SELECTED ENVIRONMENTAL INDICATORS

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PREFACE

Statistics and indicators are useful to policy makers because they quantify existing situations that are sometimes already known qualitatively or generally. The quantification of such situations provides policy makers with a basis upon which they can make constructive decisions on national policy. If a situation is of concern (e.g. fuelwood depletion, water scarcity, high population growth rate or high water pollution levels) but has not been quantified, it becomes difficult for policy makers to make policies that will effectively bring the situation under control/mitigate resultant adverse impacts.

There is not always a clear distinction made between a statistic and an indicator and to date, no single, widely applied definitions of a statistic or indicator exist. A statistic is generally considered as refined or treated raw data, for example, the number of threatened species or carbon dioxide emissions. An indicator can generally be considered as a value derived from a statistic and which provides combined information about a phenomenon or issue such as a ratio or a proportion of two statistics, for example, the number of threatened species as a percentage of known species or carbon dioxide emissions per capita. An indicator has significance that extends beyond the properties directly associated with the value of the statistic. Indicators possess a synthetic meaning and are developed for a specific purpose. Some of the benefits of using indicators are that they: (i) reduce the number of raw data measurements and/or statistics that would normally be required to give an exact presentation of a situation; (ii) simplify the communication process by which the results of measurements are provided to the user; and (iii) are easy to understand and interpret. Because of data paucity, not all the data environmental indicators that are presented in this publication are in ratio/proportion form. However, as data availability improves, this shall be our aim.

This is the first publication on Environmental Indicators that the Central Statistics Office (CSO) has issued. Due to paucity of the necessary data, only selected indicators on air, energy and conservation of biodivesity are covered. This situation, however, is expected to improve because primary data providers have now been sensitised about the need for environmentally related data. The CSO therefore hopes to be in a position to include additional topics and indicators in subsequent issues of the same publication.

All the data presented in the Tables in the Emissions Section of this publication (Section 1) was derived from calculations that made use of energy combustion data supplied by the Energy Affairs Division (EAD). Therefore, no sources are indicated on all the data tables in Section 1. The CSO wishes to thank the Energy Affairs Division for this contribution. Similarly, the CSO wishes to thank the Department of Mines, and the Department of Meteorological Services for providing the data used in this publication (Sections 2 and 3, respectively) and for their technical input.

G.M. Charumbira
GOVERNMENT STATISTICIAN

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LIST OF ABBREVIATIONS

CFC	Chloroflourocarbon
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
FEC	Final energy Consumption
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GJ	Giga Joules
HC	Hydrocarbons other than methane
HCFC	Hydrochloroflourocarbon
LPG	Liquefied Petroleum Gas
MJ	Mega Joules
NES	Net Energy Supply
NO_X	Oxides of Nitrogen
N_2O	Nitrous Oxide
ODS	Ozone Depleting substance
ODP	Ozone Depleting Potential
PES	Primary Energy Supply
SO_X	Oxides of Sulphur
TJ	Tera Joules
TSP	Total Suspended Particulates
t	Tonnes
UNFCC	United Nations Framework for Climate Change

1.0 Emissions from the Energy Sector

Emissions from the energy sector include both greenhouse gases (GHGs) and other emissions.

The major GHGs are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_20), other oxides of nitrogen (NOx) and carbon monoxide (CO). All these gases occur naturally in the atmosphere and they are more efficient at absorbing long wavelength radiation of heat form the earth to the atmosphere than the incoming short-wave radiation heat, which is from the sun to the earth. As a result the gases trap more heat than they release, a process referred to as the natural greenhouse gas effect. This natural process becomes of concern, however, when as a result of emissions arising from anthropogenic activities, the GHGs accumulate in the atmosphere above natural levels. This results in more heat being trapped and the resulting concern about global warming. Globally, the energy sector is a principal contributor to GHG emissions. The data presented in this publication on GHG emissions covers only those emissions that arise out of energy generation and use. As more activity-level data becomes available on additional relevant sectors, this analysis will be extended to cover GHG emissions from those sectors as well.

There are various none GHG emissions from the energy sector. Those covered in this publication are emissions of Sulphur Oxides (SOx), Total Suspended Particulates (TSP) and hydrocarbons other than methane (HC).

1.1 Emission Coefficients

The quantity of any emission that results from the combustion of a fuel depend on many factors that include the chemical composition of the fuel and the combustion conditions of the medium (equipment/atmosphere) in which the combustion takes place. Emissions are always calculated (as opposed to concentrations which are measured) because the emitted pollutants disperse into the atmosphere and hence measurements made at any point in the dispersion chain yield concentrations of the pollutants which are less than the actual emission levels.

In this publication, the emission quantities of gases are estimated by multiplying the energy quantities[1] of the fuel combusted with respective emission coefficients. Table 1.1 gives the emission coefficients (in tonnes (t) per one TJ of energy) for the fuels used in Botswana. The second column (Fraction Oxidised) is only used when estimating CO_2 emissions as the production of this gas is very sensitive to the oxidation process.

According to Botswana's Initial Communication to the United Nations Framework Convention on Climate Change (UNFCC)[2], the amount of biomass volume increase resulting from natural tree re-growth rate exceeds the amount of biomass harvested. Additionally, since plants use CO_2 in the photosynthesis process, the contribution of wood to CO_2 emissions is nil at most, which explains the CO_2 emission coefficient value of zero under wood in Table 1.1.

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[1] Energy consumption data is from the Energy Affairs Division, Ministry of Minerals, Energy and Water Affairs.

[2] Prepared by the Department of Meteorological Services, Ministry of Works, Transport and Communications and presented in 2001

Emission coefficients for additional gases (non-GHGs) are included in Table 1.1. They will be used in estimating emissions in sections 1.4 and 1.5.

Table 1.1 Emission Coefficients, (t/TJ)

Energy Source	Fraction Oxidised	*CO_2	*CH_4	*N_2O	*NOx	*CO	**HC	**SOx	**TSP
Coal	0.98	92.00	0.012	0.025	0.375	0.013	0.001	0.813	0.208
LPG	0.99	63.07	0.001	0.030	0.043	0.529	0.066	0.000	0.000
Av Gas	0.99	69.30	0.030	0.022	0.079	0.056	0.826	..	..
Jet A	0.99	71.50	..	0.022	0.297	0.123	0.079	..	..
Petrol	0.99	69.30	0.100	0.022	1.101	8.620	0.669	28.037	0.007
Paraffin	0.99	71.87	0.023	0.022	0.014	1.125	2.478	0.383	0.090
Diesel	0.99	74.07	0.002	0.026	0.323	0.308	0.079	0.186	0.095
Fuel Oil	0.99	77.37	0.002	0.026	..	..	..	..	..
Wood	0.00	0.00	0.563	0.003	0.050	6.250	0.469	0.031	0.625

.. Data unavailable
Sources:
****Emission Coefficients are from Botswana Initial Communication to the United Nations Framework Convention on Climate Change (UNFCC), Ministry of Works, Transport and Communications, 2001***
*****Emission Coefficients are from the Long Range Energy Alternative Planning and its associated Environmental Databases (LEAP/EDB)***

1.2 Emission of Greenhouse Gases (GHGs, tonnes and percentages)

All GHGs contribute to the twin threats of global warming and climate change. Data presented in this section covers emissions of five GHGs, namely, CO_2, CH_4, N_2O, NOx and CO. The emissions of the gases are presented in tonnes and percentage contributions (see Tables 1.2 to 1.12).

CO_2 (Tables 1.2 and 1.3) is released during combustion and oxidation in quantities that are proportional to the carbon content of the fuel. Coal is the main source of CO_2 emissions (57 to 65 percent) within the energy sector in Botswana, followed by petrol (15 to 21 percent) and Diesel (14 to 18 percent). The total contribution of the remaining energy sources to CO_2 emissions is comparatively insignificant (5 percent to 9 percent).

The main sources of CH_4 emissions (Tables 1.4 and 1.5) from the energy sector are wood (91 to 93 percent), petrol (5 percent to 7 percent) and coal (about 2 percent). The total contribution of the remaining fuels is less than 1 percent.

Coal is the main contributor to N_2O energy sector emissions (49 to 57 percent). Diesel; (15 to 20 percent) and petrol 15 to 21 percent) also contribute significantly to N_2O emissions. (See Tables 1.6 and 1.7)

In addition to contributing to the effects of GHGs, NOx are known to contribute to acidification, to affect the respiratory system and to react with volatile organic compounds in the presence of sunlight to form tropospheric ozone and other oxidising chemicals all of which are toxic to human beings and other living creatures. Petrol (40 to 48 percent), coal (34 to 43 percent) and diesel (9 to 12 percent) are the main sources of NOx emissions in the energy sector. (See Tables 1.8 and 1.9)

Carbon monoxide (CO) has negative respiratory impacts because it inhibits the flow of oxygenated blood in the human body in addition to being a GHG. Furthermore, CO contributes directly and indirectly to the increase of GHGS in the atmosphere. The main contributors to CO emissions (Tables 1.10 and 1.11) are wood (62 to 69 percent), petrol (30 to 37 percent) and diesel (about 1 percent). The sum contribution of the remaining energy sources is less than 2 percent.

Table 1.2 Emissions of CO_2 (Tonnes)

Energy Source	1990	1992	1993	1994	1995	1996	1997
Coal	1,503,911	2,032,928	1,947,456	1,975,586	1,973,440	1,682,249	1,729,333
LPG	31,557	33,717	34,675	37,311	32,670	34,351	35,390
Av Gas	5,725	6,998	3,910	4,542	6,956	7,010	7,010
Jet A	35,228	23,925	13,335	14,281	19,202	16,626	18,316
Petrol	379,704	498,979	535,119	531,498	583,425	595,362	628,685
Paraffin	31,720	33,228	34,864	36,445	34,826	34,899	35,943
Diesel	422,379	494,899	454,887	415,125	469,535	481,037	546,841
Fuel Oil	23,922	190,801	166,124	8,071	12,114	12,784	17,821
Wood	-	-	-	-	-	-	-
Total	2,434,145	3,315,475	3,190,370	3,022,859	3,132,169	2,864,318	3,019,338

- : zero contribution

Table 1.3 Emissions of Carbon dioxide (CO_2, Percentages)

Energy Source	1990	1992	1993	1994	1995	1996	1997
Coal	61.8	61.3	61.0	65.4	63.0	58.7	57.3
LPG	1.3	1.0	1.1	1.2	1.0	1.2	1.2
Av Gas	0.2	0.2	0.1	0.2	0.2	0.2	0.2
Jet A	1.4	0.7	0.4	0.5	0.6	0.6	0.6
Petrol	15.6	15.1	16.8	17.6	18.6	20.8	20.8
Paraffin	1.3	1.0	1.1	1.2	1.1	1.2	1.2
Diesel	17.4	14.9	14.3	13.7	15.0	16.8	18.1
Fuel Oil	1.0	5.8	5.2	0.3	0.4	0.4	0.6
Wood	-	-	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

- : zero contribution

Table 1.4 Emissions of Methane (CH_4, tonnes)

Energy Source	1990	1992	1993	1994	1995	1996	1997
Coal	200	271	259	263	263	224	230
LPG	1	1	1	1	1	1	1
Av Gas	3	3	2	2	3	3	3
Jet A	..	..	..	..	..	..	..
Petrol	553	727	780	775	850	868	916
Paraffin	10	11	11	12	11	11	12
Diesel	12	13	12	11	13	13	15
Fuel Oil	1	5	4	-	-	-	-
Wood	9,917	11,484	11,828	12,062	11,922	11,846	12,079
Total	10,696	12,515	12,897	13,125	13,063	12,966	13,256

.. : Data unavailable

- : Zero or less than one unit

Table 1.5 Emissions of Methane (CH_4, Percentages)

Energy Source	1990	1992	1993	1994	1995	1996	1997
Coal	1.9	2.2	2.0	2.0	2.0	1.7	1.7
LPG	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Av Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jet A	..	..	..	..	..	..	..
Petrol	5.2	5.8	6.0	5.9	6.5	6.7	6.9
Paraffin	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Diesel	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Fuel Oil	-	-	-	-	-	-	-
Wood	92.7	91.8	91.7	91.9	91.3	91.4	91.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

.. : Data unavailable

- : Less than 0.1 percent contribution

Table 1.6 Emissions of Nitrous Oxide (N_2O, tonnes)

Energy Source	1990	1992	1993	1994	1995	1996	1997
Coal	417	564	540	548	547	466	480
LPG	15	16	17	18	16	17	17
Av Gas	2	2	1	1	2	2	2
Jet A	11	7	4	4	6	5	6
Petrol	122	160	172	170	187	191	202
Paraffin	10	10	11	11	11	11	11
Diesel	150	175	161	147	166	171	194
Fuel Oil	8	65	56	3	4	4	6
Wood	53	61	63	64	64	63	64
Total	787	1,061	1,025	968	1,003	930	981

Table 1.7 Emissions of Nitrous Oxide (N_2O, Percentages)

Energy Source	1990	1992	1993	1994	1995	1996	1997
Coal	53.0	53.2	52.7	56.6	54.5	50.1	48.9
LPG	1.9	1.5	1.7	1.9	1.6	1.8	1.7
Av Gas	0.3	0.2	0.1	0.1	0.2	0.2	0.2
Jet A	1.4	0.7	0.4	0.4	0.6	0.5	0.6
Petrol	15.5	15.1	16.8	17.6	18.6	20.5	20.6
Paraffin	1.3	0.9	1.1	1.1	1.1	1.2	1.1
Diesel	19.1	16.5	15.7	15.2	16.6	18.4	19.8
Fuel Oil	1.0	6.1	5.5	0.3	0.4	0.4	0.6
Wood	6.7	5.7	6.1	6.6	6.4	6.8	6.5
Total*	100.1	99.9	100.0	99.8	100.0	100.0	100.1

* Totals that are not exactly 100 are due to rounding off errors

Table 1.8 Emissions of Nitrogen Oxide (NOx, tonnes)

Energy Source	1990	1992	1993	1994	1995	1996	1997
Coal	6,255	8,456	8,100	8,217	8,208	6,997	7,193
LPG	22	23	24	26	22	24	24
Av Gas	7	8	5	5	8	8	8
Jet A	148	100	56	60	81	70	77
Petrol	6,093	8,008	8,588	8,529	9,363	9,554	10,089
Paraffin	6	7	7	7	7	7	7
Diesel	1,860	2,180	2,004	1,829	2,068	2,119	2,409
Wood	881	1,020	1,050	1,071	1,059	1,052	1,073
Total	15,272	19,801	19,833	19,744	20,816	19,830	20,880

Table.1.9 Emissions of Nitrogen Oxide (NOx, Percentages)

Energy Source	1990	1992	1993	1994	1995	1996	1997
Coal	41.0	42.7	40.8	41.6	39.4	35.3	34.4
LPG	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Av Gas	-	-	-	-	-	-	-
Jet A	1.0	0.5	0.3	0.3	0.4	0.4	0.4
Petrol	39.9	40.4	43.3	43.2	45.0	48.2	48.3
Paraffin	-	-	-	-	-	-	-
Diesel	12.2	11.0	10.1	9.3	9.9	10.7	11.5
Wood	5.8	5.2	5.3	5.4	5.1	5.3	5.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

- *Less than 0.1 percent units*

Table 1.10 Emissions of Carbon monoxide (CO, tonnes)

Energy Source	1990	1992	1993	1994	1995	1996	1997
Coal	217	293	281	285	285	243	249
LPG	267	286	294	316	277	291	300
Av Gas	5	6	3	4	6	6	6
Jet A	61	42	23	25	33	29	32
Petrol	47,707	62,693	67,234	66,779	73,303	74,803	78,990
Paraffin	502	525	551	576	551	552	568
Diesel	1,774	2,079	1,911	1,744	1,972	2,020	2,297
Wood	110,090	127,488	131,300	133,900	132,344	131,500	134,090
Total	160,623	193,411	201,597	203,628	208,771	209,444	216,532

Table 1.11 Emissions of Carbon monoxide (CO, Percentages)

Energy Source	1990	1992	1993	1994	1995	1996	1997
Coal	0.1	0.2	0.1	0.1	0.1	0.1	0.1
LPG	0.2	0.1	0.1	0.2	0.1	0.1	0.1
Av Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jet A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Petrol	29.7	32.4	33.4	32.8	35.1	35.7	36.5
Paraffin	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Diesel	1.1	1.1	0.9	0.9	0.9	1.0	1.1
Wood	68.5	65.9	65.1	65.8	63.4	62.8	61.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 1.12 Total Emissions in Tonnes

Emission	1990	1992	1993	1994	1995	1996	1997
CO_2	2,434,145	3,315,475	3,190,370	3,022,859	3,132,169	2,864,318	3,019,338
CH_4	10,696	12,515	12,897	13,125	13,063	12,966	13,256
N_2O	787	1,061	1,025	968	1,003	930	981
NO_X	15,272	19,801	19,833	19,744	20,816	19,830	20,880
CO	160,623	193,411	201,597	203,628	208,771	209,444	216,532

1.3 Emissions of GHGS (CO_2 Equivalent tonnes).

Different GHG emissions when presented in units of weight cannot be compared to assess their comparative impacts on global warming and climate change. This is because the emissions have different chemical compositions and therefore different heat-trapping and global-warming potentials. To overcome this hindrance to comparative analysis of the impact of different GHG emissions, a Global Warming Potential (GWP) has been proposed for each GHG. The GWP of each emission is the relative ability of the emission to trap as much heat in the atmosphere as an equivalent weight of CO_2. GWPs have been derived by taking into account the radiation absorption properties and lifetime of the emissions in comparison with the same properties of CO_2. Table 1.13 presents the GWPs of the GHGS presented in this publication.

The emission quantities of different GHGs are converted to one unit of measurement called "carbon dioxide equivalent" by multiplication of the quantity (in tonnes) of each emission with the corresponding GWP.

Table 1.13 Global Warming Potentials

Emission	GWP
Carbon dioxide	1
Methane	21
Nitrous oxide	310
Nitrogen oxides	40
Carbon monoxide	3

Table 1.14 Emissions of Methane (CH_4, tonnes) in CO_2 Equivalents

Energy Source	1990	1992	1993	1994	1995	1996	1997
Coal	4,200	5,691	5,439	5,523	5,523	4,704	4,830
LPG	21	21	21	21	21	21	21
Av Gas	63	63	42	42	63	63	63
Petrol	11,613	15,267	16,380	16,275	17,850	18,228	19,236
Paraffin	210	231	231	252	231	231	252
Diesel	252	273	252	231	273	273	315
Fuel Oil	21	105	84	-	-	-	-
Wood	208,257	241,164	248,388	253,302	250,362	248,766	253,659
Total	224,637	262,815	270,837	275,646	274,323	272,286	278,376

- Less than 1 unit

Table 1.15 Emissions of Nitrous Oxide (N_2O, tonnes) in CO_2 Equivalents

Energy Source	1990	1992	1993	1994	1995	1996	1997
Coal	129,270	174,840	167,400	169,880	169,570	144,460	148,800
LPG	4,650	4,960	5,270	5,580	4,960	5,270	5,270
Av Gas	620	620	310	310	620	620	620
Jet A	3,410	2,170	1,240	1,240	1,860	1,550	1,860
Petrol	37,820	49,600	53,320	52,700	57,970	59,210	62,620
Paraffin	3,100	3,100	3,410	3,410	3,410	3,410	3,410
Diesel	46,500	54,250	49,910	45,570	51,460	53,010	60,140
Fuel Oil	2,480	20,150	17,360	930	1,240	1,240	1,860
Wood	16,430	18,910	19,530	19,840	19,840	19,530	19,840
Total	244,280	328,600	317,750	299,460	310,930	288,300	304,420

Table 1.16 Emissions of Nitrogen Oxides (NOx, tonnes) in CO_2 Equivalents

Energy Source	1990	1992	1993	1994	1995	1996	1997
Coal	250,200	338,240	324,000	328,680	328,320	279,880	287,720
LPG	880	920	960	1,040	880	960	960
Av Gas	280	320	200	200	320	320	320
Jet A	5,920	4,000	2,240	2,400	3,240	2,800	3,080
Petrol	243,720	320,320	343,520	341,160	374,520	382,160	403,560
Paraffin	240	280	280	280	280	280	280
Diesel	74,400	87,200	80,160	73,160	82,720	84,760	96,360
Wood	35,240	40,800	42,000	42,840	42,360	42,080	42,920
Total	610,880	792,080	793,360	789,760	832,640	793,240	835,200

Table 1.17 Emissions of Carbon monoxide (CO, tonnes) in CO_2 Equivalents

Energy Source	1990	1992	1993	1994	1995	1996	1997
Coal	651	879	843	855	855	729	747
LPG	801	858	882	948	831	873	900
Av Gas	15	18	9	12	18	18	18
Jet A	183	126	69	75	99	87	96
Petrol	143,121	188,079	201,702	200,337	219,909	224,409	236,970
Paraffin	1,506	1,575	1,653	1,728	1,653	1,656	1,704
Diesel	5,322	6,237	5,733	5,232	5,916	6,060	6,891
Wood	330,270	382,464	393,900	401,700	397,032	394,500	402,270
Total	481,869	580,236	604,791	610,887	626,313	628,332	649,596

Comparison of Tables 1.12, 1.18 and 1.19 reveals that the order of significance, based on weight of emission, of the contribution of the individual emissions to the GHG pool changes after taking into account the global warming potentials of the gases. While CO_2 is the leading contributor in both units of measurement (that is, in tonnes and CO_2 equivalent tonnes, Table 1.12 and 1.18) the order of significance of the other gases is not the same.

Table 1.19 presents the emissions in CO_2 equivalent tonnes and shows that the energy sector emissions that contribute the most to global warming are CO_2 (59 to 63 percent), NOx (15 to 16 percent) and CO (11 to 13 percent).

Table 1.18 Total of GHG Emission in CO2 Equivalent Tonnes

GHG Emission	1990	1992	1993	1994	1995	1996	1997
CO_2	2,434,146	3,315,475	3,190,370	3,022,859	3,132,168	2,864,318	3,019,339
CH_4	224,637	262,815	270,837	275,646	274,323	272,286	278,376
N_2O	244,280	328,600	317,750	299,460	310,930	288,300	304,420
NO_X	610,880	792,080	793,360	789,760	832,640	793,240	835,200
CO	481,869	580,236	604,791	610,887	626,313	628,332	649,596
Total	3,995,812	5,279,206	5,177,108	4,998,612	5,176,374	4,846,476	5,086,931

Table 1.19 Percentages of GHG Emission in CO_2 Equivalent Tonnes

GHG Emission	1990	1992	1993	1994	1995	1996	1997
CO_2	60.9	62.8	61.6	60.5	60.5	59.1	59.4
CH_4	5.6	5.0	5.2	5.5	5.3	5.6	5.5
N_2O	6.1	6.2	6.1	6.0	6.0	5.9	6.0
NO_X	15.3	15.0	15.3	15.8	16.1	16.4	16.4
CO	12.1	11.0	11.7	12.2	12.1	13.0	12.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

1.4 Other Emissions

The emissions reported in this sections are on hydrocarbons other than methane (HC), oxides of Sulphur (SOx) and Total Suspended Particulates (TSPs).

HC emissions contribute to the production of ground level ozone which negatively effects the respiratory system and is therefore dangerous to human health. We observe from Tables 1.20 and 1.21 that within the energy sector, the main sources of HC emissions are the use of wood (55 to 60 percent), petrol (27 to 34 percent), paraffin (7 to 8 percent) and diesel (3 percent).

SOx emissions are known to significantly contribute to acidification and to respiratory health problems in both human beings and animals. The major contributors to this group of emissions within the energy sector are petrol (91 to 94 percent) and coal (6 to 8 percent) as can be seen in Tables 1.22 and 1.23.

TSPs are emitted during combustion of various energy sources as a function of non-combustible fuel contaminants such as ash content. When exposed in large doses, TSPs can cause respiratory infections and vision impairment.

Table 1.20 Emissions of Hydrocarbons other than Methane (HC, tonnes)

Energy Source	1990	1992	1993	1994	1995	1996	1997
Coal	17	23	22	22	22	19	19
LPG	33	36	37	39	35	36	37
Av Gas	69	84	47	55	84	84	84
Jet A	39	27	15	16	21	19	20
Petrol	3,703	4,866	5,218	5,183	5,689	5,805	6,130
Paraffin	1,105	1,157	1,214	1,269	1,213	1,215	1,252
Diesel	455	533	490	447	506	518	589
Wood	8,261	9,567	9,853	10,048	9,931	9,868	10,062
Total	13,682	16,292	16,895	17,079	17,501	17,565	18,195

Table 1.21 Emissions of Hydrocarbons other than Methane (HC, Percentages)

Energy Source	1990	1992	1993	1994	1995	1996	1997
Coal	0.1	0.1	0.1	0.1	0.1	0.1	0.1
LPG	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Av Gas	0.5	0.5	0.3	0.3	0.5	0.5	0.5
Jet A	0.3	0.2	0.1	0.1	0.1	0.1	0.1
Petrol	27.1	29.9	30.9	30.3	32.5	33.0	33.7
Paraffin	8.1	7.1	7.2	7.4	6.9	6.9	6.9
Diesel	3.3	3.3	2.9	2.6	2.9	2.9	3.2
Wood	60.4	58.7	58.3	58.8	56.7	56.2	55.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

It should be observed that because emission coefficients for the emission of SOx from four of the nine energy sources (LPG, Av Gas, Jet A and fuel oil) were not available, the total energy sector emissions of SOx are underestimated in Tables 1.22 and 1.23. For the same reasons, the TSP emissions presented in Table 1.24 and 1.25 are also understated. Nevertheless, we note within the specified limits that petrol (91 to 94 percent) and wood (70 to 74 percent) are the leading contributors to SOx and TSP emissions.

Table 1.22 Emissions of Oxides of Sulphur (SOx, tonnes)

Energy Source	1990	1992	1993	1994	1995	1996	1997
Coal	13,561	18,332	17,561	17,814	17,795	15,169	15,594
Petrol	155,170	203,913	218,682	217,203	238,423	243,301	256,919
Paraffin	171	179	188	196	187	188	193
Diesel	1,071	1,255	1,154	1,053	1,191	1,220	1,387
Wood	546	632	651	664	656	652	665
Total	170,520	224,311	238,236	236,930	258,253	260,531	274,758

Table 1.23 Emissions of Oxides of Sulphur (SOx, Percentages)

Energy Source	1990	1992	1993	1994	1995	1996	1997
Coal	8.0	8.2	7.4	7.5	6.9	5.8	5.7
Petrol	91.0	90.9	91.8	91.7	92.3	93.4	93.5
Paraffin	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Diesel	0.6	0.6	0.5	0.4	0.5	0.5	0.5
Wood	0.3	0.3	0.3	0.3	0.3	0.3	0.2
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 1.24 Emissions of Total Suspended Particulates (TSP, tonnes)

Energy Source	1990	1992	1993	1994	1995	1996	1997
Coal	3,470	4,690	4,493	4,558	4,553	3,881	3,990
Petrol	39	51	55	54	60	61	64
Paraffin	40	42	44	46	44	44	45
Diesel	547	641	589	538	608	623	708
Wood	11,009	12,749	13,130	13,390	13,234	13,150	13,409
Total	15,105	18,173	18,311	18,586	18,499	17,759	18,217

Table 1.25 Emissions of Total Suspended Particulates (TSP, Percentages)

Energy Source	1990	1992	1993	1994	1995	1996	1997
Coal	23.0	25.8	24.5	24.5	24.6	21.9	21.9
Petrol	0.3	0.3	0.3	0.3	0.3	0.3	0.4
Paraffin	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Diesel	3.6	3.5	3.2	2.9	3.3	3.5	3.9
Wood	72.9	70.2	71.7	72.0	71.5	74.0	73.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

1.5 Emissions from Selected Sectors

In this Section, emissions from five sectors (Households, Industry, Transport, Government and Transformation[3]) on which data is given in Botswana's Energy Balances are analysed. The sectors whose emissions are not analysed (Agriculture, Trade and Hotels and, Social and Private Services) are estimated to contribute less than 5 percent of the total energy used in the country (as shown in section 4.2 Table 4.4) and hence their contribution to total energy sector emissions is minimal.

Tables 1.26 and 1.27 show that the leading sectoral CO_2 emissions are from the Transformation (51 to 54 percent), Transport (23 to 31 percent) and Industry (13 to 21 percent) sectors. This is not surprising since the combustion of coal (mostly used in the Transformation sector) and petrol and diesel (mostly used in the transport sector) are the main sources of CO_2 emissions from the energy sector (Tables 1.2 and 1.3). The household sector produces over 90 percent of CH_4 emissions, the majority of which (over 90 percent) is a result of the use of fuelwood - the main source of energy in the household sector.

By analysing the emissions arising from the use of different energy sources and the sectors where they are predominantly used, similar explanations can be given for the dominance of:

- the Transformation (39 to 48 percent), Transport (24 to 32 percent) and Industry (12 to 20 percent) sectors in N_2O emissions;
- the Transport (44 to 53 percent), Transformation (27 to 35 percent) and Industry (9 to 12 percent) sectors in NOx emissions; and
- the Households(62 to 65 percent) and Transport (30 to 35 percent) sectors in CO emissions.

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[3] Refers to the sector involved in the transformation of energy from one source to another

Table 1.26 Emissions of GHGs from Selected Sectors, (tonnes 1992 – 1997)

Emission	**Sector**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
CO_2	Households	62,511	66,272	69,844	67,813	70,088	72,677
	Industry	679,834	637,968	478,582	401,542	538,780	545,552
	Transport	774,913	737,114	713,442	855,738	861,915	931,939
	Government	80,765	110,734	111,323	71,102	72,184	67,207
	Transformation	1,671,300	1,594,212	1,609,534	1,699,540	1,276,283	1,365,708
	Total	**3,269,323**	**3,146,300**	**2,982,725**	**3,095,735**	**2,819,250**	**2,983,083**
CH_4							
	Households	232,869	240,114	247,884	242,949	249,018	253,911
	Industry	1,533	1,512	1,344	1,113	1,449	1,386
	Transport	13,902	14,595	14,595	16,842	17,199	18,249
	Government	5,082	5,418	5,418	1,008	1,008	1,008
	Transformation	4,578	4,368	4,452	4,683	3,507	3,759
	Total	**257,964**	**266,007**	**273,693**	**266,595**	**272,181**	**278,313**
N_2O							
	Households	25730	26660	27900	27280	27900	28520
	Industry	64480	60450	43710	37200	49600	50840
	Transport	79980	75950	73160	88040	88660	96100
	Government	11160	14260	14260	7440	7440	7130
	Transformation	144460	137950	138880	146630	110360	118110
	Total	**325810**	**315270**	**297910**	**306590**	**283960**	**300700**
NOx							
	Households	41,000	42,360	43,720	42,880	43,920	44,840
	Industry	87,680	85,320	83,440	70,000	92,960	93,600
	Transport	343,560	348,680	344,560	402,400	409,080	437,000
	Government	33,840	44,120	43,360	26,800	26,960	26,160
	Transformation	277,160	264,360	267,320	282,320	211,880	226,640
	Total	**783,240**	**784,840**	**782,400**	**824,400**	**784,800**	**828,240**
CO							
	Households	371,121	382,701	395,127	387,237	396,927	404,781
	Industry	5,043	5,526	4,503	4,641	4,842	5,148
	Transport	172,284	180,792	180,591	208,236	212,691	225,768
	Government	22,113	26,166	25,662	12,135	12,138	12,135
	Transformation	1,113	1,068	957	999	813	852
	Total	**571,674**	**596,253**	**606,840**	**613,248**	**627,411**	**648,684**

Table 1.27 Emission of GHGs from selected sectors (Percentages, 1992 – 1997)

Emission	Sector	1992	1993	1994	1995	1996	1997
CO_2	Households	1.9	2.1	2.3	2.2	2.5	2.4
	Industry	20.8	20.3	16.0	13.0	19.1	18.3
	Transport	23.7	23.4	23.9	27.6	30.6	31.2
	Government	2.5	3.5	3.7	2.3	2.6	2.3
	Transformation	51.1	50.7	54.0	54.9	45.3	45.8
	Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
CH_4							
	Households	90.3	90.3	90.6	91.1	91.5	91.2
	Industry	0.6	0.6	0.5	0.4	0.5	0.5
	Transport	5.4	5.5	5.3	6.3	6.3	6.6
	Government	2.0	2.0	2.0	0.4	0.4	0.4
	Transformation	1.8	1.6	1.6	1.8	1.3	1.4
	Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
N_2O							
	Households	7.90	8.46	9.37	8.90	9.83	9.48
	Industry	19.79	19.17	14.67	12.13	17.47	16.91
	Transport	24.55	24.09	24.56	28.72	31.22	31.96
	Government	3.43	4.52	4.79	2.43	2.62	2.37
	Transformation	44.34	43.76	46.62	47.83	38.86	39.28
	Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
NOx							
	Households	5.2	5.4	5.6	5.2	5.6	5.4
	Industry	11.2	10.9	10.7	8.5	11.8	11.3
	Transport	43.9	44.4	44.0	48.8	52.1	52.8
	Government	4.3	5.6	5.5	3.3	3.4	3.2
	Transformation	35.4	33.7	34.2	34.2	27.0	27.4
	Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
CO							
	Households	64.9	64.2	65.1	63.1	63.3	62.4
	Industry	0.9	0.9	0.7	0.8	0.8	0.8
	Transport	30.1	30.3	29.8	34.0	33.9	34.8
	Government	3.9	4.4	4.2	2.0	1.9	1.9
	Transformation	0.2	0.2	0.2	0.2	0.1	0.1
	Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Tables 1.28 and 1.29 show that the Household (63 to 66 percent) and Transport (29 to 34 percent) sectors are the main generators of HC emissions. This is not surprising because the two sectors are the main users of wood (household sector), and; petrol and diesel (Transport sector). The three energy sources are the principal sources of this group of emissions.

For similar reasons, the Transport sector is the leading generator of SOx emissions (81 to 88 percent) because the main source of these emissions is the use of petrol; and TSPs are mainly generated from the use of fuel wood in the household sector.

Table 1.28 Non-GHG Emissions from Selected Sectors (tonnes)

Emission	**Sector**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
HC							
	Households	10,348	10,690	11,058	10,827	11,107	11,339
	Industry	214	221	194	232	217	248
	Transport	4,783	4,922	4,907	5,704	5,815	6,181
	Government	593	708	690	339	339	339
	Transformation	53	51	41	42	37	38
	Total	**15,991**	**16,592**	**16,890**	**17,144**	**17,515**	**18,145**
SOx							
	Households	814	845	874	856	878	899
	Industry	7,622	8,053	6,895	6,204	7,326	7,077
	Transport	183,322	193,156	193,214	222,441	227,323	241,103
	Government	17,091	21,421	21,004	12,991	13,000	12,956
	Transformation	14,794	14,109	14,337	15,150	11,333	12,133
	Total	**223643**	**237584**	**236324**	**257642**	**259860**	**274168**
TSP							
	Households	12,347	12,732	13,144	12,882	13,203	13,465
	Industry	1,019	979	974	780	1,080	1,055
	Transport	432	371	338	428	425	474
	Government	257	292	301	69	71	60
	Transformation	3,806	3,630	3,682	3,890	2,913	3,118
	Total	**17,861**	**18,004**	**18,439**	**18,049**	**17,692**	**18,172**

Table 1.29 Non-GHG Emissions from Selected Sectors (Percentages)

Emission	Sector	1992	1993	1994	1995	1996	1997
HC							
	Households	64.7	64.4	65.5	63.2	63.4	62.5
	Industry	1.3	1.3	1.1	1.4	1.2	1.4
	Transport	29.9	29.7	29.1	33.3	33.2	34.1
	Government	3.7	4.3	4.1	2.0	1.9	1.9
	Transformation	0.3	0.3	0.2	0.2	0.2	0.2
	Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
SOx							
	Households	0.36	0.36	0.37	0.33	0.34	0.33
	Industry	3.41	3.39	2.92	2.41	2.82	2.58
	Transport	81.97	81.30	81.76	86.34	87.48	87.94
	Government	7.64	9.02	8.89	5.04	5.00	4.73
	Transformation	6.62	5.94	6.07	5.88	4.36	4.43
	Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
TSP							
	Households	69.1	70.7	71.3	71.4	74.6	74.1
	Industry	5.7	5.4	5.3	4.3	6.1	5.8
	Transport	2.4	2.1	1.8	2.4	2.4	2.6
	Government	1.4	1.6	1.6	0.4	0.4	0.3
	Transformation	21.3	20.2	20.0	21.6	16.5	17.2
	Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

2.0 Ambient Concentrations of Pollutants.

The monitoring of ambient air quality is the responsibility of the Air Pollution Division of the Department of Mines. Monitoring activities are conducted daily at strategically located pollution control stations around the country. Ambient air quality objectives have been established (Table 2.1) and are used as a guide in monitoring air quality in Botswana. The objectives for SO_2 have been locally set while those set by the World Health Organisation are applicable for the other pollutants.

The ambient concentrations of pollutants at any location could be a result and therefore sum of several factors at the location, such factors include:

- the national background concentration;
- the regional background concentration;
- the location's average concentration;
- the volume and type of traffic on the roads and streets;
- the volume and type of activities in large emission sources, e.g. industries;
- the meteorological conditions, particularly wind direction and speed; and
- the population density of the location.

Table 2.1 Air Quality Objectives

Pollutant		Standard Value
Carbon Monoxide (CO)		
	8-hour Average	10 000 $\mu g/m^3$
	1-hour Average	40 000 $\mu g/m^3$
Nitrogen Dioxide (NO_2)		
	Annual Arithmetic Mean	100 $\mu g/m^3$
Ozone (O_3)		
	1-hour Average	235 $\mu g/m^3$
	8-hour Average	157 $\mu g/m^3$
Particulates		
	Annual Arithmetic Mean	100 $\mu g/m^3$
	Monthly Arithmetic Mean	200 $\mu g/m^3$
Sulphur dioxide (SO_2)		
	24-hour Average	90 percent of hourly observation to be less than 300 $\mu g/m^3$
	Annual Arithmetic Mean	80 $\mu g/m^3$
	Monthly Arithmetic Mean	160 $\mu g/m^3$

Source: Air Pollution Control, Annual Report 2000; Department of Mines

To obtain information on the impact of these different contributions, it is therefore necessary to locate monitoring stations in a way that captures the impacts of these factors on ambient air quality. Hence, in locations where many of the above factors are at play, two or more monitoring sites are necessary for the adequate measurement of the resultant impacts.

Ambient air quality monitoring is carried out at 31 stations around the country, twenty of which are government owned. The Selebi-Phikwe Copper-Nickel mine, which is the most polluting industry in the country, operates the remaining eleven stations. Each station measures one or more of the following air quality parameters:

- sulphur dioxide (SO_2)
- carbon monoxide (CO)
- nitrogen oxides (NOx)
- ozone (O_3)
- methane (CH_4)
- non-methane hydrocarbons (NMHC)
- total Suspended Particulates (TSPs)
- meteorological parameters (wind speed and direction)

Only SO_2 concentration information is reported here. Information on the other pollutants is not included here because their data availability on a time series basis (for a given location) is inadequate, mainly due to frequent equipment breakdown.

2.1 Concentration of Sulphur dioxide in Gaborone.

Information on the concentration of sulphur dioxide in Gaborone is available from two stations, one at the Civic Centre and the other one in Naledi. These two stations have been strategically placed to ensure that the impacts of the different factors that contribute to SO_2 concentration are captured. Civic Centre is in the centre of the city, at a busy traffic intersection, and at one of the densely populated parts of the city during day time. Naledi is in a predominantly residential area that is also densely populated and there is a high volume of traffic passing through or near the location.

We observe from Table 2.2 that the annual mean concentrations of sulphur dioxide at both stations fall within the air quality objective of 80 $\mu g/m^3$ set by the Government of Botswana. The other objectives for SO_2 concentrations (24-hour average and monthly mean) are met as well.

Table 2.2 Concentration of Sulphur Dioxide* in Gaborone, $\mu g/m^3$

Location	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Mines Lab / Civic Centre**											
Annual Mean	20	< 20	30	30	..	28	28	42	42	24	25
24 hr maximum	20	< 20	580	590	..	100	217	583	158	101	156
Naledi											
Annual Mean	20	< 20	20	20	..	23	19	32	58	24	24
24 hr maximum	20	< 20	190	143	..	70	179	605	217	88	106

**Two methods were used . The Hydrogen Peroxide Absorbtion method was used up to 1995 only. This method can not detect concetrations below 20 $\mu g/m^3$. From 1996 to 2000, the Acidimetric method was used.*
** *The station was at Mine's Lab till 1995 and relocated across the street to Civic Centre in 1996*
.. Data unavailable
Source: Department of Mines, Air Pollution Annual Reports

2.2 Concentration of Sulphur dioxide in Selebi-Phikwe

Selebi-Phikwe has the highest levels of SO_2 concentration in the country as comparison of Table 2,3 with Tables 2.2 and 2.4 clearly reveals. This is attributable to smelting activities at the BCL copper-nickel mine that is located in the area. The extent of the impact of BCL's smelting activities, however, depends on the direction and speed of the winds in the area and not only on the actual emissions from the smelter. Consequently, air pollution becomes a concern when the wind blows from the direction of the smelter to densely populated locations like the township, hospital or school area. Whenever such winds are observed, smelter activities are cut down to minimize air pollution and its consequent impact on human health.

Selebi-Phikwe therefore has the highest number of pollution monitoring stations for any single locality in Botswana. The Botswana Government (Air Pollution Division) operates some of the stations and the BCL copper-nickel mine operates the others.

The stations on which data is given in Table 2.3 below are selected for several reasons:

- Smelter West (a and b) – The stations are on the ground at the mine itself and measurements taken here indicate the impact of downwind and the resultant occupational health hazard for mine workers.
- Railway Station – The station is close to the source and gives an indication of the occupational health hazard for mine workers who do not use protective gear.
- Hospital, Township West and SPSS – These stations are least influenced by emission from the smelter. Therefore, high levels of SO_2 would be indicative of other sources, e.g., anthropogenic activities in the residential area of Township West or institutional area of the Hospital and SPSS (a school).

With the exception of the two Smelter West stations, all the other stations are within the Botswana air quality objective of 80 $\mu g/m^3$. Violations have only been observed for short-term air quality objectives such as the 24-hour maximum objective. However, concentrations that are of great concern, especially for human health, are those that indicate long-term exposures, such as the monthly and annual mean, which are within the set objectives.

The concentrations of SO_2 at the Smelter West stations are above the levels set in the objectives and hence indicate an occupational health hazard. However, it should be noted that mine staffers and visitors who go near the smelter always wear appropriate protection.

Table 2.3 Concentration of Sulphur dioxide[#] in Selebi-Phikwe, $\mu g/m^3$

Location	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Slag Tap Floor*											
Annual Mean	86,440	2,780	28,660	34,370	27,070	19,650	5,176	2,085	6,733	7,293	5,802
24 hr maximum	822,890	124,760	803,320	90,209	65,088	85,565	20,094	7,513	23,945	18,020	15,618
Smelter West (a)*											
Annual Mean	1,980	1,770	1,980	2,080	1,780	1,340	764	844	904	1,174	936
24 hr maximum	10,140	17,660	5,450	5,139	6,282	3,617	2,767	2,380	2,961	8,728	2,289
Smelter West (b)*											
Annual Mean	1,980	1,770	2,040	2,080	1,780	1,340	764	844	904	1,097	989
24 hr maximum	10,140	17,660	5,200	5,139	6,282	3,617	2,767	2,380	2,961	9,942	2,734
Railway Station*											
Annual Mean	80	80	80	70	50	50	53	47	76	50	32
24 hr maximum	500	510	570	399	260	170	241	246	441	299	96
Hospital**											
Annual Mean	180	70	50	40	40	40	25	18	28	35	55
24 hr maximum	1,410	510	120	193	185	340	367	137	230	251	542
Township West**											
Annual Mean	70	60	30	50	40	30	31	38	46	50	..
24 hr maximum	490	430	100	202	237	140	239	295	217	341	..
S.P.S.S.**											
Annual Mean	100	90	40	50	40	50	39	43	42	41	98
24 hr maximum	730	420	190	376	301	290	231	175	256	337	5,600

#: Two methods were used . The Hydrogen Peroxide Absorbtion method was used up to 1995 only. This method can not detect concetrations below 20 $\mu g/m^3$. From 1996 to 2000, the Acidimetric method was used.

**: BCL Mine stations*

***: Government of Botswana stations*

..: Data unavailable

Source: Department of Mines, Air Pollution Annual Reports

2.3 Concentration of Sulphur dioxide in Other Locations

The other locations covered in this publication are Lobatse, Palapye, Francistown and Mmadinare whose information is presented in Table 2.4. There are several other stations in the country that could be covered in this section but they are omitted due to data paucity. It should be noted that the measurements of SO_2 concentrations in these locations indicate the following:

- Lobatse – concentration of SO_2 due to traffic as well as SO_2 loading in a small town.
- Palapye – concentration of SO_2 in an industrial area located in a sparsely populated area as opposed to Selebi-Phikwe which is also industrial but more densely populated.
- Francistown – concentration of SO_2 in a relatively big town/city.
- Mmadinare – the station is downwind from the BCL mine and reasonably populated hence SO_2 concentration levels indicate a composite consequent of the impacts of downwind, long transportation and residential impacts.

As Table 2.4 shows, measurements at all the stations covered fall within the SO_2 concentration objectives set by the Government of Botswana.

Table 2.4 Concentration of Sulphur dioxide in Other Locations (Lobatse, Palapye, Francistown and Mmadinare), µg/m^3

Location	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Lobatse (Bus Terminal)											
Annual Mean	20	< 20	20	70	..	40	20	25	23	20	21
24 hr maximum	20	< 20	70	180	..	94	128	128	135	31	78
Palapye (Hospital)											
Annual Mean	100	30	20	270	..	20	21	23	28	20	24
24 hr maximum	1,490	130	150	330	..	76	263	348	230	42	243
F/town Council (Works Deport)											
Annual Mean	30	40	20	210	..	20	17	24	25	20	36
24 hr maximum	230	310	70	490	..	143	114	196	345	51	411
Mmadinare (Makome CJSS)											
Annual Mean	░	░	░	░	░	░	25	24	25	26	41
24 hr maximum	░	░	░	░	░	░	107	152	195	107	1,730

.. Data unavailable

**Two methods were used . The Hydrogen Peroxide Absorbtion method was used up to 1995 only. This method can not detect concetrations below 20 µg/m^3. From 1996 to 2000, the Acidimetric method was used.*

░ *Mmadinare Station was not yet established.*

Source: Department of Mines, Air Pollution Annual Reports

3.0 Use of Ozone Depleting Substances

3.1 Introduction

Ozone (O_3) is a gas that forms a thin layer in the atmosphere at a distance of about 10 to 50 kilometres above the earth, a part of the atmosphere that is called the stratosphere. Only three out of every 10 million molecules in the air are ozone and 90 percent of the gas is in the stratosphere.

Although rare, ozone plays a vital role in supporting animal and plant life on earth. Ozone absorbs most of the harmful solar ultraviolet–B (UV-B) radiation and hence shields all animal and plant life from damage. Ozone also plays a role in the thermal structure of the atmosphere particularly the stratosphere, where temperature increases with height. Adding Ozone in the troposphere causes warming and reducing ozone causes cooling.

3.1.1 What are the Causes of Ozone Depletion?

Ozone is formed in the atmosphere through the reaction of solar radiation with oxygen molecules. Under normal conditions, some of the created ozone molecules are continuously destroyed through their reaction with naturally occurring compounds in the atmosphere that contain oxygen, nitrogen, hydrogen, chlorine or bromine. Without the human factor, these two reactions would be in balance.

The human factor is introduced through the use of what is called Ozone Depleting Substances (ODS). The most common ODS are the halocarbons, a generic term referring to a number of human produced gases containing carbon and halogen (fluorine, chlorine and bromine) atoms

Halocarbons are able to deplete the ozone layer because they are highly stable. Their stability helps them to reach the stratosphere and stay there for long hence can destroy ozone over a long period. When released on ground level through any of the above or other usages, they diffuse without breaking down till they reach the stratosphere where high solar energy radiation frees halogen atoms. When the released halogen atoms come in contact with ozone gas in the atmosphere, they react with ozone molecules and detach from them one oxygen atom thus producing ordinary oxygen molecules. The freed oxygen atom attaches itself to the halogen atom to produce a halogen oxide (e.g. chlorine oxide and bromine oxide). The produced halogen oxide undergoes further reactions that regenerate the original halogen atoms (e.g. chlorine, fluorine and bromine) thus enabling a repetition of the reactions many times. As a consequence of this loop of reactions, one chlorine atom can destroy an estimated 100,000 ozone molecules before it is removed from the stratosphere.

Although UV radiation continually recreates ozone from atmospheric oxygen, the presence of halogen atoms speeds up ozone destruction, and not its creation, hence reduces the concentration of ozone in the atmosphere. The destruction of ozone through the use of halocarbons is particularly striking/shocking in view of the fact that the halogen atoms produced from the use of these products is many times greater than those reaching the atmosphere by natural means.

In this way, through the use of halocarbons, human beings interfere with the natural balance between the creation and destruction of ozone molecules and therefore they enhance ozone destruction.

3.1.2 The Impacts of Ozone Depletion

Concerns regarding the negative effect (as discussed above) of halocarbons on the ozone layer were first voiced in the early 1970s[4]. At first presented without satisfactory evidence and therefore received with reservations, convincing scientific evidence on the linkage between ozone depletion and the use of halocarbons was presented in 1988[5] in the Ozone Trends Panel Report.

When ozone is depleted, its life-protecting role is jeopardised because it becomes difficult/impossible for the ozone layer to absorb all the dangerous UV-B radiation from the sun. The "little" UV-B radiation that penetrates through the ozone shield as a result of the thinning of the layer can cause significant harm/damage as follows:

- harm to human health
- harm to plants
- harm to animals
- harm to water bodies
- damage to materials
- adverse impact on air quality

3.1.3 Actions Taken to Control and Reverse Ozone Depletion

The most significant step taken by the international community towards the control, prevention and/or reversal of ozone depletion and its accompanying impacts on the quality of human, animal and plant life was the adoption of the Montreal Protocol in 1987 by 46 countries. The original Protocol covered only 5 major chlorofluorocarbons (CFCs) and Halons.

Since then, additional scientific evidence has emerged from time to time on the worsening damage to the ozone layer and its relationship with the use of compounds containing chlorine and bromine. The Parties to the Montreal Protocol have responded by progressively strengthening the requirements. Therefore, the original Protocol has been subjected to 5 sets of adjustments to the original control measures (1990, 1992, 1995, 1997 and 1999) and to four amendments (London 1990, Copenhagen 1992, Montreal 1997 and Beijing 1999).

Figure 3.1 shows the expansion in the list of Ozone Depleting Substances (ODS) with each additional amendment.

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[4] UNEP: The Ozone Story, 1998, and UNEP Ozone Secretariat: Action on Ozone, 2000.

[5] UNEP Ozone Secretariat: Action on Ozone, 2000

Figure 3.1: Phase-out Schedules under the Montreal Protocol

	Developing Countries		**Industrialised Countries**	
	Baseline	**Phase-out Schedule**	**Baseline**	**Phase-out Schedule**
(1) Parties to the **Montreal Protocol (1987)**				
A I (5 Major CFCs)	Average of 1995-1997	July 1999: freeze 2005: -50 percent 2007: -85 percent 2010: -100 percent	1986	July 1989: freeze 1994: -75 percent 1996: -100 percent
A II (Halons)	Average of 1995-1997	2002: freeze 2005: -50 percent 2010: -100 percent	1986	1992: freeze 1994: -100 percent
(2) Additional Obligations after Ratification of the **London Amendment (1990)**				
BI (10 Other CFC's)	Average of 1998-2000	2003: -20 percent 2007: -85 percent 2010: -100 percent	1989	1993: -20 percent 1994: -75 percent 1996: -100 percent
BII Carbon Tetra-chloride	Average of 1998-2000	2005: -85 percent 2010: -100 percent	1989	1995: -85 percent 1996: -100 percent
BIII Methyl chloride	Average of 1998-2000	2003: freeze 2005: -30 percent 2010: -70 percent 2015: -100 percent	1989	1993: freeze 1994: -50 percent 1996: -100 percent
(3) Additional Obligations after Ratification of the **Copenhagen Amendment (1992)**				
CI (HCFCs)	2015	2016: freeze 2040: -100 percent	1989 +2.8 percent of 1989 AI Consumption	1996: freeze 2004: -35 percent 2010: -65 percent 2015: -90 percent 2020: -99.5 percent 2030: -100 percent
CII (HBFCs)	-	1996: -100 percent	-	1996: -100 percent
EI (Methyl Bromide)	Average of 1995-1998	2002: freeze 2005: -20 percent 2015: -100 percent	1991	1995: freeze 1999: -25 percent 2001: -50 percent 2003: -70 percent 2005: -100 percent
(4) Additional Obligations after Ratification of the **Beijing Amendment (1999)**				
CIII (Bromochloromethane)	-	2002: -100 percent (With possible extension for essential uses)	-	2002: -100 percent (With possible extension for essential uses)

The control period runs from 1 January to 31 December of the indicated years unless otherwise stated. The Montreal Amendment (19987) is not in Table 3.1 because it had no additional ODS. It dealt with trade controls and licencing requirements for trade in ODS.

Source: United Nations Environmental Programme and Multilateral Fund for the Implementation of the Montreal Protocol; Handbook on Data Reporting under the Montreal Protocol, 1999. (Beijing Amendment not included in the source)

The ODS list at present includes the original five CFCs (11, 12, 113, 114 and 115)[6] and other substances such as the fully halogenated CFCs (13, 111, 112, 211, 212, 213, 214, 215, 216, 217), halons (1211, 1301, 2402), carbon tetrachloride (CCl_4), methyl chloroform ($C_2H_3Cl_3$), methyl bromide (CH_3Br), hydrochlorofluorocarbons (HCFSs), and bromochloromethane (CH_2BrCl).

3.2 Consumption of Ozone Depleting Substance (ODS)

ODS is the name that refers to all substances having an Ozone Depleting Potential (ODP) above zero. Generally, ODS are chemicals that contain chlorine or bromine. Only the most important ODS are controlled under the Montreal Protocol. ODP is the value assigned to each ODS that indicates its impact on the stratospheric ozone layer per unit mass of the gas as compared to the same mass of CFC-11. ODP tonnes therefore indicate the relative environmental damage arising from the use of the substance better than does its physical quantity.

All the ODS used in Botswana are imported because the country does not produce any. The main ODS used in Botswana are CFCs, halons, methyl bromide and HCFCs. The CFCs are mainly used in the repair and maintenance of refrigerators, chillers and coolers (industrial, commercial and domestic) and in air conditioning units that are installed in cars, refrigerated trucks, trains, houses and offices. Halons are used in both fixed and portable fire extinguishers. Methyl bromide (less than 1 tonne annually) is used for pest management in greenhouses, other soil treatment and in grain storage. HCFCs are increasingly being used as substitutes for CFCs because although they also damage the ozone layer, they do so at a much slower rate than CFCs. This can be easily seen from Table 3.1 where the ODPs of various HCFCs are given. With one exception (ODP = 0.11), they are all less than 0.1. On the other hand, ODPs of CFCs are between 0.6 and 1. Consequently, HCFCs have been assigned a longer phase-out period than CFCs in the Montreal Protocol phase-out schedule.

The data reported in Tables 3.2 to 3.5 on ODS refers to bulk substances (i.e. substances that are not part of a use system. Therefore the data does not cover ODS in imported/exported equipment like refrigerators, air conditioners heat pumps, spraycans, fire extinguishers, etc.; which contain ODS that are used directly to serve their purpose.

Parties to the Montreal Protocol are encouraged to ensure that the HCFCs are used only as direct replacements for other ODS where other more environmentally suitable alternatives are not available. This strategy has been adopted by Botswana, as evidenced in the data presented in Tables 3.2 to 3.5 below. On the basis of ODS tonnes, the share of HCFC-22 has increased from 38.9 percent in 1986 to 88.3 percent in the year 2000, and on the basis of ODP tonnes the same shares are 1.3 to 23.1 percent. The reduction in percentage is due to the very low ODP value (0.055) of HCFC-22.

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[6] CFCs (11, 12, 113, …….) refers to CFC-11, CFC-12, CFC-113,……e.t.c.; which are all chlorofluorocarbons (CFCs).

Table 3.1: ODP Values of the Most Important ODS

Only the ODP values of the most important ODS are listed below. Other ODS are rarely used and thus of little significance for reporting and assessing compliance.

Substance	**Ozone-Depleting Potential**
ANNEX A GROUP I	
CFC-11	1.0
CFC-12	1.0
CFC-113	0.8
CFC-114	1.0
CFC-115	0.6
ANNEX A GROUP II	
Halon-1211	3.0
Halon-1301	10.0
Halon-2402	6.0
ANNEX B GROUP I	
CFC-13, CFC-111 , CFC-112, CFC-211-217	1.0
ANNEX B GROUP II	
Carbon Tetrachloride	1.1
ANNEX B GROUP III	
Methyl Chloroform	0.1
ANNEX C GROUP I	
HCFC-21	0.04
HCFC-22	0.055
HCFC-31	0.02
HCFC-123[1]	0.02
HCFC-124[1]	0.022
HCFC-133	0.06
HCFC-141b	0.11
HCFC-142b	0.065
HCFC-225	0.07
HCFC-225ca	0.025
HCFC-225cb	0.033
ANNEX E GROUP I	
Methyl Bromide	0.6

1: Only the most commercially viable isomer is given.

Source: United Nations Environmental Programme and Multilateral Fund for the Implementation of the Montreal Protocol; Handbook on Data Reporting under the Montreal Protocol, 1999

Tables 3.2 to 3.3 give the quantity of ODS consumed in Botswana in tonnes and ODP tonnes, respectively. Tables 3.4 and 3.5 give the percentage contribution of individual ODS to the quantities in Tables 3.2 and 3.3, respectively. Table 3.6 gives, on the basis of the Montreal Protocol Schedule given in Figure 3.1, Botswana's maximum allowable consumption levels of CFCs and Halons that are used in the country. Similar information on Methyl bromide and HCFC-22, which are ODS that are also used in the country, has not been included in the Table 3.6 because their phase-out are scheduled to begin in 2002 and 2016, respectively.

We note from Tables 3.2 to 3.6 that in response to Botswana's commitments as a party to the Montreal Protocol, CFC-11 has been phased out well ahead of schedule, and the phase-out of CFCs (12 and 115) is in line with the Protocol Schedule judging from their consumption levels for the years 1998 to 2000. The use of Halon-1301, which has the highest ODP among all ODS controlled under the Protocol, is on the decline both on the basis of ODS tonnes and ODP tonnes (Table 3.2 to 3.5). The percentage shares for Halon-1301 for 1986 and 2000 are, respectively, 11.1 and 0.3 percent for ODS tonnes; and 70.0 and 15.9 percent for ODP tonnes. On the other hand, progress in phasing-out Halon-1211 followed a haphazard pattern during the period 1986 to 2000 as Figures 3.2 to 3.4 reveal. The total quantity of Halon-1211 used in the country in the last three years of this period (1998-2000) is three times more than what was used in the first three years of the same period (1986-1989) and five times more than the quantity used in the phase-out base period (1995 – 1997). In terms of shares however, the average of the percentage shares based on ODS tonnes (Table 3.4) for the two three-year periods is about the same (2 percent). Therefore, the data indicates that 'phase-out' progress has been minimal with this substance. This is evident from Table 3.6 where the 2000 consumption of the substance is four times the 1995 to 1997 average, a trend that could lead to failure to meet the schedule requirements. Figures 3.7 and 3.8 also support this observation. Therefore, relevant strategies will need to be put in place if the Montreal Protocol phase-out schedule requirement of reducing the consumption of Halon-1211 to 50 percent of the average of 1995 to 1997[7] by the year 2005 is to be achieved.

As a developing country Party of the Montreal Protocol, Botswana qualifies for, and receives, technical and financial support to develop projects and programmes aimed at reducing and eventually phasing-out the use of ODS as per requirement of the phase out schedule given in Figure 3.1. At present, two projects are being implemented; the Refrigeration Management Plan Project and the Demonstration Project on the use of alternatives of methyl bromide. These projects will help Botswana meet its requirements as specified in the phase-out schedule.

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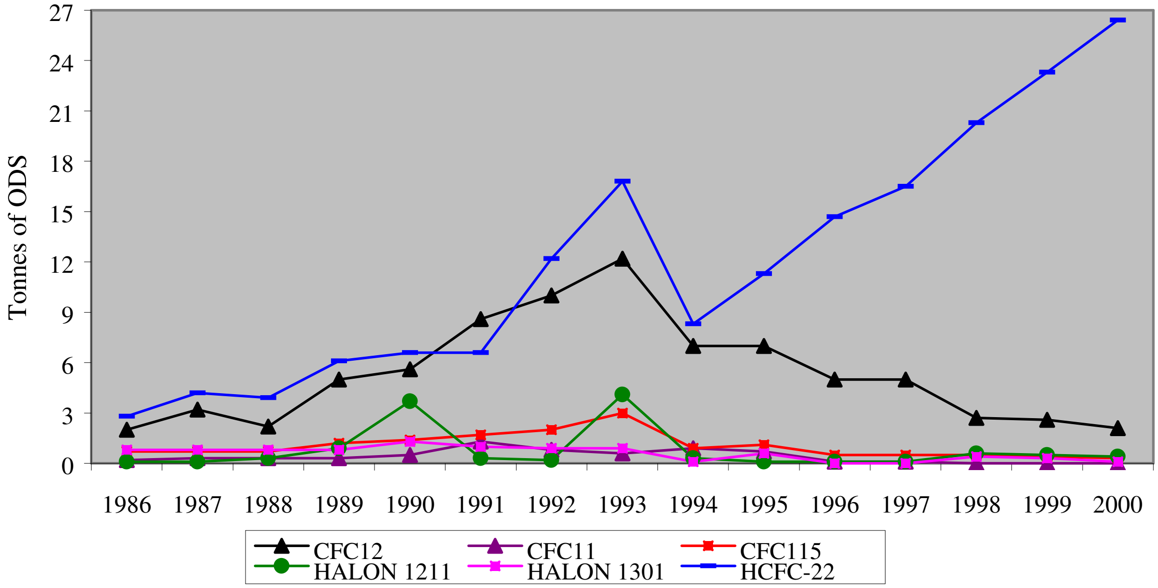
[7] The requirement for Halon-1211 in 2005 is a maximum consumption level of 0.05 tonnes (see Table 3.6) which is one-eighth of the Halon's consumption in 2000)

Table 3.2 Consumption of Ozone Depleting Substances (Tonnes)

YEAR	CFC-12	CFC-11	CFC-115	HALON-1211	HALON-1301	SUB-TOTAL	METHYL BROMIDE	HCFC-22	GRAND TOTAL
1986	2.0	0.2	0.7	0.1	0.8	3.8	0.6	2.8	7.2
1987	3.2	0.3	0.7	0.1	0.8	5.1	0.6	4.2	9.9
1988	2.2	0.3	0.7	0.3	0.8	4.3	0.6	3.9	8.8
1989	5.0	0.3	1.2	0.9	0.8	8.2	0.6	6.1	14.9
1990	5.6	0.5	1.4	3.7	1.3	12.5	0.6	6.6	19.7
1991	8.6	1.3	1.7	0.3	1.0	12.9	0.6	6.6	20.1
1992	10.0	0.8	2.0	0.2	0.9	13.9	0.6	12.2	26.7
1993	12.2	0.6	3.0	4.1	0.9	20.8	0.6	16.8	38.2
1994	7.0	0.9	0.9	0.3	0.1	9.2	0.6	8.3	18.1
1995	7.0	0.7	1.1	0.1	0.6	9.5	0.6	11.3	21.4
1996	5.0	0.1	0.5	0.1	0.0	5.7	0.6	14.7	21.0
1997	5.0	0.1	0.5	0.1	0.0	5.7	0.6	16.5	22.8
1998	2.7	0.0	0.5	0.6	0.4	4.2	0.6	20.3	25.1
1999	2.6	0.0	0.4	0.5	0.3	3.8	0.6	23.3	27.7
2000	2.1	0.0	0.3	0.4	0.1	2.9	0.6	26.4	29.9

Source: Ozone Office, Department of Meteorological Services

Figure 3.2 Consumption of Ozone Depleting Substances (Tonnes)



Source: Derived from Table 3.2

The quantities of CFC-12 and HCFC-22 that are used in the country are much higher than that of other ODS hence the pattern of use of the later can not be easily seen from Figure 3.2. Figure 3.3 presents the consumption pattern of the other four ODS whose trends are not easily traced from Figure 3.2.

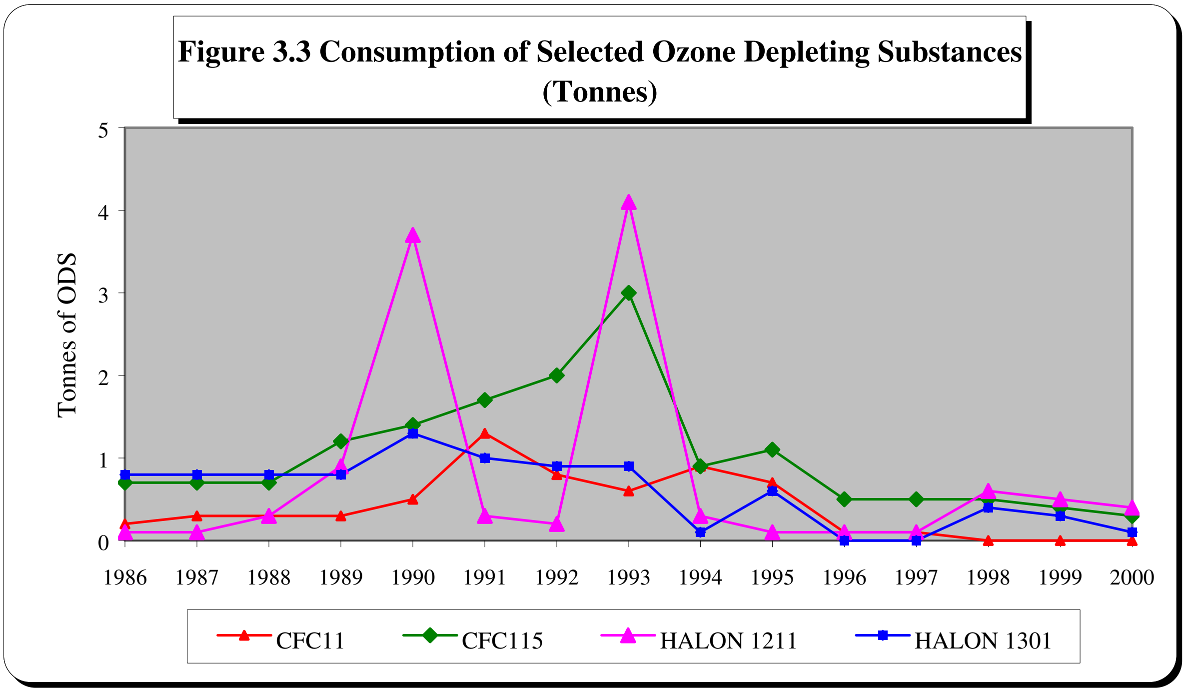


Figure 3.3 Consumption of Selected Ozone Depleting Substances (Tonnes)

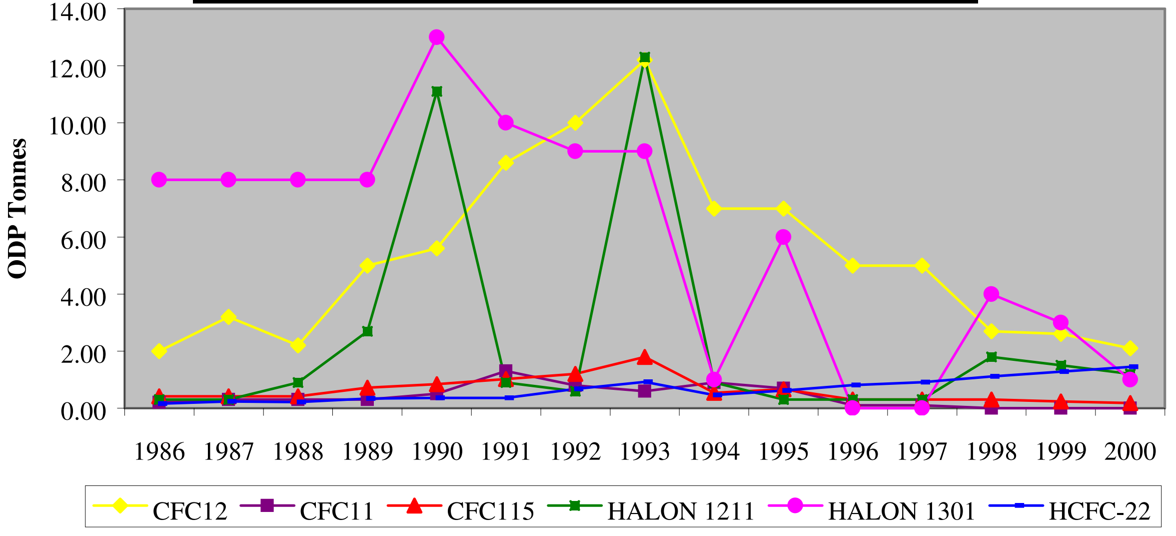
Source: Derived from Table 3.2

Table 3.3 Consumption of Ozone Depleting Substances (ODP Tonnes)

YEAR	CFC-12	CFC-11	CFC-115	HALON-1211	HALON-1301	SUB-TOTAL	METHYL BROMIDE	HCFC	GRAND TOTAL
1986	2.00	0.20	0.42	0.30	8.00	10.92	0.36	0.15	11.43
1987	3.20	0.30	0.42	0.30	8.00	12.22	0.36	0.23	12.81
1988	2.20	0.30	0.42	0.90	8.00	11.82	0.36	0.21	12.39
1989	5.00	0.30	0.72	2.70	8.00	16.72	0.36	0.34	17.42
1990	5.60	0.50	0.84	11.10	13.00	31.04	0.36	0.36	31.76
1991	8.60	1.30	1.02	0.90	10.00	21.82	0.36	0.36	22.54
1992	10.00	0.80	1.20	0.60	9.00	21.60	0.36	0.67	22.63
1993	12.20	0.60	1.80	12.30	9.00	35.90	0.36	0.92	37.18
1994	7.00	0.90	0.54	0.90	1.00	10.34	0.36	0.46	11.16
1995	7.00	0.70	0.66	0.30	6.00	14.66	0.36	0.62	15.64
1996	5.00	0.10	0.30	0.30	0.00	5.70	0.36	0.81	6.87
1997	5.00	0.10	0.30	0.30	0.00	5.70	0.36	0.91	6.97
1998	2.70	0.00	0.30	1.80	4.00	8.80	0.36	1.12	10.28
1999	2.60	0.00	0.24	1.50	3.00	7.34	0.36	1.28	8.98
2000	2.10	0.00	0.18	1.20	1.00	4.48	0.36	1.45	6.29

Source: Calculated using ODPs and data in Table 3.2

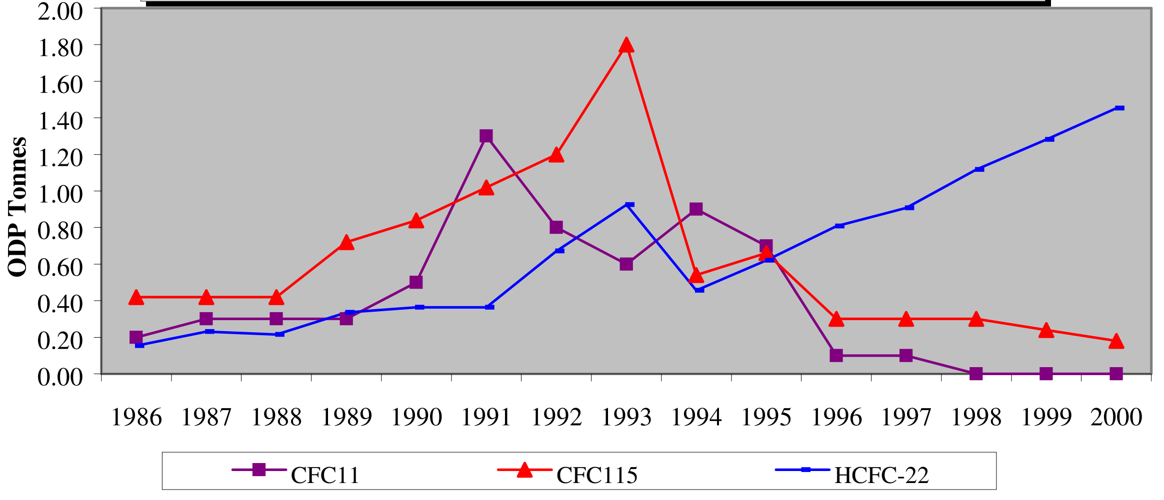
Figure 3.4. Consumption of Ozone Depleting Substances (ODP Tonnes)



Source: Derived from Table 3.3

The ODP tonnes for CFC-12 and Halons are much higher than that of other ODS hence the pattern of use of the later cannot be easily observed from Figure 3.4. Figure 3.5 presents ODP consumption of the other four ODS whose trends are not readily detectable in Figure 3.4.

Figure 3.5. Consumption of Selected Ozone Depleting Substances (ODP Tonnes)



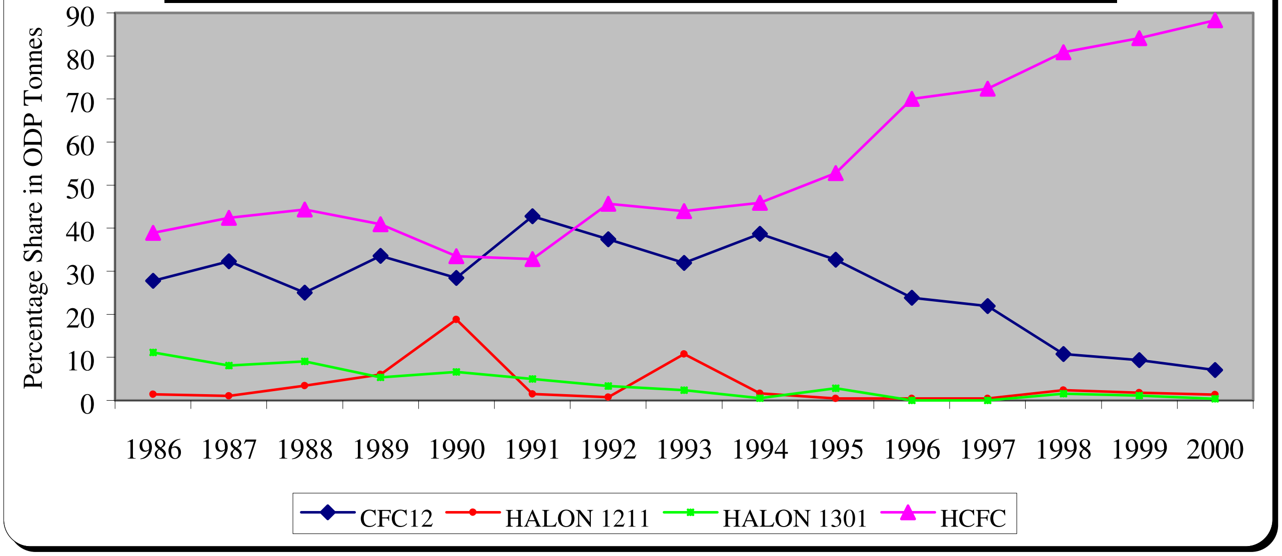
Source: Derived from Table 3.3

Table 3.4 Percentage Shares of ODS Tonnes Consumed

YEAR	CFC-12	CFC-11	CFC-115	HALON-1211	HALON-1301	SUB-TOTAL	METHYL BROMIDE	HCFC	GRAND TOTAL
1986	27.8	2.8	9.7	1.4	11.1	52.8	8.3	38.9	100.0
1987	32.3	3.0	7.1	1.0	8.1	51.5	6.1	42.4	100.0
1988	25.0	3.4	8.0	3.4	9.1	48.9	6.8	44.3	100.0
1989	33.6	2.0	8.1	6.0	5.4	55.0	4.0	40.9	100.0
1990	28.4	2.5	7.1	18.8	6.6	63.5	3.0	33.5	100.0
1991	42.8	6.5	8.5	1.5	5.0	64.2	3.0	32.8	100.0
1992	37.5	3.0	7.5	0.7	3.4	52.1	2.2	45.7	100.0
1993	31.9	1.6	7.9	10.7	2.4	54.5	1.6	44.0	100.0
1994	38.7	5.0	5.0	1.7	0.6	50.8	3.3	45.9	100.0
1995	32.7	3.3	5.1	0.5	2.8	44.4	2.8	52.8	100.0
1996	23.8	0.5	2.4	0.5	0.0	27.1	2.9	70.0	100.0
1997	21.9	0.4	2.2	0.4	0.0	25.0	2.6	72.4	100.0
1998	10.8	0.0	2.0	2.4	1.6	16.7	2.4	80.9	100.0
1999	9.4	0.0	1.4	1.8	1.1	13.7	2.2	84.1	100.0
2000	7.0	0.0	1.0	1.3	0.3	9.7	2.0	88.3	100.0

Source: Derived from Table 3.2

Figure 3.6 Percentage Shares of ODS Tonnes Consumed for Selected ODS



Source: Derived from Table 3.4

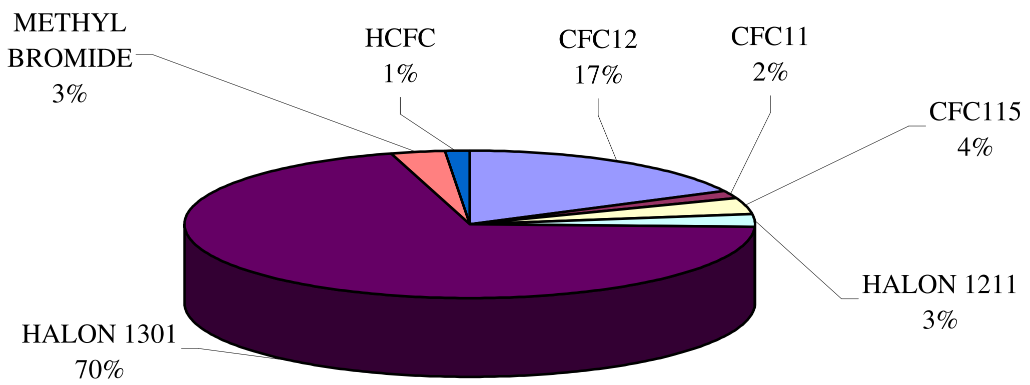
Table 3.5 Percentage Shares of ODP Tonnes Consumed

YEAR	CFC12	CFC11	CFC115	HALON 1211	HALON 1301	SUB-TOTAL	METHYL BROMIDE	HCFC-22	GRAND TOTAL
1986	17.5	1.7	3.7	2.6	70.0	95.5	3.1	1.3	100.0
1987	25.0	2.3	3.3	2.3	62.4	95.4	2.8	1.8	100.0
1988	17.7	2.4	3.4	7.3	64.5	95.4	2.9	1.7	100.0
1989	28.7	1.7	4.1	15.5	45.9	96.0	2.1	1.9	100.0
1990	17.6	1.6	2.6	34.9	40.9	97.7	1.1	1.1	100.0
1991	38.1	5.8	4.5	4.0	44.4	96.8	1.6	1.6	100.0
1992	44.2	3.5	5.3	2.7	39.8	95.4	1.6	3.0	100.0
1993	32.8	1.6	4.8	33.1	24.2	96.5	1.0	2.5	100.0
1994	62.7	8.1	4.8	8.1	9.0	92.7	3.2	4.1	100.0
1995	44.8	4.5	4.2	1.9	38.4	93.7	2.3	4.0	100.0
1996	72.8	1.5	4.4	4.4	0.0	83.0	5.2	11.8	100.0
1997	71.8	1.4	4.3	4.3	0.0	81.8	5.2	13.0	100.0
1998	26.3	0.0	2.9	17.5	38.9	85.6	3.5	10.9	100.0
1999	28.9	0.0	2.7	16.7	33.4	81.7	4.0	14.3	100.0
2000	33.4	0.0	2.9	19.1	15.9	71.2	5.7	23.1	100.0

Source: Derived from Table 3.3

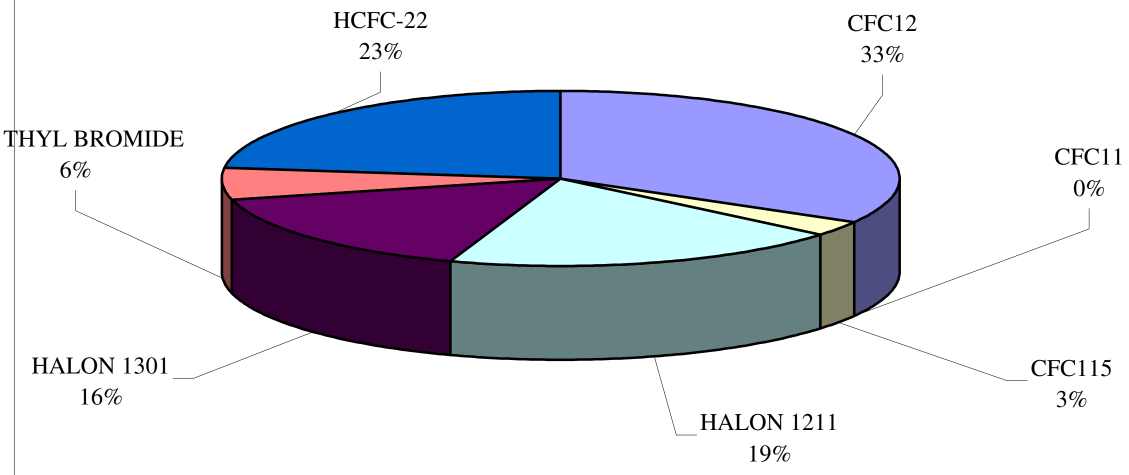
Figures 3.7 and 3.8 show the changing percentage shares of ODS in the country. The shares of HCFC-22, CFC-12, Halon-1211 and Methyl bromide have increased while those of the remaining ODS have decreased. The increase in HCFC percentage share is a welcome development since it has a relatively low ODP value compared to the CFCs that would otherwise be used. The increase in methyl bromide share should not be interpreted as implying increasing levels of consumption of the substance as its consumption is constant at about 600 kilograms per year. The increase in Halon-1211 percentage share is of great concern as already indicated above.

Figure 3.7 ODS Percentage Shares of ODP Tonnes consumed in 1986



Source: Derived from Table 3.5

Figure 3.8 ODS Percentage Shares of ODP Tonnes consumed in 2000



Source: Derived from Table 3.5

TABLE 3.6 Allowable Maximum Levels of Consumption of Ozone Depleting Substance (Tonnes), as per Montreal Protocol Schedule

YEAR	CFC-12	CFC-11	CFC-115	HALON-1211	HALON-1301
1995	7.0	0.7	1.1	0.1	0.6
1996	5.0	0.1	0.5	0.1	0.0
1997	5.0	0.1	0.5	0.1	0.0
2000	2.1	0.0	0.3	0.4	0.1
Average (1995 - 1997)*	5.7	0.3	0.7	0.1	0.2
Average (1998 - 2000)	2.5	0.0	0.4	0.5	0.3
2005**	2.8	0.2	0.4	0.1	0.1
2010**	0.0	0.0	0.0	0.0	0.0

* : Quantities on which the controls are based

**: Allowable maximum quantities

Source: Derived from Figure 3.1 and Table 3.2

4.0 Energy Use

The energy sector in Botswana is characterised by both traditional and commercial energy sources. The dominant energy sources are fuelwood for the traditional group and petrol for the commercial group. Botswana is endowed with abundant coal reserves from which over 95 percent of the locally produced electricity is generated. However, coal of higher grade is imported for use in some sections of the industrial sector. The country also has abundant solar energy resources although their current share of final energy consumption is negligible. The share of imported energy, which is dominated by petroleum products, is on the increase.

4.1 Final Energy Consumption (FEC)

As can be seen from Tables 4.1 and 4.2 and from Figure 4.1, FEC is increasing over time in Botswana. This can be attributed to increased output from all sectors and to population growth. Wood is the leading contributor to FEC. Its proportional share is on the decline, however. This is due to a combination of several factors that include, inter-alia, the scarcity of wood in some parts of the country and the increased use of other energy sources (e.g., LPG, paraffin and electricity) because of improvement in the standards of living in the household sector. The consumption of petrol and diesel, which are the main petroleum products used in the country, is on the increase.

Table 4.1 Final Energy Demand (Terajoules) by Energy Source, 1981 - 1997

Year	Coal	LPG	Av-Gas	Jet A	Petrol	Para-ffin	Diesel	Fuel Oil	Lubes	Electricity	Wood	Solar	Other RE	Total
1981	4,241	86	56	55	1,744	142	2,745	32	112	1,826	15,456	2	-	26,497
1982	4,135	95	56	57	1,978	144	2,767	24	122	2,038	15,984	5	-	27,405
1983	4,162	114	51	60	2,235	146	2,836	23	112	2,187	16,528	9	-	28,463
1984	4,613	130	59	74	2,511	148	2,847	10	109	2,205	17,088	12	-	29,807
1985	4,949	146	63	88	2,766	150	2,923	9	119	2,233	17,680	16	-	31,142
1986	4,949	164	73	114	3,161	224	3,392	9	121	2,330	18,288	16	-	32,842
1987	4,949	205	85	133	3,743	243	3,373	9	142	2,411	17,808	16	-	33,116
1988	5,224	283	83	322	4,071	319	3,678	32	134	2,664	20,624	16	-	37,449
1989	5,023	464	94	309	4,718	415	4,473	159	200	2,711	21,168	18	1	39,752
1990	4,460	505	83	498	5,534	446	5,373	203	220	2,862	17,616	21	1	37,823
1991	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1992	4,452	531	102	338	7,273	466	6,307	2,395	227	3,549	20,240	34	1	45,915
1993	4,344	555	57	188	7,800	490	5,776	2,076	251	3,758	21,008	34	1	46,340
1994	4,344	598	66	202	7,747	512	5,368	52	209	4,374	21,424	35	1	44,932
1995	3,322	523	101	271	8,504	489	6,106	108	233	4,546	21,168	21	1	45,395
1996	4,786	550	102	235	8,678	490	6,266	114	306	5,094	21,040	21	1	47,684
1997	4,325	567	102	259	9,164	505	7,164	171	252	5,369	21,456	21	1	49,354

.. *Data unavailable*

Source: Energy Affairs Division, Ministry of Minerals, Energy and Water Affairs.

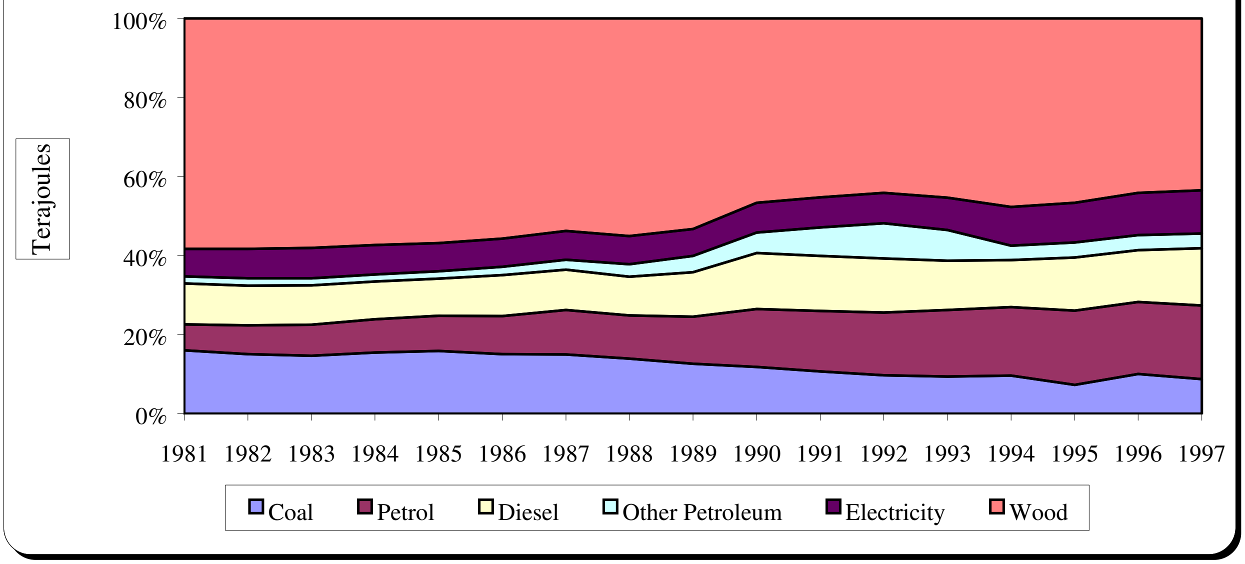
Table 4.2 Final Energy Demand (Percentages) by Energy Source, 1981 - 1997

Year	Coal	LPG	AvGas	Jet A	Petrol	Paraffin	Diesel	Fuel Oil	Lubes	Electricity	Wood	Solar	Other RE	Total
1981	16.0	0.3	0.2	0.2	6.6	0.5	10.4	0.1	0.4	6.9	58.3	0.0	0.0	100
1982	15.1	0.3	0.2	0.2	7.2	0.5	10.1	0.1	0.4	7.4	58.3	0.0	0.0	100
1983	14.6	0.4	0.2	0.2	7.9	0.5	10.0	0.1	0.4	7.7	58.1	0.0	0.0	100
1984	15.5	0.4	0.2	0.2	8.4	0.5	9.6	0.0	0.4	7.4	57.3	0.0	0.0	100
1985	15.9	0.5	0.2	0.3	8.9	0.5	9.4	0.0	0.4	7.2	56.8	0.1	0.0	100
1986	15.1	0.5	0.2	0.3	9.6	0.7	10.3	0.0	0.4	7.1	55.7	0.0	0.0	100
1987	14.9	0.6	0.3	0.4	11.3	0.7	10.2	0.0	0.4	7.3	53.8	0.0	0.0	100
1988	14.0	0.8	0.2	0.9	10.9	0.9	9.8	0.1	0.4	7.1	55.1	0.0	0.0	100
1989	12.6	1.2	0.2	0.8	11.9	1.0	11.3	0.4	0.5	6.8	53.3	0.0	0.0	100
1990	11.8	1.3	0.2	1.3	14.6	1.2	14.2	0.5	0.6	7.6	46.6	0.1	0.0	100
1991	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1992	9.7	1.2	0.2	0.7	15.8	1.0	13.7	5.2	0.5	7.7	44.1	0.1	0.0	100
1993	9.4	1.2	0.1	0.4	16.8	1.1	12.5	4.5	0.5	8.1	45.3	0.1	0.0	100
1994	9.7	1.3	0.1	0.4	17.2	1.1	11.9	0.1	0.5	9.7	47.7	0.1	0.0	100
1995	7.3	1.2	0.2	0.6	18.7	1.1	13.5	0.2	0.5	10.0	46.6	0.0	0.0	100
1996	10.0	1.2	0.2	0.5	18.2	1.0	13.1	0.2	0.6	10.7	44.1	0.0	0.0	100
1997	8.8	1.1	0.2	0.5	18.6	1.0	14.5	0.3	0.5	10.9	43.5	0.0	0.0	100

.. Data unavailable

Source: Energy Affairs Division, Ministry of Minerals, Energy and Water Affairs.

Figure 4.1 Contribution of Energy Sources to Final Energy Consumption (TJ)



Source: Derived from Table 3.1. Data for 1991 estimated as average of 1990 and 1992 figures for purposes of graphing.

4.2 Final Energy Consumption (FEC) for Selected Sectors

On a sectoral basis, the household sector is the main user of FEC in the country, as Tables 4.3 and 4.4, and Figure 4.2 show. The main energy source used in the household sector is fuelwood, which is harvested on a free-for-all basis and therefore is easily accessed by all the users, particularly the rural poor who are unable to afford alternative energy sources. However, the sector's share in the FEC in the 1990s (46 to 50 percent) is lower than it was in the 1980s (49 to 59 percent). This can be attributed to at least two factors. First, there has been a decline in the proportion of the country's population that live in rural areas due to the rural-to-urban migration and it resulted in decline in the use of fuelwood as more people have found jobs and therefore, with the increased income can afford more convenient commercial substitutes of wood like paraffin and LPG. Second, there has been an increase in commercial energy consumption in the mining, manufacturing and transport sectors corresponding to growth in the activities/production of the sectors.

The other major contributors to FEC in the country are the Transport (13 to 27 percent) and Industry (16 to 25 percent) sectors.

Table 4.3 Final Energy Consumption by Sector (TJ)

Year	Households	Agricul-ture	Industry	Trade & Hotels	Transport	Social & Private Services.	Govern-ment	Total
1981	15,488	288	6,590	336	3,517	34	240	26,492
1982	16,045	291	6,607	336	3,840	37	249	27,406
1983	16,626	266	6,654	327	4,255	41	290	28,459
1984	17,232	343	7,036	325	4,535	45	293	29,809
1985	17,912	338	7,518	328	4,700	50	295	31,143
1986	18,606	426	7,685	332	5,437	53	309	32,847
1987	18,171	352	7,757	333	6,021	50	437	33,121
1988	21,191	367	8,276	318	6,737	58	506	37,454
1989	22,035	488	8,244	364	7,367	58	1,199	39,757
1990	18,578	488	8,633	364	8,499	58	1,199	37,821
1991	....	..	..		..	..	..	..
1992	21,020	528	10,517	967	11,160	221	1,719	46,133
1993	21,733	528	9,941	1127	10,683	217	2,110	46,340
1994	22,534	528	8,229	982	10,329	217	2,113	44,932
1995	22,126	521	7,451	1444	12,376	208	1,275	45,402
1996	22,719	521	9,246	1364	12,472	..	1,361	47,682
1997	23,229	521	9,587	1282	13,409	..	1,324	49,352

.. Data unavailable

Source: Energy Affairs Division, Ministry of Minerals, Energy and Water Affairs.

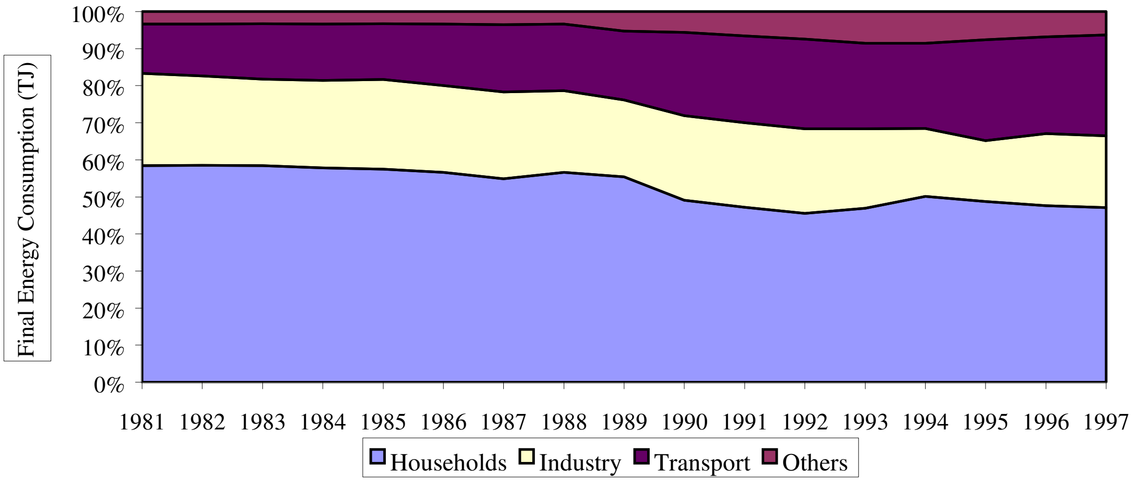
Table 4.4 Final Energy Consumption by Sector (Percentages)

Year	Households	Agricul-ture	Industry	Trade & Hotels	Transport	Social & Private Services.	Govern-ment	Total
1981	58.5	1.1	24.9	1.3	13.3	0.1	0.9	100.0
1982	58.5	1.1	24.1	1.2	14.0	0.1	0.9	100.0
1983	58.4	0.9	23.4	1.1	15.0	0.1	1.0	100.0
1984	57.8	1.1	23.6	1.1	15.2	0.2	1.0	100.0
1985	57.5	1.1	24.1	1.1	15.1	0.2	0.9	100.0
1986	56.6	1.3	23.4	1.0	16.6	0.2	0.9	100.0
1987	54.9	1.1	23.4	1.0	18.2	0.2	1.3	100.0
1988	56.6	1.0	22.1	0.8	18.0	0.2	1.4	100.0
1989	55.4	1.2	20.7	0.9	18.5	0.1	3.0	100.0
1990	49.1	1.3	22.8	1.0	22.5	0.2	3.2	100.0
1991	..	..	..	..	..	..	..	..
1992	45.6	1.1	22.8	2.1	24.2	0.5	3.7	100.0
1993	46.9	1.1	21.5	2.4	23.1	0.5	4.6	100.0
1994	50.2	1.2	18.3	2.2	23.0	0.5	4.7	100.0
1995	48.7	1.1	16.4	3.2	27.3	0.5	2.8	100.0
1996	47.6	1.1	19.4	2.9	26.2	..	2.9	100.0
1997	47.1	1.1	19.4	2.6	27.2	..	2.7	100.0

Source: Energy Affairs Division, Ministry of Minerals, Energy and Water Affairs.

.. Data Unavailable

Figure 4.2 Final Energy Consumption (TJ) by Sector



Source: Derived from Table 4.3

4.3 Final Energy Consumption per Unit of Gross Domestic Product (TJ/GDP)

This ratio measures the quantity of energy used to produce one unit of GDP (one million pula). Information on it is given in Table 4.5 and is presented graphically in Figure 4.3.

The quantity of energy spent on the production of one unit of GDP took a downward trend during the period 1984 to 1997. While in 1984 the ratio was 5.65 TJ/GDP, it had gone down to less than 4 TJ/GDP by 1994. This indicates an improvement in energy efficiency because the quantity of energy required to produce a unit of GDP was on the decline during the period. Since fuelwood is the dominant energy source and its share in final energy declined in the same period, this result should be interpreted with caution because the decline might be solely a result of a shift in the energy source shares. This consideration is pertinent because fuelwood, the main contributor to FEC and whose shares are declining, is commonly used in a none-energy-efficient manner. It is commonly burned in the open (whether used for cooking food or space-warming) and hence a lot of energy is lost in the process. Although woodstoves exist which would ensure efficient use of this energy source, they are very expensive and hence are beyond affordability of the majority of the rural households, the main users of fuelwood.

In an attempt to remove the impact of a shift in the energy source shares (as discussed) from the TJ/GDP energy-efficiency measure, fuelwood energy consumption was subtracted from the FEC total for each year. The reminder is largely a measure of the commercial component of FEC. It gives an indication of the change in energy efficiency that can be more easily controlled through appropriate measures. The resulting ratio has been referred to as "Commercial TJ/GDP" in Table 4.5 and Figure 4.3.

Table 4.5 Energy Use per Unit of Gross Domestic Product and Per Capita

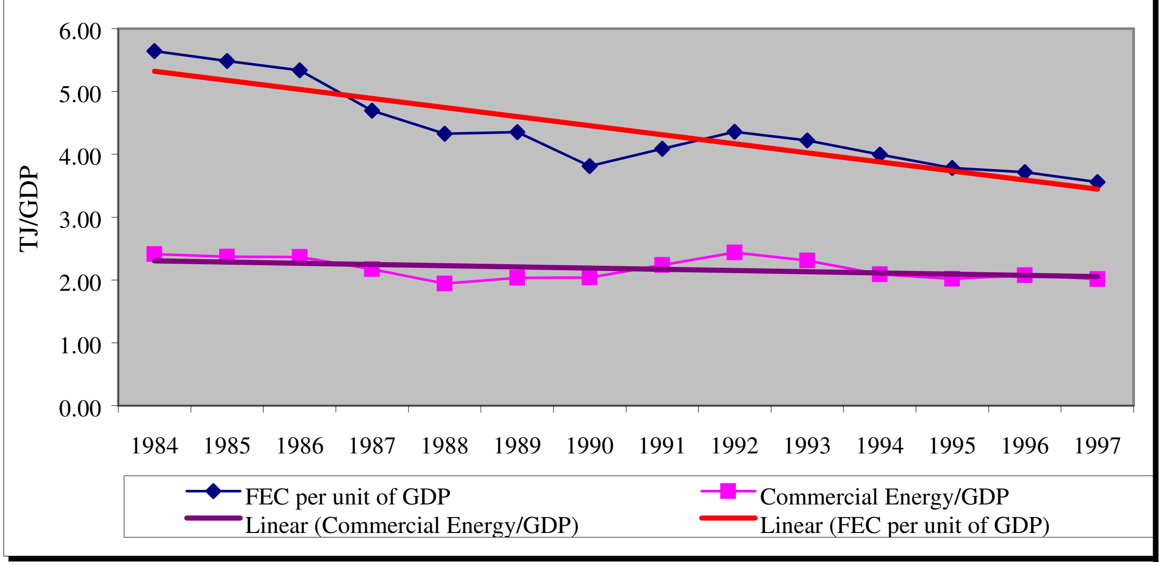
Year	*FEC (TJ)	GDP (Million Pula)	TJ/ GDP	Commercial FEC	Commercial TJ/ GDP
1984	29,806.68	5,280.1	5.65	12,718.68	2.41
1985	31,141.51	5,676.7	5.49	13,461.51	2.37
1986	32,842.24	6,153.3	5.34	14,554.24	2.37
1987	33,116.44	7,056.0	4.69	15,308.44	2.17
1988	37,449.27	8,651.8	4.33	16,825.27	1.94
1989	39,751.78	9,127.4	4.36	18,583.78	2.04
1990	37,822.93	9,918.7	3.81	20,206.93	2.04
1991	..	..	..	..	..
1992	45,915.39	10,532.7	4.36	25,675.39	2.44
1993	46,339.60	10,972.2	4.22	25,331.60	2.31
1994	44,931.60	11,249.2	3.99	23,507.60	2.09
1995	45,394.89	11,995.2	3.78	24,226.89	2.02
1996	47,684.35	12,838.3	3.71	26,644.35	2.08
1997	49,353.55	13,868.5	3.56	27,897.55	2.01

FEC: Final Energy Consumption

.. Data unavailable

Source: Energy Affairs Division, Ministry of Minerals, Energy and Water Affairs.

Figure 4.3 Energy Input per Unit of GDP



Source: Derived from Table 4.5

It is observed that the commercial TJ/GDP ratio also followed a downward trend during the period 1984 to 1997 - like the standard TJ/GDP ratio. The average percent decrease over the covered 14-year period is l4.9 percent for TJ/GDP but the same measure is only 2.8 percent for commercial TJ/GDP. Hence, commercial energy efficiency is improving at a slower rate than indicated by the TJ/GDP ratio, which is based on total FEC.

4.4 Household Sector Energy Consumption per Capita

During the period 1992 to 1997, the household sector's energy consumption was 15.1 to 15.8 and 14.0 to 14.7 GJ per capita per year, on the basis of total household FEC and fuelwood energy consumption, respectively. Energy use per capita in the household sector is therefore increasing by about 117 MJ per capita per year. The closeness of the two ratios further highlights the dominance of wood as a source of energy in the household sector and shows that the country's ability to meet the energy needs of households is closely linked with the availability of wood resources at present.

Table 4.6 Household Sector Energy Consumption per Capita

Year	Household Sector FEC (TJ)	Wood (TJ)	Population	Household FEC /Capita (GJ)	Household Sector Wood Usage /Capita (GJ)
1992	21,020	19,677	1,358,639	15.5	14.5
1993	21,733	20,288	1,391,246	15.6	14.6
1994	22,534	20,944	1,424,636	15.8	14.7
1995	22,126	20,527	1,458,828	15.2	14.1
1996	22,719	21,039	1,495,993	15.2	14.1
1997	23,229	21,454	1,533,393	15.1	14.0

4.5 Coal Depletion

Coal is the only locally produced commercial energy source in Botswana. Furthermore, the public-supply thermal power plants used in electricity generation are coal-fired. The plants contribute at least 80 percent of the locally produced electricity, and at least 43 percent of the net electricity supply in the country, in any one year. Consequently, the importance of coal resources to energy self-sufficiency and to a steady and reliable supply of electricity in the country cannot be over-emphasised. With energy being the backbone of economic development, it is expected that along with environmentalists, economic planners/policy makers in the country are concerned about the depletion rates of coal.

Depletion rates of the measured stock of coal reserves have been calculated from the historical consumption pattern for the years 1975 to 2001 and are presented in Table 4.7. The consumption for the years 1973 and 1974 has not been used to determine consumption forecasts. An attempt has been made in the same table to establish a relationship between coal consumption and available coal stocks so as to estimate the life span of the proven coal reserves.

The Depletion Index (DI) in Table 4.7 (Column d) gives the proportion of initial reserves that would have been mined by the end of the year in question. Column d therefore shows the rate at which coal is being depleted. We observe that although coal mining started in l973, accumulated production was at less than 1 percent of the original proven reserves by the end of 2001 (twenty nine years later; latest available data is on 2001). Using the method of least squares, production was forecast for the years 2002 onwards, assuming that there are no new discoveries and that future production will follow the trend observed up to 2001. The Depletion Index estimations (Column d) show that the percentage of the original proven reserves that would have been mined will be less than 4 percent half way into the present century, (year 2050); less than 8 percent at the end of the century, (year 2100); and about 82 percent four centuries from now (year 2400).

The Life Index (Column e, Table 4.7) of Botswana's proven coal reserves is the lifetime in years of the remaining proven coal reserves at the end of a given year. It is the ratio of the remaining coal reserves at the end of a given year to the production of the coal during that year. It is calculated without taking into account the possibility of future changes in the production trend. The life index is therefore the time in years that the remaining reserves would last if production were to continue at the level observed during the year under consideration.

Using the foregoing assumptions, Table 4.7 has been derived and it is estimated that the proven reserves will be exhausted during the course of 2446 (i.e. last through more than four centuries of exploitation). This conclusion is obvious from the negative values arrived at for both Remaining Reserves and Life Index for the year 2446, and which follow positive values in the previous year. Furthermore, the greater-than-100 percent value for the Depletion Index (value of 100.291 percent), and the greater-than-the-initial reserves value of the accumulated production for the year 2446, both indicate that additional reserves would be needed for production to be maintained at the assumed rate that is based on the historical trend.

In future, the rate of coal consumption may change and hence modify the rate of depletion of the coal reserves that was observed up to 2001, and on which this analysis is based, as a result of the following.

- The introduction of clean coal technologies may encourage more utilization of coal, especially at the household level.
- An increase in the cost of petroleum products may also influence more consumers to switch to coal.
- With the inevitable increase in fuelwood scarcity, coal may increasingly become its substitute, especially in low-income households.
- The consumption of coal may also decrease due to international pressure to reduce greenhouse gas emissions from fossil fuel combustion.

However, it should be noted that there are other coal reserves ('indicated' and 'inferred') in the country that have not been taken into consideration in this analysis.

Table 4.7 Stocks (Million Tonnes) and Changes in Stocks of Coal

(Initial proven reserves = 3,340 million tonnes)

Year*	**Production (a)**	**Accumulated Production (b)**	**Remaining Reserves (c)**	**Depletion Index (d)**	**Life Index (e)**
1973	0.032732	0.032732	3,339.97	0.001	102,039.82
1974	0.020229	0.052961	3,339.95	0.002	165,106.88
1975	0.060117	0.113078	3,339.89	0.003	55,556.45
1976	0.225000	0.338078	3,339.66	0.010	14,842.94
1977	0.357269	0.695347	3,339.30	0.021	9,346.75
1978	0.310587	1.005934	3,338.99	0.030	10,750.59
1979	0.349641	1.355575	3,338.64	0.041	9,548.78
1980	0.307603	1.663178	3,338.34	0.050	10,852.74
1981	0.377026	2.040204	3,337.96	0.061	8,853.39
1982	0.430684	2.470888	3,337.53	0.074	7,749.37
1983	0.378707	2.849595	3,337.15	0.085	8,811.96
1984	0.388687	3.238282	3,336.76	0.097	8,584.70
1985	0.492609	3.730891	3,336.27	0.112	6,772.65
1986	0.522583	4.253474	3,335.75	0.127	6,383.19
1987	0.582777	4.836251	3,335.16	0.145	5,722.88
1988	0.521753	5.358004	3,334.64	0.160	6,391.23
1989	0.794141	6.152145	3,333.85	0.184	4,198.06
1990	0.804778	6.956923	3,333.04	0.208	4,141.57
1991	0.921579	7.878502	3,332.12	0.236	3,615.67
1992	0.870746	8.749248	3,331.25	0.262	3,825.74
1993	0.900778	9.650026	3,330.35	0.289	3,697.19
1994	0.907569	10.557595	3,329.44	0.316	3,668.53
1995	0.728430	11.286025	3,328.71	0.338	4,569.71
1996	0.801167	12.087192	3,327.91	0.362	4,153.83
1997	0.818884	12.906076	3,327.09	0.386	4,062.96
1998	0.938992	13.845068	3,326.15	0.415	3,542.26
1999	0.714952	14.560020	3,325.44	0.436	4,651.28
2000	0.939386	15.499406	3,324.50	0.464	3,539.01
2001	0.914584	16.413990	3,323.59	0.491	3,633.99
2050	2.419370	100.688702	3,239.31	3.015	1,338.91
2100	3.876615	258.816945	3,081.18	7.749	794.81
2150	5.333860	489.807449	2,850.19	14.665	534.36
2200	6.791105	793.660215	2,546.34	23.762	374.95
2250	8.248351	1,170.375242	2,169.62	35.041	263.04
2300	9.705596	1,619.952531	1,720.05	48.502	177.22
2350	11.162841	2,142.392081	1,197.61	64.143	107.29
2400	12.620086	2,737.693893	602.31	81.967	47.73
2440	13.785883	3,266.396171	73.60	97.796	5.34
2444	13.902462	3,321.831151	18.17	99.456	1.31
2445	13.931607	3,335.762758	4.24	99.873	0.30
2446	13.960752	3,349.723510	(9.72)	100.291	(0.70)

1: This table has been worked out for all years of the period 1973 - 2446, but a sample of years after 2001 (within this period) has been selected to highlight the rate of depletion of the proven coal reserves over time

2: Entries of annual production (**a**) after 2001 are forecasts. It is assumed that there are no new discoveries and therefore no adjustments to initial reserves.

* These values indicate that the reserves will be exhausted during the year 2446.

b Equals the sum over all the years of production up to current year

c Equals initial reserves less accumulated reserves (**b**)

d Equals accumulated production divided by initial reserves (**b**/3,340)

e Equals **c / a**

Source: Coal Production for the years 1973 – 2001 are from Morupule Colliery
Initial Reserves are from the Department of Geological Survey

5.0 Protected Land Area as a Percentage of Total Land Area

This indicator measures the area of protected ecosystems as a percentage of total land area of the country. Ecosystem refers to a habitat system in which the interaction between different living organisms (plants, animals, fungi and microbes) and their environment (ecological complexes in which they occur) generates cyclic interchanges of material and energy that make them inter-dependent for their survival. Maintenance of the state of ecosystems is essential for the well-being of the human race because various living organisms provide medicines, food, and raw materials for many other purposes. Human activities (e.g. destruction of ecosystems in an attempt to expand the use of land resources for agricultural and other purposes, introduction of exotic species and pollution generating activities) pose the main threats to the set-up and delicate balance in these ecosystems. Protected areas (whether they offer partial or full protection to living organisms) are an important starting point for the conservation of biodiversity since they enable the conservation of diversity at the ecosystem, species and genetic levels within the protected area.

Table 5.1 Protected Land Area in Botswana

Protected Areas	**Size (km^2)**	**Ecosystems protected**	**Purpose of Protection**
National Parks:			
1. Chobe National Park	10,589.00	Forests, riparian swamps, alluvial floodplain, mopane forest	Ecosystem conservation
2. Kgalagadi Transfrontier National Park	28,000.00 Botswana Side	Arid shrub savannah, Kalahari bush savannah, fossil rivers and pans	Ecosystem conservation, Peace Park between RSA and Botswana
3. Makgadikgadi and Nxai Pans National Park	7,400.00	Fossil lakebed, pan grassland, northern Kalahari tree and bush savannah	Ecosystem conservation
Game Reserves/Parks:			
4. Moremi Game Reserve	4,800.00	Okavango Delta, floodplain, northern Kalahari tree and bush savannah	Ecosystem conservation
5. Central Kalahari Game Reserve	52,800.00	Kalahari bush savannah, northern Kalahari tree and bush savannah	Ecosystem conservation
6. Khutse Game Reserve	2,500.00	Kalahari bush savannah, fossil rivers and pans	Ecosystem conservation

Protected Areas	**Size (km^2)**	**Ecosystems protected**	**Purpose of Protection**
7. Mannyelanong Game Reserve	3.00	Rocky hill closed tree woodland	Ecosystem conservation and cape vulture breeding site
8. Maun Wildlife Educational Park	3.00	Ngamiland tree savannah	Urban environmental education
9. Gaborone Wildlife Educational Park	5.00	Mixed bushveld	Urban environmental education
10. Francistown Educational Park		Mixed bushveld	Environmental education, species management (rhino), under development
11. Nnywane Dam Game Reserve	n/a	Artificial wetland	Bird sanctuary
12. Mogobane Bird Sanctuary	n/a	Artificial wetland	Bird sanctuary
13. Bathoen Dam Bird Sanctuary	n/a	Artificial wetland	Bird sanctuary
Other Government Holdings:			
14. Ditopo Ranch	22.75	Mixed bushveld	Eland Domestication Project
15. Matlho-a-Phuduhudu Demonstration Game Ranch	n/a	Mixed bushveld	Demonstration game ranch
Private or Community Owned Nature Reserves:			
16. Le Roo Le Tau Community Area	n/a	Mixed bushveld	Community tourism initiative
17. Nata Sanctuary	230.00	Open pan/mopane woodland, 45 percent of the sanctuary is comprised of salt pans	Community project, bird sanctuary
18. Seboba Community Area	n/a	Riverine habitat	Community area operated under the Seboba Community Trust
19. Northern Tuli	450.00	Mixed bushveld, riparian woodland, mopane woodland	Game farms/tourism
20. Jwaneng Game Reserve	22.00	Kalahari bushveld savannah	Ecosystem conservation
21. Orapa Game Reserve	8.50	Mixed bushveld	Education
22. Mokolodi Nature Reserve	4.00	Mixed bushveld	Education
23. Khama Rhino Sanctuary	4.50	Mixed bushveld	Species management (white rhino)
Forest Reserves:			
24. Kasane Forest Reserve and Extension	833.00	Teak woodlands	Protection of woodland resources
25. Kazuma Forest Reserve	194.00	Teak woodlands	Protection of woodland resources

Protected Areas	**Size (km^2)**	**Ecosystems protected**	**Purpose of Protection**
26. Maikaelelo Forest Reserve	529.00	Teak woodlands	Protection of woodland resources
27. Chobe Forest Reserve	1427.00	Teak woodlands	Protection of woodland resources
28. Sibuyu Forest Reserve	1187.00	Teak woodlands	Protection of woodland resources
Total Protected Area	111,011.75		

n/a. Not available

Sources:

1. ***Government of Botswana, National Report on Measures taken to Implement the Convention of Biological Diversity, 1998***
2. ***The National Conservation Strategy Coordinating Agency, Southern African Biodiversity Support Program, Status of Biodiversity in Botswana, 2002***

As Table 6.1 shows, Botswana has at least 111,011.75 km^2 of protected area, which is 19.1 percent of the total land area. In addition, a further 20 percent of total land area is reserved for conservation use as Wildlife Management Area. Therefore a total of about 39 percent of Botswana's total land area is reserved for conservation use.

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