	8.9	203.5	374.5	3156.1
Manufacturing	3.7	7.53	8.8	8-10 (18.3)	293.2	741.5	6394.0 (49514.2)
Construction	7.8	3.26	1.5	9.2	258.3	304.3	2747.1
Trade and Hotels	24.0	7.18	5.6	8.9	790.5	1 439.5	12131.3
Social Services	6.2	10.62	6.5	8.9	223.8	447.4	3770.4
water & Electricity	15.0	11.83	5.8	6.2	122.4	227.6	1024.0
Financial services	25.4	10.82	8.7	8.9	493.8	1 236.2	10418.0
Government	6.8	12.25	6.1	4.0	836	1 603.5	4294.7
National GDP	100*	7.82	4.7-5.5	7.9	4728.7	8 453.6	47763.6 (90883.8)

Table A.2 Total Sectoral energy demand in the baseline for the Energy Sector of Botswana

DEMAND SECTOR	**1994**	**2005**	**2030**
Household	22.53	27.39	41.15
Transport	10.33	17.02	52.92
Industry	8.21	9.50	21.60
Commerce (+govt.)	3.32	6.39	10.22
Agriculture.	0.53	0.53	1.60
TOTAL	44.92	61.33	127.49

Table A.3 Energy Input Demand by Power Plant

Power Plant	**1994**	**2005**	**2030**
Morupule	14220	42110	42110
Selibe Phikwe	1670	0	0
Soda Ash	1450	1540	1540
Diesel BPC	290	0	0
diesel DEMS	350	720	720
Central Solar	0	20	40
Imports	1190	0	9460
TOTAL	19170	44390	53870

(80) Capacity factor of plants

Table A.4a CO_2 equivalent emissions from demand-side and transformation energy + % share of total gas types.

Gg (=x 1000 tons)

Sector Side	*1994 Gg*	*2005 Gg*	*2030 Gg*	*1994share %*	*2005 share %*	*2030share %*
Demand-CO_2 equivalent	**1660**	**2426**	**6657**	**43**	**33**	**57**
CO_2	1391	2075	5825	45	34	59
CH_4	104	118	221	23	17	22
N_2O	165	233	611	54	41	65
Transf-Electricity-CO_2 equivalent	1834	4318	4318	48	59	37
CO_2	1689	3978	3978	55	66	41
CH_4	2.73	6	6	1	1	1
N_2O	142.6	334	334	46	59	35
Coal Mining-CO_2 equivalent	344	573	764	9	8	7
CH_4	344	573	764	76	82	77
TOTAL-CO_2 equivalent	3838	7317	11739	100	100	100
CO_2	3080	6053	9802	100	100	100
CH_4	451	697	992	100	100	100
N_2O	308	567	945	100	100	100

Table A.5 GHG contribution by all sectors in the baseline

GHG TYPE	**1994**	**2005**	**2030**
Household	126	158	234
Transport	797	1312	4080
Industry	549	682	1914
Commerce	128	233	308
Agriculture-CO_2 equivalent Gg	40	41	121
TOTAL-demand	**1640**	**2425**	**6657**
electricity sector	1834	4317	4317
coal mining	344	573	764
TOTAL supply side	**2178**	**4890**	**5081**
TOTAL	**3819**	**7315**	**11739**