TNA

BOTSWANA TECHNOLOGY NEEDS ASSESSMENT ON CLIMATE CHANGE

FINAL REPORT

NOVEMBER 2004

THE GOVERNMENT OF BOTSWANA
Ministry of Environment, Wildlife and Tourism
Department of Meteorological Services

UNDP
United Nations Development Programme

Foreword

Botswana ratified the United Nations Framework Convention on Climate Change (UNFCCC) on January 24, 1994; and the Convention came into effect on April 27th of the same year. The Convention's objective is to reduce greenhouse gas emissions, for it is understood that Botswana, like many developing countries, will be impacted by climate change.

Botswana needs to develop a comprehensive action plan to improve its medium to long-term capacity to address climate change. One important way to achieve the Convention's objective to reduce greenhouse gas emissions, and thus improve public health, is to promote technologies that are clean, affordable and secure. These technologies should facilitate the use of coal to hydrogen vehicles, solar and wind power, clean-burning methane, and non-polluting power plants.

Stakeholder participation was crucial to the successful completion of this Technology Needs Assessment (TNA). It also led to the fruitful exchange of information and data needed to assess technology use in Botswana.

A TNA is not an end in itself, but a part of the technology transfer process, and national objectives should be held clearly in mind. The result is a living document that can be revisited and revised to reflect the latest socio-economic and technological developments in the country.

This TNA identified technologies for possible donor funding, singled out policy improvement that could lead to more enabling environments, demonstrated how the capacity of local institutions and experts could be increased, and showed how public awareness of climate change issues could be enhanced.

The TNA process included the following:

(a) Establishment of criteria;
(b) Definition of priority sectors;
(c) Compilation of technology & market information;
(d) Selection of priority technologies;
(e) In-depth technology and barrier assessment;
(g) Selection of actions;
(h) Preparation of a needs assessment report.

The report identifies and assesses environmentally sound technologies which will reduce the rate of greenhouse gas emissions and climate change in Botswana, and which are in synergy with national development objectives. This was done through building on Botswana's past activities under the UNFCCC, as provided in the Botswana Initial National Communication of October 2001.

P. Phage

National Focal Point for the UNFCCC,
Director, Meteorological Services Department

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David Lesolle
Chief Meteorologist
Department of Meteorological Services

BOT/95/G31 - Climate Change Enabling Activity (Phase II)

Abbreviations & Acronyms

AC	Alternating Current
ADB	African Development Bank
AFREPREN	African Energy Policy Research Network
ALDEP	Arable Land Development Programme
BCA	Botswana College of Agriculture
BDC	Botswana Development Corporation
BDF	Botswana Defense Force
BEMP	Botswana Energy Master Plan
BGC	Botswana Gas Corporation
BHC	Botswana Housing Corporation
BINC	Botswana Initial National Communication
BMC	Botswana Meat Commission
BNPC	Botswana National Productivity Centre
BOBS	Botswana Bureau of Standards
BOTEC	Botswana Technology Centre
BP	British Petroleum
BPC	Botswana Power Corporation
BSTEP	Botswana Solar Thermal Electricity Generation Project
BWP	Botswana Pula
CBM	Coal Bed Methane
CBO	Community Based Organisations
CDM	Clean Development Mechanism
CEDA	Citizen Entrepreneur Development Agency
CEEEZ	Centre for Energy, Environment, Engineering of Zambia
CER	Certified Emission Reduction
CFL	Compact Fluorescent Lighting
CIDA	Canadian International Development Agency
COP	Conference of Parties
CSIR	Council for Scientific and Industrial Research
CSO	Central Statistics Office
CTO	Central Transport Organisation
DAHP	Department Animal Health and Production
DANCED	Danish Cooperation for Environment and Development
DANIDA	Danish International Development Agency
DAR	Department of Agricultural Research
DBES	Department of Building and Engineering Services
DC	Direct Current
DCPF	Department of Crop Production and Forestry
DGS	Department of Geological Survey
DMS	Department of Meteorological Services

DOE	Department of Energy
DOM	Department of Mines
DRTS	Department of Roads Transport and Safety
DSWM	Department of Sanitation and Waste Management
DWA	Department of Water Affairs
EDG	Energy and Development Group
EDRC	Energy and Development Research Centre
EECG	Energy, Environment, Computer and Geophysical Applications Ltd.
EST	Environmentally Sound Technologies
EU	European Union
FAB	Forestry Association of Botswana
FAO	Food and Agriculture Organisation
FDI	Foreign Direct Investment
FES	Future Energy Solutions
GCC	Gaborone City Council
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GNP	Gross National Product
GTZ	German Agency for Technical Cooperation
GVC	Gaborone Veterinary Clinic
HFC	HydroFlouroCarbons
HHWW	Household Wastewater
HIV/AIDS	Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome
HVAC	Heating, Ventilation and Air Conditioning
ICWE	International Conference on Water and Environment
IHDP	International Human Dimension Programme
IHE	International Institute for Infrastructural, Hydraulics and Environmental Engineering
ILO	International Labour Organisation
IPCC	Inter-Governmental Panel on Climate Change
ITDG	Intermediate Technology Development Group
IUCN	World Conservation Union
IWSD	Institute of Water and Sanitation Development
JICA	Japanese Agency for International Cooperation
KITE	Kumasi Institute of Technology- Ghana
KSDAH	Kanye Seventh Day Adventist Hospital
KW	Kilowatt
LPG	Liquefied Petroleum Gas
MJ	Mega Joules
Ml	Mega Litre
MLG	Ministry of Local Government
MOA	Ministry of Agriculture

MODIMP	Modern Implements
MOE	Ministry of Education
MOH	Ministry of Health
MMEWR	Ministry of Minerals, Energy and Water Resources
MT	Motorised Transport
MW	Mega Watt
NAMPAADD	National Master Plan for Arable Agriculture and Dairy Development
NCSA	National Conservation Strategy Agency
NDB	National Development Bank
NDP	National Development Plan
NEPAD	New Partnership for Africa's Development
NGO	Non Governmental Organisation
NMPWWS	National Master Plan for Wastewater and Sanitation
NPVREP	National Photovoltaic Rural Electrification Programme
NWMP	National Water Master Plan
PV	Photovoltaic
RE	Renewable Energy
RETS	Renewable Energy Technologies
RIIC	Rural Industries Innovation Centre
RIPCO (B)	Rural Industries Promotion Company (Botswana)
ROM	Run of Mine
RSA	Republic of South Africa
SACU	Southern Africa Customs Union
SADC	Southern African Development Community
SGP	Small Grants Programme
SIDA	Swedish International Development Agency
SME	Small and Medium Enterprises
SMME	Small Medium and Micro Enterprises
SPSS	Statistical Package for Social Scientists
SVFA	Serorome Valley Farmers Association
SWH	Solar Water Heaters
TG	Terra-Grammes
TNA	Technology Needs Assessment
UB-FET	University of Botswana – Faculty of Engineering Technology
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNFAO	United Nations Food and Agriculture Organisation
UNFCCC	United Nations Framework Convention on Climate Change
US$	United States Dollar
USA	United States of America
USAID	United States Agency for International Development
VFA	Volatile Fatty Acids
WWTW	Wastewater Treatment Works

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Executive Summary

This project for Botswana on Technology Needs Assessment is being undertaken in the context of the United Nations Framework Convention on Climate Change (UNFCCC).

The main objective of this consultancy was to identify and assess environmentally sound technologies that have synergy between reducing impact of climate change the rate of GHG emissions in Botswana with national development objectives. This was done by building on Botswana's past activities under the UNFCCC as provided in the Botswana Initial National Communication (BINC).

The terms of reference have been addressed adequately to allow a conclusion to be drawn that the study has achieved its purpose. Technologies in energy, water and agriculture were identified and, with the assistance of the stakeholders, prioritised.

Suppliers, users and potential users of these technologies have also been identified and are encouraged to take these technological ideas further and to develop them into projects that will assist the Government to achieve its developmental goals.

The following are the major findings:

1. **Botswana has significant potential for environmentally sound technology (EST) application in coal, coal bed methane (CBM), biogas and biofuels.**

   a. The biggest opportunity for EST is in coal washing to improve quality and exploitation.
   b. The utilisation of the recently discovered CBM resources for power generation and as transport fuels is feasible.
   c. The utilisation of landfill waste, abattoir waste and manure to generate biogas for domestic, institutional and industrial use is feasible.
   d. The abundance of land would allow for the production of oil bearing plants, like Jetropha, that have potential to grow in Botswana to provide biofuels.

2. **With the abundance of solar energy in Botswana, there is potential for solar pumping, solar water heating, passive solar designs, solar PV and solar cooling.**

   a. Solar PV technologies (for water pumping, as off-grid electricity supply) are still too expensive to be adopted in large scale and hence can only be disseminated through a government subsidy.
   b. There is also limited application of solar cooling and passive designs, due to limited expertise and cost of designs in those areas.
   c. There is potential to widely disseminate solar water heaters in the country by using the improved SWH technologies developed in-country and outside Botswana.
   d. Solar cooking will face competition from the use of LPG that is entrenched in the country.

3. **Application of wind, and other biomass (elephant grass), is limited in scope.**

   a. Wood fuel is the most affordable source of energy for the majority of Batswana and would continue to contribute substantially to the national energy demand.
   b. Elephant grass has a potential as an alternative energy source and can be grown in Botswana.
   c. Wind regimes are low and therefore not sufficient for electricity generation and water pumping

4. **Energy efficiency and demand side management activities have not been fully exploited in Botswana, and yet there is potential in various sectors. Potential is recognised in the following technologies:**

   a. Compact fluorescent lighting;
   b. Passive solar design;
   c. Energy management systems.

5. **There is abundant wastewater generated in Botswana, but it is not currently fully utilised. Potential for the utilisation of wastewater is recognised in the following technologies:**

   a. Activated sludge treatment plants can treat municipal wastewater with final effluent ready for re-use in the irrigation of a variety of crops, such as fruit trees, fodder, vegetable and landscaping.
   b. Waste stabilisation ponds have a high rate of evaporation; this results in loss of wastewater that could otherwise have been used.
   c. Initial capital and running costs for conventional systems (activated sludge,

percolating filter, etc.) are higher than non-conventional systems (stabilisation ponds and wetlands).

d. A high percentage (64.6%) of respondents are willing to re-use treated grey water.

6. **The treatment of brackish water to potable quality is expensive. Technologies identified are:**

   a. Reverse osmosis which produces water to very high levels of purity;
   b. De-mineralisation which takes out dissolved minerals from water;
   c. Evaporation stills for small scale water treatment facilities.

7. **Agricultural technologies for methane abatement are not well known in Botswana; however, several technologies were identified as follows:**

   a. Livestock number reduction is a way of reducing methane from enteric fermentation, but is not popular as it may affect income levels of farmers.
   b. Low emitter animals can be bred that can impact on the reduction of emissions.
   c. There are certain antibiotics that can reduce methane emissions from animals.
   d. The use of improved quality forage reduces methane emissions from animals because of high feed conversion ratios.

MAJOR RECOMMENDATIONS

1. **Support for the following activities is required in order to realise the prioritised technologies in each of the energy sectors.**

   a. For the coal bed methane, there is a need to establish resource base and potential markets for CBM use.
   b. On the policy side, Government would have to liberalise the energy market to allow other players that might provide CBM based energy services.
   c. Research and capacity building in relation to exploitation and utilisation of CBM technologies should be pursued.
   d. In relation to coal beneficiation, the feasibility for coal washing should be completed and the results disseminated to attract potential entrepreneurs and to energise the market. The potential benefits in the power sector, industry and household sectors need to be explored.
   e. Government can support promising entrepreneurs with funding from sources such as CEDA, BDC and NDB.
   f. There is a need to identify biofuels and related crops that can be produced in Botswana and to undertake pilot projects to produce these biofuels.

g. Government can encourage through policy the use of biofuels and infuse the policy into the Botswana Energy Master Plan.

2. Further work is required to assess the potential of energy efficiency and to establish and demonstrate energy efficiency practises and technologies in industry, households, commercial buildings and the power sector. This can be done through promoting an institutional framework for providing:

a. Energy audit and management services;
b. Awareness creation to potential beneficiaries;
c. Incentives for the uptake of energy efficient measures to potential beneficiaries;
d. An environment that will ensure that wastewater is exploited for various end uses; this environment could create awareness about the scarcity of water and the safety of treated wastewater, develop an infrastructure for the distribution of treated wastewater; and complete and enforce wastewater treatment standards.

3. On the treatment of brackish water, the Government should provide subsidies for the adoption of reverse osmosis technology.

4. In agriculture the following is recommended:

a. Animal breeding for methane abatement is currently not being done; however, some work on high productivity animals is being carried out by DAR. It is recommended therefore that DAR should disseminate research results to farmers.
b. The Botswana Agricultural Union should take an active role in methane abatement, and farmers should reduce their livestock numbers to optimise pastures. It should be emphasised that there is the added benefit of higher productivity with reduced numbers and higher quality livestock.
c. Conservation tillage is being tried in the country, namely by Masedi Farms in Pandamatenga, NAMPAADD in Barolong Farms and RIPCO (B) in association with MODIMP of the Republic of South Africa. It is therefore recommended that NAMPAADD disseminate reduced tillage methods and emphasise its advantages as part of the purpose for implementation.

General Recommendations

a. Many of the technologies identified need to be adapted to be compatible with the social, cultural, economic and environmental priorities of Botswana.
b. The role of the private sector will be vital in the identification and adoption of

environmentally sound technologies and therefore should continue to be engaged in future TNA activities.

c. Technology needs will continue to change and Government should ensure that this TNA report is frequently updated and new action plans developed for implementation.

d. There should be training for organisations that will manage technologies and conduct environmental impact studies and risk assessments.

e. General stakeholder participation should be ensured in the technology transfer process.

f. Indigenous capacities should be developed, as an exclusive dependence on imports can prove harmful in the future.

g. There is a need to undertake project life cycle confirmation studies to determine the methane mitigation potential for each technology identified.

Section 1

Introduction

Section 1.1

Project Background

This project for Botswana on Technology Needs Assessment is being undertaken in the context of the United Nations Framework Convention on Climate Change (UNFCCC).

The overall objective of the UNFCCC is to achieve the stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic activities from interfering with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable development to proceed in a sustainable manner.

To that end Article 4.5 of the UNFCCC requires that developed country parties to the convention take all practical steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies (EST), and to transfer accompanying skills to other parties, particularly developing country parties, to enable them to implement the provisions of the Convention. In this process, developed country parties shall support the development and enhancement of the indigenous capacities and technologies of developing country parties. Other parties and organisations may also assist in facilitating the transfer of such technologies.

A framework of technology transfer that was developed and adopted at the sixth Conference of Parties (COP6) to the UNFCCC requires developing countries to carry out their climate change technology needs assessment and to communicate this to COP. A Technology Needs Assessment (TNA) assists developing country parties to identify and analyse priority EST needs that can be adapted to projects and programmes to achieve both Article 4.5 and national development objectives.

Botswana ratified the UNFCCC in 1994. In 2001 it submitted its First Initial Communication to the Conference of Parties. The Botswana Initial National Communication (BINC) offered opportunities for policy refinement and development and posed challenges for achieving a lasting balance between national development and mitigating the potential impacts of climate change. BINC also acted as a marketing document to sell the national opportunities for foreign and local investment, and for safeguarding the environment and atmosphere against further deterioration. The BINC has always been viewed as a living document, one that will require further improvements.

This TNA project has been undertaken to introduce technologies that could improve Botswana's developmental and environmental integrity.

Section 1.2

Objectives

1.2.1 Main Objective

The main objective of this consultancy is to identify and assess environmentally sound technologies that have synergy between reducing the impact of climate change and the rate of GHG emissions in Botswana with national development objectives. This will be done through building on Botswana's past activities under the UNFCCC, as provided in the Botswana Initial National Communication (BINC).

1.2.2 Specific Objectives

The specific objectives will be to:

a. Assess BINC's past efforts to identify GHG mitigation technologies and adaptation measures in critical economic and vulnerable sectors;

b. Define priority sectors for which technologies are needed to sustain national development projects and programmes in light of the UNFCCC and potential impacts of climate change;

c. Identify suitable technologies that mitigate GHG emissions from the energy and non-energy (e.g. agriculture) sectors that have a beneficial impact on development;

d. Review Government policies and programmes, such as Vision 2016, National Development Plans, Botswana Energy Master Plan, Science and Technology Policy, Industrial Development Policy, National Agricultural Master Plan for Arable Agriculture and Dairy Development, in relation to the TNA;

e. Identify possible sources of technologies, their cost-effectiveness, and barriers to adoption, adaptation [1] and mitigation [2] potential;

f. Develop a project screening mechanism for the incorporation of Botswana's priorities into the design of all new projects;

[1] Reduction of risk potential and enhancement of sustainability

[2] GHG reduction potential and development benefits

g. Undertake a study on water conservation, treatment, recycling, harvesting and industrial cooling;

h. Investigate the social acceptability of wastewater recycling;

i. Identify and assess methods of reducing methane production from livestock and crop technology that would maximise the storage of carbon and nitrogen, and the efficient use of water and energy, and would minimise the use of chemical fertilisers.

Section 1.3 Analytical Framework

The analytical framework entails making technology assessments for greenhouse gas emission mitigation and adaptation to the impact of climate change for selected sectors. The critical economic and most vulnerable sectors have been considered.

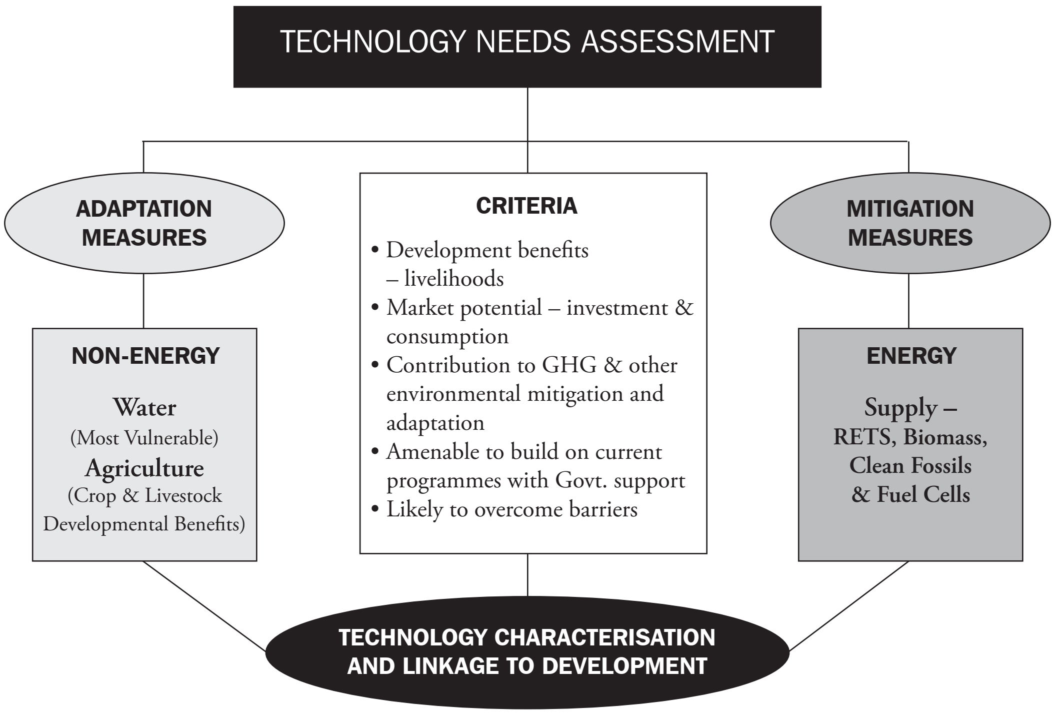

Figure 1 Analytical Framework

The critical economic sectors, in relation to greenhouse gas emissions, are energy and agriculture, while water and agriculture are the most vulnerable sectors in Botswana.
In considering adaptation and mitigation measures in these sectors, criteria have been set to assist in the characterisation of priority technologies that should be adopted. The criteria require that technologies have:

- Highest developmental benefits in terms of value added and the improvement of the quality of life for the majority of the population;

- High market potential in terms of attracting investment and being in demand;

- High potential to reduce greenhouse gas emissions as per the requirements of this TNA;

- Potential to build on existing/on-going national programmes that are already receiving government support;

- Implementation inhibitors that can be overcome at a reasonable cost.

Both adaptation and mitigation measures for the selected sectors are therefore characterised according to the criteria above.

Section 1.4 Methodology

1.4.1 Data Collection

Both primary and secondary data collection were carried out.

Secondary data collection entailed the review of past studies on:

- Vulnerability and adaptation in the water and agriculture sectors to assess the proposed measures that could alleviate the impact of climate change on these sectors;
- Mitigation studies in both the energy and non-energy sectors;
- Botswana Initial National Communication;
- Vision 2016, National Development Plans, sectoral policies, strategies, projects and programmes;
- Best practises in Botswana and other countries in relation to integrating climate change programmes with national development and employing state-of-the-art technologies that are environmentally friendly and acceptable to end-users.

Primary data collection entailed:

- Interviews with Government policy/decision-makers on national and sectoral priorities;
- Interviews with the users and potential users of recycled/treated water;
- Consultations with internal and external technology suppliers to understand the performance of such technologies and how they fit into the country's economy;

- A two-day workshop for government decision-makers, technology providers and other experts to familiarise them with desired solutions; technology providers presented their products to government stakeholders, culminating in group sessions that defined priority technology needs in the sectors selected for this study.

Section 1.5

Sampling

To determine a representative sample for populations greater than 10,000, the following standard formula was used to determine the sample size (IWSD, 2003).

$$n = z2pq/d2$$

Where:

n = the desired sample size

z = the standard normal deviate, usually set at 1.96 which corresponds to the 95 percent confidence level

p = the proportion in the target population estimated to have particular characteristics (normally set between 0.1 and 0.5)

q = 1.0 – p

d = degree of accuracy desired, usually set at 0.05

In this study it was assumed that the proportion of the population to be tested was about 170,000, which is 10% of the whole population. Therefore p is = 0.1

$$\text{Sample size } n = [(1.96)2 \times 0.1 \times 0.9)/(0.05)2] = 138$$

Figure 2:

The vulnerability of Botswana's wildlife to climate change requires further investigation (Photo: Illustritive Options).

The study administered 138 questionnaires.

1.5.1 Data Analysis

The survey data on the social acceptability of wastewater recycling was processed using SPSS. The technology assessment employed the expert judgment of consultants and stakeholders who participated in the technology prioritisation.

Section 2

Development & Environment Nexus

Section 2.1

Sectoral Development Analysis

Botswana's population and its distribution are indicators of the sizes and locations of potential markets that can adopt environmental techniques and services.

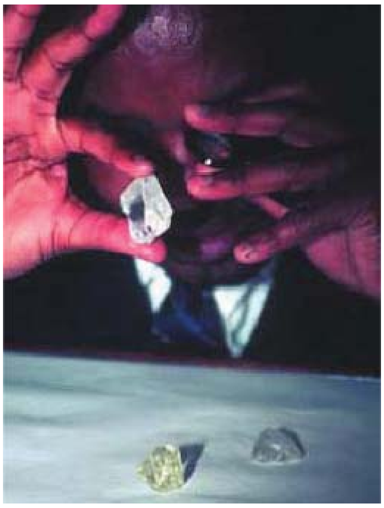

Figure 3:

Mining contributes about one third of the country's Gross Domestic Product (Photo: Illustrative Options)

[3] By the CSO definition, an urban area has a population of more than 5000, and 25% or less are engaged in agricultural activities

2.1.1 Population and Distribution

The population of Botswana, accordining to the last census of 2001 (CSO, 2001) was 1.7 million. The growth rate averaged 2.4% between 1991 and 2001, compared to 3.5% between 1981 and 1991.

Although the impact of HIV/AIDS is believed to have contributed to a lower growth rate, the decline however started earlier than 1991 (NDP 9, 2001). In 2001, the towns and cities held 22% of the total national population, and the districts held 77%; the remaining 1% resided in other localities, such as cattleposts.

The urban [3] - rural shares were 55% and 45% respectively. The urban population share of towns/cities alone was 41% of the total urban population and that of the urban villages was 59%.

The 2001 Census indicates that larger urban populations are now found in district villages than in towns/cities, and that there are now more Batswana residing in urban areas than in rural areas. This situation carries the potential for better income for urban dwellers, and hence the adoption of environmentally sound technologies.

2.1.2 Economic Performance

Economic Trends

Botswana's total GDP, as an indicator of economic performance, has been steadily growing, as has been the per capita GDP. Botswana's Vision 2016 sets an economic growth target of 8% in real GDP per annum, and an investment to GDP ratio of 41% as the growth rates that can enable Botswana to eradicate absolute poverty by 2016. During the 8th National Development Plan (NDP8), actual real GDP grew at 6.7%, with an investment GDP ratio of 26%. The estimate of investment GDP ratio in the current NDP9 is 30%. These indicators still fall below the targets.

The inflation rate has been below 10% for decades. The current balance of payments can last for 39 months and the exchange rate of the Botswana Pula against the South Africa Rand has appreciated by 23.5% in 2001 (EECG, 2003). This is a healthy economic situation that can support the needed transfer of environmentally sound technologies in the country. The high exchange rate however reduces the competitive position of domestic producers by making the imports of competing products from the Republic of South Africa (RSA) cheaper and the exports from Botswana to RSA more expensive.

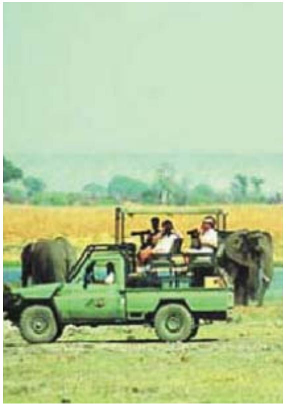

Figure 4:

Tourism is one such non-mining activity (Photo: Illustrative Options)

Sectoral Performance

The economy of Botswana has been fuelled by growth in the mining sector, the largest single contributor to the GDP. The fluctuations in the growth rate of GDP for the mining sector largely influence that of total GDP (EECG, 2003). The sector's contributions to GDP have ranged between 35% and 47% between 1981 to date. The growth rate in the mining sector is however expected to decline, as no further expansion of mining operations is anticipated in the near future.

The manufacturing and construction sectors have the potential to contribute to economic diversification. Agriculture, although not performing well, remains important to the economy (EECG, 2003). The performance of the above sectors is however currently far below that of mining, and interventions in these sectors could accelerate the growth rates of the non-mining sector to meet the Vision 2016 goals. Potentially, technologies that will enhance the performance of the non-mining sectors will add to Botswana's development benefits.

Employment and Income Levels

Data based on the Annual Economic Report (2000) show that formal employment levels only increased by 5% between 1994 and 1998 and by 4% to date. Mining, the main economic contributor, is a capital-intensive sector and has limited employment opportunities. For example, the sector only created 600 additional jobs in the decade between 1990 and 2000 (Annual Economic Report, 2000). The growth in employment is then expected to be fuelled by growth in the non-mining sectors, among them manufacturing.

Data on employment in the informal [4] sector is not readily available, but the Annual Economic Report of 1997 indicated that in 1991, the proportion of people employed in the informal sector was 8% and increased to 24% in 1994. The informal sector is an important source of income for the majority of Batswana. Environmentally sound technologies are required to boost the performance of the informal sector in Botswana, while achieving sustainable development.

[4] The informal sector includes those self-employed, those who carry out unpaid family work or unpaid work at lands/farms/cattle posts, and those in unregistered businesses with less than 10 employees. The majority of those in self-employment and unpaid family work were females while males dominated in unpaid work at lands/farms/cattle posts.

Data on household income and expenditure levels is about 10 years old; and the results of a recent survey carried out in 2002/2003 are not yet available. However, according to the 1993/94 Household Income and Expenditure Survey (CSO, 1995), 38% of Botswana households and 47% of the population were living in poverty [5] or below the poverty datum line (BNPC, 2002). A lack of income is the major and immediate cause of poverty and it is attributed to the lack of employment, insufficient income earning opportunities and the low potential of traditional agriculture. Poverty is higher and more severe in rural areas and urban villages than in urban areas, particularly in female-headed households (UNDP, 2002).

In fulfilling the mandate of synergy between development and reducing the rate and impact of GHG emissions, a measure of poverty reduction can be achieved through the adoption and transfer of technologies that can improve household incomes and through development projects.

Enterprises

Most developing countries are supporting Small, Medium, and Micro Enterprises (SMMEs) to catalyse industrialisation and to create much needed employment. SMMEs comprise 50% of formal employment but only 6% of the GDP in Botswana. They need more support to realise their full potential and to be competitive in local and world markets (BNPC,2002).

Typically, micro-enterprises are the most numerous, with approximately 75% owned by women. The micro-enterprises play a crucial role in people's efforts to meet basic needs and help marginalised groups to survive, given that the formal sector cannot absorb the increasing labour supply. Whilst micro-enterprises survive longer than small and medium enterprises, they do not grow and less than 1% of micro-enterprises reach small-scale level.

A lack of financial resources, a shortage of business premises, a lack of awareness of Government assistance programmes, poor management and marketing skills and inadequate appropriate technologies are often cited as some of the constraints to the growth of micro-enterprises.

Many small and medium enterprises (SME) survive for less than 5 years. About 50% of newly established SMEs go bankrupt before the end of the 3rd year, and 80 to 85% do not survive beyond 5 years, often mainly due to lack of management and entrepreneurial skills and market opportunities (SMME, 1998).

The medium enterprises, however, have an export potential and can adopt technologies that would make them competitive in export markets. Medium enterprises are mainly located in urban areas where they can also create sustainable employment.

Globalisation has created niche markets for these SMMEs, but the threat of international competition also compels SMMEs to adjust or face bankruptcy. The SMMEs require

[5] The study conducted by BIDPA in 1996, defined poverty at household level to be a situation of lack of choice arising from low income or low human capabilities. UNDP (2002) has a similar definition of poverty.

advanced and appropriate technologies and good management to take advantage of the niche markets and to survive fierce competition.

International Outlook

Botswana is a free economy characterised by an openness to external investments and trade. Botswana's outward looking strategy is supported by its membership in a number of regional, international and multi-lateral trade agreements. The Southern African Customs Union (SACU) Agreement is one of its most important trade agreements, since Botswana sources over 80% of its imports from other SACU countries, particularly South Africa. Through this Agreement Botswana receives custom revenues and unfettered access to the large South African market.

The Southern African Development Community, SADC, of which Botswana is a member, has a number of protocols and agreements on all aspects of development, including among others, energy, trade and industry, finance and investments and food security. Botswana has ratified all SADC protocols through which it can benefit from financial, investment and trade flows.

The New Partnership for Africa's Development (NEPAD) is expected to boost the continent's economy. Botswana's participation in NEPAD may create opportunities for the country to benefit from regional projects and programmes, for example, for poverty alleviation and for improving access and quality of energy and water.

2.1.3 Vision and National Development Agenda

Vision 2016, Botswana's primary development agenda, places emphasis on:

a. Education and information - for instance HIV/AIDS awareness building will be achieved through all possible media;

b. Prosperity, productivity and innovation - emphasising the role of Government as a facilitator in partnership with the private sector to create an environment where business and entrepreneur activities are encouraged and supported;

c. Compassion, justice and care - offering support and opportunity to those who are poor;

d. Safety and security – protecting the life and property of all;

e. Democracy, transparency and accountability;

f. Morality, tolerance, unity and pride.

The Ninth National Development Plan, NDP9, is based on Vision 2016 and emphasises sustainable development through competitiveness in global markets resulting in:

a. Economic diversification;
b. Employment creation;
c. Poverty alleviation;
d. Continued macro-economic stability and financial discipline;
e. Public sector reforms;
f. Environmental protection;
g. Rural development;
h. Human resource development, including the fight against HIV/AIDS and disaster management.

Selecting and prioritising environmentally sound technologies should be included in the national development agenda.

Section 2.2 Environment Analysis

2.2.1 Greenhouse Gas Emissions

With respect to greenhouse gas emissions, the critical sectors in Botswana are energy, industry, agriculture, land use, forestry and waste. For the 1994 GHG inventory, agriculture was the largest emitter, resulting from livestock methane (see Table 1).

Sector	CO_2 Equiv (Gigagrams)	Percentage (%)
Energy	3866	41
Industrial	211	2
Agriculture	5067	55
Land Use & Forestry [6]	-	0
Waste	172	2
Total	**9316**	**100**

Source:
Botswana Initial National Communication, 2001

Table 1: Summary of Sectoral GHG Emissions (1994)

This is not surprising, as Botswana is a cattle country. The next GHG emitter was energy, and this is mainly due to the use of coal in power generation and the use of motorised vehicles that use petrol and diesel. The industry and waste sectors were not major contributors to GHG emissions, and the land use and forestry sectors were determined largely as a sink.

[6] Land Use and Forestry is a net sink.

2.2.2 Sectoral Vulnerability

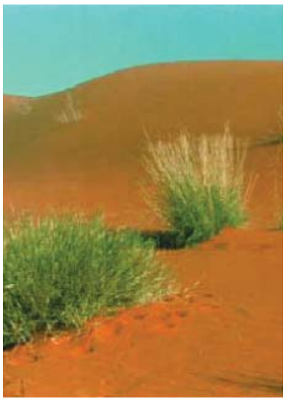

Figure 5:

The Kalahari sand dunes found over Southwestern Botswana (Photo: Fonsag)

Agriculture is important to Botswana as in other developing countries as a source of livelihood. Livestock production in particular is socially and culturally important, but is often affected by droughts, which may be exacerbated by climate change. Crop production in previous studies was predicted to reduce by 30% for the main crops of maize and sorghum, possibly due in part to climate change. This is a reduction from a current low production of 23% of national requirements.

The importance of energy in Botswana's development process cannot be over-emphasised, since it plays a vital role both for households and industries. The unwarranted use of energy can lead to the adverse effects of green house gas emissions. As industries and populations are growing, Botswana needs to take stock of its available resources so that all available energy resources are optimised.

In woodlands and forests, bush encroachment is expected to expand under climate change, with thorn and shrub displacing grasslands and moister forests and woodlands.

Figure 6:

Botswana's wetlands are internationally renowned for their beauty and biodiversity (Photo: Illustrative Options)

The national water supply is already critical, even without considering climate change; and the demand for water is predicted to outstrip supply. The challenge will become even greater if climate change sets in.

Another sector that has been assessed for vulnerability is health. Malaria, which is a killer in northern infested areas, will affect double the number of people now already affected (BINC, 2001).

2.2.3 Technology Assessment

The Botswana Initial National Communications (BINC) presented technologies that could be used to mitigate the rate of GHG emissions and to assist affected sectors to adapt to the impact of climate change.

Mitigation

In the energy sector, the following technologies were assessed: spanned solar (solar home systems, solar water heaters, central PV plants, solar PV water pumps), petroleum economy (paving roads, electrifying rails, fuel pricing, vehicle inspection/efficiency, vehicle-rail freight, zero tillage, vehicle/rail to oil pipeline), electrical energy efficiency (efficient lighting, pre-payment meters, geyser timers, power factor corrections, efficient motors), thermal efficiency (efficient boilers), waste to energy (land fill gas and cow dung biogas) and sinks (reforestation).

In non-energy sectors, the mitigation related technologies assessed were the following: fuel wood efficiency (cook stoves), forest/woodlands management (natural woodlands management, veld fire guard), substitution (wooden to steel poles), waste management (land fills and manure), cattle feed, sink (afforestation), and industrial substitution (SF6 to air blasts).

A good number of these energy and non-energy technological options could be implemented inexpensively, but further work is required to develop projects.

It is recognised that as new resources are developed and priorities change, the order in which identified options are implemented will also change.

Adaptation

With regards to adaptation, the technological options analysed for the water sector were inter-basin transfers, water conservation, wastewater recycling, desalination, etc.

In the health sector, the suggested measures were improvement to the health care system, disease surveillance and public awareness.

For land use and forestry, the proposed technological measures included: the prevention of further deforestation, improved rangeland management, the expansion of protected areas and sustainable management of vegetation stands.

In agriculture, grazing and livestock, the technological options included the following: community based natural resource management for sustainable grazing practices, policy incentives for herd management, regulating the numbers of herds based on the carrying capacity of grazing lands, diversification of breeds and species and greater use of managed wildlife. In crop production, suggestions included: national programmes to increase food production, to improve the capacity for drought warning, reduction of food imports, diversifying livelihood activities, increasing minimum tillage, using crop varieties with short growing seasons, and strategic planting dates.

These technological options require further planning and refinement in order to develop into real projects.

Figure 7:

Coal washing is one of the major sources of energy in Botswana (Photo: Bugarski)

Section 3

Technology Needs Assessment

Section 3.1

Sectoral Selection

As indicated in the discussion of the Botswana Initial National Communication, several sectors were considered in the selection of climate change adaptation and mitigation technologies. These included energy, agriculture, waste and forestry (mitigation), and water, agriculture, forestry and health (adapation).

Due to limited resources and time constraints, it was important to select a few sectors that required urgent attention with respect to the Technology Needs Assessment (TNA).

In the case of mitigation, priority was given to those sectors that were the highest GHG emitters and that had the highest potential to reduce emissions using available technologies. These sectors were to have the most market potential in terms of attracting investment and penetrating the market. The sectors that could address developmental issues, such as improvement in livelihoods, were of high priority.

The BINC found that the energy and agricultural sectors had the highest GHG emissions; this situation has not changed. Both sectors further address issues in the other sectors. For instance energy technologies could consider utilisation of resources in the waste sector (e.g. landfill gas, biogas), the forestry sector (e.g. wood chip briquettes, biofuels such as biodiesel) and the agriculture sector (e.g. elephant grass as fuel). Similarly, agriculture addresses forestry and rangelands. The Terms of Reference provided for this project had specific issues to be addressed for the energy and agriculture sectors.

On the adaptation side, the most vulnerable sectors were water, agriculture, forestry and health.

The water sector is undoubtedly one of the most vulnerable sectors and already there were Terms of Reference specific to this sector.

Section 3.2

Energy

3.2.1 The Role of Energy in the Economy

Energy is often referred to as the engine of a country's economy, without which socio-economic goals cannot be achieved.

a. The energy sector, particularly in the areas of electricity and petroleum, contributes significantly to the national GDP and national employment, and is therefore a significant component of the national economy.

b. Energy is an input into all productive facilities, and therefore influences production costs and thus the economic competitiveness of industry. This is an important area for Botswana to take cognisance of, as the need to develop economic sectors other than the diamond industry becomes increasingly important.

c. Energy is a basic need for the population, and thus important to their welfare. Energy is required for cooking and lighting. Households cannot do without a basic amount of energy for these purposes. Poor households spend a relatively high proportion of their income on meeting their energy needs - typically up to 20% and 30 % for the urban poor and rural households respectively (EECG/RIIC, 2001; EDRC/EDG/FAB, 2001). Government, therefore, has a role in ensuring that these segments of the population are not unduly burdened.

d. Energy efficiency is becoming increasingly important internationally, because of environmental benefits associated with avoided energy generation and use, and improvements in the economic competitiveness of the economy - i.e. maintaining industrial output with reduced input resources. Botswana needs to follow suit in this area if it is to maximise economic development opportunities and to become competitive in the global market.

e. Energy use has significant environmental impacts - both localised and global. In Botswana, fuel wood collection is a significant factor in the sustainable use of forest reserves. Botswana will increasingly need to acknowledge its responsibilities in the global arena concerning global warming associated with the use of fossil fuels, particularly coal and petroleum products that are in prevalent use in Botswana.

f. An adequate energy supply facilitates education. For instance electric lighting in schools enables night classes, homework, and the running of increasingly necessary information appliances such as computers and copiers.

g. The electricity supply is important for adequate health care, as many necessary appliances used in clinics and hospitals are electrically powered.

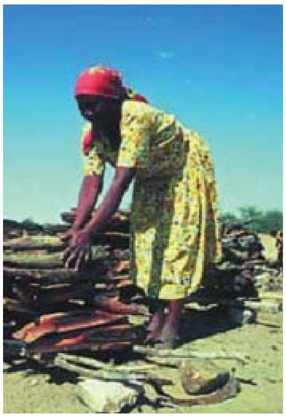

Figure 8:

Fuelwood from Botswana's forests and woodlands is the main energy source for rural households (Photo: Illustrative Options)

3.2.2 Overview of the Energy Sector

This section provides a broad overview of energy tends in Botswana, capturing the salient features of the entire sector in the country as a whole. Botswana is endowed with biomass (mainly fuel - wood), coal, and solar energy. All petroleum products are imported. There is also a small potential for wind energy and waste as an energy source.

Coal contributes the largest share of the primary energy supply (33-34%), followed by wood (30-32%) and petroleum products (30-32%). Electricity was 4% of all national energy imports. With the exception of fuel-wood, new and renewable energy sources are hardly used and solar power, which is highly promoted in the country, accounts for less than 1% of total energy consumption (Botswana Energy Statistics, DOE, 2002).

The net energy supply in the formal sector is dominated by petroleum products (34-40%) and wood (38-39%) followed by coal (13-18%). Locally generated and imported electricity contributes 9-10%. Locally generated electricity is mainly coal based, with a few decentralised diesel generators operated in areas remote from the grid (EECG, 2004).

A similar pattern is maintained in final energy consumption. Considering all energy sources used in Botswana, the household sector is still the largest consumer of energy, accounting for 42.0% of all energy consumed by the demand sectors. The second largest is transport (23.3%), followed by mining (19.1%), government (5.8%), trade and hotels (4.5%) and manufacturing (4.3%).

When only considering the commercial energy sources (i.e. excluding fuel-wood), the transport sector leads with 38.0% of all energy consumed, followed by mining 31.2%, government 9.5%, trade and hotels 7.3%, and manufacturing 7.0%. Household consumption drops from 42% to 5.5%, indicating its predominant dependence on fuel-wood. The agricultural and construction sectors consume less than 1.5% - whether in terms of commercial energy sources or fuel-wood.

Both supply and demand energy sub-sectors could be beneficiaries of energy substitution (decarbonisation and renewable energy) and energy efficiency.

Below are the energy technologies identified in this project as part of the TNA.

3.2.3 Energy Technologies Identified

The supply technologies identified in the energy sector largely fall within three categories, namely: solar, biomass, and coal; all three are the major natural resources in Botswana. The other supply technologies presented are LPG, fuel cells, wind and hybrid systems. On the energy demand side, energy efficiency technologies are presented. The barriers to implementation of the identified technologies are included for each technology.

3.2.3.1 Solar

Solar PV Technologies

Botswana has a long history of disseminating solar PV technologies. Previous notable projects that have been undertaken include: Manyana PV pilot project, Motshegaletau centralised PV pilot project, the National Photovoltaic Rural Electrification Programme, and the Japanese International Cooperation Agency (JICA) supported PV Master Plan (Botswana Energy Master Plan, 2004; JICA, 2002).

Some of the recent initiatives of relevance to this study are presented below.

Solar International is providing solar PV off-grid mini-grids and in some instances hybrid with diesel generator sets. An example of where these have been tried in Botswana is the Remote Area Development Programme in the following areas:

- Central District Council: Mokgenene 52 km West of Dibete and Khwee 60 km SSW of Letlhakane where 20 panels of 300 Wp (6 kW) were installed in each settlement;

- Ghanzi District Council: New Xade where 12 panels of 3600 Wp each (42 kW) and a 3-phase diesel generator set were installed.

Figure 9:

A house in Lorolwana Village installed with a 60Wp 12VDC solar power system

These systems have adequate power for most energy requirements in rural government institutions including clinics, schools etc. The current major supplier in Botswana is Solar International. The systems are maintained by the District Councils and Solar International only provides technical backstopping.

The investment costs for these technologies are high, at about BWP400,000 to BWP500,000, and could prove to be the barrier to uptake, as these special panels with 3-phase inverters are imported from the USA. Even with expected solar energy efficiency improvements, the technology cannot be sustainable without a subsidy. It is recommended that BPC provide PV mini-grids, pending the consolidation of conventional grid electricity.

Figure 10:

The Grundfos Solar pump used for livestock and irrigation

According to the UNDP, the Government of Botswana, through the Department of Energy Affairs and in conjunction with UNDP/GEF, will implement the Widespread Adoption of Renewable Energy Technologies in Rural Areas in 2005. The intention of this project is to remove the technology adoption barriers.

In the Netherlands and Germany, where the building integrated PV technology is widely used, lighting is normally provided, but not heating, ventilation or air conditioning (HVAC). This is highly subsidised by government and cannot be self-sustaining. Passive solar designs are much better than integrated PV. There is little information on the cost of grid connected PV. In any case, these figures are distorted, because in Europe there is an artificial market due to high subsidies. Wherever Government subsidies are applied, it would always be better if they were for the benefit of the poor rather than companies and the urban rich.

Other solar PV lighting systems disseminated by Solar International are lanterns at a cost of BWP550 to BWP750. These are rather expensive for the intended market, and have no subsidy, and this could be the biggest barrier to uptake.

Solar Cooling

RIPCO (B), in collaboration with UB FET and other international renewable energy (RE) organisations, is investigating the possibilities of solar refrigeration using ammonia absorption technology.

The complexity of the technology proves to be the main barrier, as there is not enough expertise in Botswana, and even around the world, to install and maintain the equipment.

Passive Solar Designs [7]

The BOTEC building is one example of this technology in action, and it is currently being evaluated and will provide valuable information for the future of this technology in Botswana. There are no regulations regarding the advancement of passive solar designs in the country. Even though the BOTEC building has been built around the concept, it has not been done exclusively, e.g. the paint and the windows are used in conventional buildings.

Possible barriers here are the cost of design and the availability of expertise in the country.

Solar Cooking

The potential for solar cooking is limited in terms of the market, but RIIC has developed various sizes of cookers that would cater to domestic and instititional facilities.

The barriers to the uptake of this technology are high costs and the entrenched use of LPG in Botswana, which is easily accessible, very flexible and user friendly.

Solar Water Pumping

This is one of the technologies that is not doing well in Botswana, despite the abundance of sunshine and the problems associated with the use of other pumping technologies like diesel engines and windmills. The major barriers are the capital cost, which hinders a lot of prospective users from purchasing the system and the fact that most boreholes in Botswana are more than a hundred metres deep, making the system unaffordable to most farmers.

The Government, mostly the District Councils and the Department of Wildlife and National Parks, have some installations employing solar power for pumping water.

Boreholes are usually situated some distance from the homesteads, making it easy for the panels to be stolen.

There are different types of solar pumping systems in the market, including: Direct Current (DC) and Alternating Current (AC) pumping systems. DC pumping systems tend to be cheaper and simpler than AC ones. Grundfos Pump Company has manufactured a hybrid

[7] Building designs that use solar energy to optimise their energy requirements

pumping system that can use either solar, wind and/or a generator in cases where one form of the energy is not sufficient to drive the pump. Grundfos and Orbit pumps have developed panels that can only be used in their pumping systems. When they are stolen, they cannot be used to meet any other energy requirement, except for the original purpose and with a compatible system.

Solar Water Heating

Solar water heaters (SWH) still have potential in both Government buildings and private households in Botswana. Previously, maintenance was not adequate, with poor water quality exacerbating the diminished life of geysers.

There is no legislation that encourages the installation of solar water heaters, particularly in Government buildings. However, the Department of Building and Engineering Services (DBES) has taken a stand that for every building they supervise, a solar water heater (industrial or household) will be part of the package.

Solarpower's Hi Pressure Solar/Electric Geyser has a lifetime guarantee, with an inner pressure cylinder that takes any corrosive water supply. This insures that there will be no corrosion chemically or electrolytically by galvanic action or otherwise. The system is almost maintenance-free, except on plumbing equipment, as it has fewer components, near zero heat loss (made of fibre glass) and does not accumulate lime or silt.

The expected life span of these Hi Pressure solar geysers is 25 years or beyond for the inner cylinder, but the price is still close to the original Solarpower solar geyser prices. The estimated market share for a company is 1000 systems/year. (Solarpower)

The vacuum glass tube technology is another option identified. This technology uses a double glazed tube with a vacuum between the two tubes to eliminate heat losses. The glass can be used in any type of water regardless of hardness, as the glass would not be corroded and does not take any salt accumulation.

The barriers to the uptake of this technology are:

- Lack of support and innovation in better quality solar water heater development;
- Lack of confidence in the technology because of past experiences with failure of solar geyser systems;
- Water quality, most water sources are from boreholes with high levels of dissolved salts;
- High investment costs;
- Lack of institutional capacity to solicit ideas, and encourage potential entrepreneurs.

Solar Thermal Electricity Generation (parabolic mirrors, chimneys, stirling dishes)

Solarpower, under the Botswana Solar Thermal Electricity Generation Project (BSTEP), intends to implement a one-mega watt (1MW) demonstration project in Botswana. The cost is currently about 6 times that of a coal plant investment per kW. However, Solarpower would like to buy the technology and start developing it in Botswana. This would be a grid connected plant that would displace some of the imports and contribute towards Botswana's self sufficiency in power. This builds on Botswana's vision to be a centre of excellence in solar technology.

The possible barriers to the adoption of this technology are the high cost of investment, limited government support and lack of financial sponsors to bring the project to fruition.

3.2.3.2 Biomass

Wood Chip Briquetting

Wood pellets are a clean, CO2 –neutral and convenient fuel, mostly produced from saw dust and wood shavings compressed under high pressure without glue or any other additives. They are highly standardised and compressed, allowing cost-efficient transportation of fuel. They also facilitate automatic operation of heat and electricity-generating facilities, be they one-family homes or large scale power plants. Pellets are cheaper and less cumbersome to transport than other forms of biomass, while the high degree of standardisation allows for extremely low-emission combustion, even in very small appliances. They are also a highly convenient form of fuel for end-users – they can be delivered by a tanker truck or in bags. In addition, they are suitable for use in automatic feeding systems, making them as user-friendly and time-efficient as gas-or oil-fired heaters.

To start a wood briquetting venture, one should be assured of the availability of the raw material, wood chips. Additionally, the following parameters are necessary:

- Low moisture content (10 – 15 %)
- Ash content and composition
  Biomass residues normally have much lower ash content (except for rice husk with 20 % ash), but their ashes have a higher percentage of alkaline minerals, especially potash (potassium carbonate/hydroxide). These constituents have a tendency to de-volatilise during combustion and condense on tubes, especially those of super heaters. These constituents also lower the sintering temperature of ash, leading to ash deposition on the boiler's exposed surfaces.
- Flow characteristics
  The material should be uniform and granular so that it can flow easily in storage silos. (Biomass Briquetting: Technology and Practices: P. D. Grover & S. K. Mishra, 1996)

There are no known industries in Botswana that are dealing with wood chip briquetting.

The major barrier is that wood chips are not adequate enough to warrant investment in the technology.

a. **Mechanical Piston Press**
Also known as ram and die technology, the biomass is punched into a die by a reciprocating ram with a very high pressure, thereby compressing the mass to obtain a briquette.

b. **Screw Press**
In a screw press the biomass is extruded continuously through a heated taper die, which is heated externally to reduce the friction.

c. **The Hydraulic Press**
In this type of press, the energy to the piston is transmitted from an electric motor via a high pressure hydraulic oil system. This machine is compact and light. Because of the slower press cylinder compared to that of the mechanical machine, it results in lower outputs.

d. **The Pelletiser**
Pelletising is closely related to briquetting, except that it uses smaller dies (approximately 30 mm) so that the smaller products are called pellets. It has a number of dies arranged as holes bored on a thick steel disc or ring, and the material is forced into the dies by means of two or three rollers. The two main types of pellet presses are: **flat type,** which has a circular perforated disk on which two or more rollers rotate, and **ring type,** which features a rotating perforated ring on which rollers press onto the inner perimeter.

Barriers

- Insufficient production of wood chips to warrant establishment of briquetting industry [8];
- No supportive regulations encouraging the use of wood chips;
- Well established superior competing alternatives;
- Technologies (like wood chip boilers) are not developed to take advantage of the raw material.

Elephant Grass

Elephant grass can grow to maturity within 9 months, and it is possible to produce 200 to 300t/ha in Botswana - 30% of which is air-dried (60-90t/ha). The elephant grass can be used to fire heat and power plants either directly or through briquettes.

Sanitas has experimented with the grass as both an energy source and a source of mulching in intensive agriculture.

The barrier to uptake is a lack of information.

[8] Timber suppliers interviewed during the study indicated that all their wood chips are used for other purposes such as poultry houses.

3.2.3.3 Biogas

Sewerage Biogas Generation

The extraction of biogas from sewerage works is already practised at the Gaborone wastewater treatment plant. Here biogas is generated at 2,400m3/ day or 876,000m3/ year. Only 230,000m3/ year is utilised for heating purposes at the site. There is potential to utilise the rest of the gas to replace fossil fuels used for heating in commerce and industry. When considering the sewerage plants in other cities and towns, a larger potential can be realised.

The current barrier is a lack of resources for project feasibility and a lack of potential investors.

Slaughterhouse Biogas Generation

There is potential to generate biogas from livestock abattoir waste. RIPCO (B) and Sangfroid are pursuing this project as a potential CDM project, where the biogas produced will be cleaned and bottled as a replacement to LPG. Potential CERs with Botswana Meat Commission (BMC) abattoir waste alone is 7kt of CO2/year from combusting methane. Additional benefit can be realised through substituting fossil fuels and fuel wood with methane from biogas. Bundling with abattoir waste at the other abattoir sites will boost CER potential to over 20kt/year including fuel substitution, but the resources are not well known and need to be evaluated. With a CER capacity of 30kt/year, the BMC project would qualify for funding for a feasibility study from the World Bank Prototype Carbon Fund.

Institutional biogas plants also have a large potential, compared with the household use of biogas.

The barriers to adoption are a lack of financial resources for feasibility studies and investment capacity for project development on the technology.

Household Biogas Plants

RIIC installed about twelve Indian type floating dome biogas plants in Botswana between 1982 and 1987 . The sizes ranged from 15m3 - 110m3 for water pumping, cooking and demonstration purposes. The sociological evaluation of the biogas installations done in 1988 revealed that investment in a biogas plant involves a substantial amount of capital, which by rural standards in Botswana is very high. The collection of cow dung, compounded by open grazing, which many farmers practise, has also been cited as a problem to regularly feed the digester.

It is important to note that where individuals owned the biogas plants, they operated for much longer periods without any problems. Problems surfaced in syndicate owned plants just a few months after commissioning. It is also worth noting that all the syndicate plants were donated, therefore there was no sense of ownership. Biogas was used as a substitute to other sources of energy. There were three demonstration sites in RIIC, BCA and the International Trade Fair Grounds. Except for the RIIC demonstration site, all the other plants are not working.

Landfill Biogas Generation

Biomass involving the use of landfill gas from municipal solid and liquid waste is becoming popular, and Gaborone City Council is planning to tap landfill gas at the proposed landfill along the Molepolole Road. Siemens (Germany) has expressed interest to develop a landfill gas project with Gaborone City Council.

Landfill projects are gaining popularity in the Clean Development Mechanism (CDM) arena. A consolidated methodology for developing baseline and monitoring for landfill gas has already been passed by the UNFCCC-CDM Executive Board. The Durban project, in South Africa, is a good example of such projects. Production boreholes will be developed at existing landfill sites that currently flare some methane for safety. Even if the landfill sites in Botswana are not developed with production boreholes, they can be retrofitted at a later stage. Heat rate of methane gas is 52MJ/kg methane compared to 24MJ/kg coal and landfill gas has 50-60% methane.

Apart from waste management, the project can reduce CO2 in the atmosphere when methane is used for energy and can earn additional revenue in certified emission reduction (CER).

The barriers to adoption are limited information and minimal investment capacity for project development and no project proponents.

Biogas Experiences from other Countries

In some countries, e.g. RSA and China, household biogas plants are constructed in homesteads and the waste from the toilets is fed directly to the digester to meet all the lighting and cooking needs of the household.

In other countries like Germany, Sweden, the Netherlands and Switzerland, the biogas produced mainly from sewage treatment works is cleaned to natural gas quality for use in cogeneration plants supplying heat and power, vehicle propellant and injection into public gas networks.

The solid waste management programme that is putting up landfills in major villages and cities in Botswana will form an impetus to this kind of technology where the gas produced can be cleaned to natural gas quality and bottled for use in households as a replacement to LPG.

In Botswana there is potential to use chicken waste to feed the biogas plants to meet the poultry farms' heating and lighting requirements; this is a problem at the moment; and the matter needs to be further investigated.

The barriers to adoption are lack of financial resources for feasibility studies and minimal investment capacity for project development of the technology. For individual biogas plants, the problems are mainly capital cost and collection of cow dung.

3.2.3.4 Bio-fuels

Jetropha

Producing bio-fuels from Jetropha has great potential and would only be limited by field size and oil pressing capacity. Mali is using it to produce bio-diesel for its multi-platform generators. In Zambia bio-diesel is used to produce lighting fuel. Jetropha has great potential in Botswana - to produce bio-diesel for water pumping and to substitute paraffin for lighting, as bio-diesel is cleaner and does not have harmful fumes.

The barriers to uptake are lack of information and the fear that Jetropha could become a weed. It should therefore be grown in open grasslands to vegetate the landscape.

3.2.3.5 Coal

Coal Washing

Coal washing is a technology that could transform Botswana's high ash and high sulphur coal into a coal of high quality. The imported coal for boilers, future demand in Botswana and coal export to Bulawayo all warrant a coal washing plant with a capacity of 30,000t/ month. (G4 Botswana)

Product	**Moisture (%)**	**Volatiles (%)**	**Ash (%)**	**Fixed C (%)**	**CV (MJ/kg)**	**Sulphur (%)**	**Mass Yield (%)**
32 mm Run Of Mine (ROM)	4.61	22.71	20.33	52.36	23.12	1.84	100
Coal Washed @ 1.6 specific gravity (sg)	5.00	22.84	14.65	57.52	25.43	0.36	71.60

Source: G4 Engineers (pers. Comm.-Preliminary Results of the Feasibility Study on Coal Washing at Morupule)

Table 2: Single-Stage Washing of Morupule Coal

Table 2 shows the improvement in coal quality after washing; it was tested by G4. There is significant reduction in sulphur and ash.

The coal quality and selling price would have to be competitive with imported coal from South Africa. Washed coal also has potential for use by BPC at Morupule Power Station, as it would reduce energy requirements for combustion and plant maintenance costs.

Excess ash in coal needs to be extracted at cost from the flue gases using capital-intensive systems. It also fuses into the plant ducts, raising maintenance costs. Reducing sulphur would also reduce desulphurisation costs, such as scrubbing systems that are required to keep ambient air at acceptable levels for fauna and flora.

The barriers for adoption are the high cost of the coal washing plant and a lack of potential investors.

Coal Bed Methane [9]

In the exploration area tested, the potential for coal bed methane (CBM) was found to be 60Tcf [10] and the associated carbonaceous shale had an additional 136Tcf (total 196Tcf), the more realisable quantity was about 12.8Tcf. Of this gas 15-20% can be developed at US$2/Mcf [11] at the wellhead. Some US companies have expressed interest, and US OPIC has funded a further feasibility study of the project.

SADC is also promoting the exploration of coal bed methane. Coal bed methane resources in Botswana are believed to be larger than the natural gas to be piped from Mozambique through the Maputo pipeline to the Secunda Sasol Plant-South Africa.

CBM can provide fuel for cars and power generation, and could alleviate the power crisis the region is about to face. There is a market for all heating and cooking end uses in industry (food, bricks, and steam) and households. Gas (CBM) can be transported in large cylinder containers similar to LPG or through pipelines.

Petrol cars can run on 100% methane and diesel cars on 90% methane and 10% diesel, which would also be a huge saving on petroleum imports.

Target markets for such transport fuel substitution are fleet organisations such as the Central Transportation Organisation (CTO) of the Botswana Government and the Botswana Defense Force (BDF).

The Botswana Gas Corporation (BGC) planning the installation of 500kW gas turbine station for site power supply, and 15 to 20 production boreholes will be installed.

The barriers to uptake are that the market is not yet established and a lack of infrastructure for exploitation, distribution, and utilisation of the gas.

[9] Methane that is trapped in the coal seams

[10] Trillion cubic feet (Tcf)

[11] Million cubic feet (Mcf)

3.2.3.6 Other Energy Sources

Decentralised Generation

The Department of Buildings and Engineering Services and the Botswana Power Corporation have been running decentralised electricity generation in villages that are not connected to the national grid. However, as more villages are being connected to the national grid, decentralised generation has decreased. There are plans, though, to provide decentralised generation to villages like Seronga in the near future. DBES, through the Electrical Services Division, is still providing a back-up of diesel generators to Government institutions like hospitals.

The barrier to adoption is high maintenance costs.

Liquefied Petroleum Gas (LPG)

LPG is available nearly anywhere in the country. It is usually brought into Botswana by tankers and then locally packaged in gas cylinders before distribution to retailers. There is no control of prices by Government and to this effect, efforts are at an advanced stage to form an LPG Association to develop standards. Training on the safety aspect of LPG is not done, despite the risks involved in handling this kind of technology.

This technology is well adopted and there are minimal barriers to uptake.

Fuel Cells

This technology is still at an early stage of development and has not made much impact on the country. In South Africa there is a known application of fuel cells for small power production.

Fuel cell technology will be assessed for application in the Botswana situation. The manner in which it can avail modern energy services to the majority of Batswana using coal bed methane as a source of hydrogen will also be assessed.

The barriers are the high cost of reformers, the storage for hydrogen and unfamiliar technology.

Modern Wind Technologies

The wind regimes in Botswana are very low hybrid systems of wind and diesel. These are the most appropriate options for the low wind speeds experienced in Botswana. This technology still needs to be assessed further based on the wind energy sources available.

The Wind Mapping Project currently jointly undertaken jointly by RIPCO (B), BOTEC and DMS has not yet been concluded. However, the results from the exercise will form the basis for decisions on wind related technologies to be adopted.

The low wind regimes in Botswana are the major barriers.

Hybrid Systems

Grundfos has developed a water pumping hybrid system that utilises both wind, solar energy and electricity. The Department of Wildlife and National Parks is using diesel/solar hybrid systems for water pumping in the Chobe National Park.

The barrier to adoption is the high cost of purchasing redundant options.

3.2.4 Energy Efficiency

3.2.4.1 Buildings

Technologies that support passive solar designs and energy management systems in buildings entail energy audits , building orientation, window glazing, sun shading louvers, compact fluorescent lighting (CFL), lighting management and design competitions. Examples of these technologies are BOTEC Maranyane house in Gaborone and Maun Hospital. The Maranyane House is currently being evaluated for its performance as a solar passive design (BOTEC per. comm. 2004).

A project will soon be implemented in Botswana under the Danish International Development Agency (DANIDA) funding to experience the energy efficiency opportunities that exist in this sector.

The barriers to adoption are a fear of not realising the possible savings and the high cost of design, as well as limited flexibility in the current building regulations.

3.2.4.2 Households

To achieve energy saving technologies for households, Somarelang Tikologo is engaged in promoting CFLs, SWHs and solar ovens. They are also involved in energy audits targeting schools and households, to raise energy conservation awareness.

The labelling of appliances such as refrigerators is another technology suitable for people to make suitable choices. This can be implemented through the Botswana Bureau of Standards (BOBS).

Possible barriers to adoption are market resistance due to an inability to realise the possible savings; returns are also not substantial enough to convince people to purchase these technologies and adoption requires government incentives.

Lack of support for NGOs is also a hindrance in Botswana.

3.2.4.3 Agriculture

Zero tillage involves the reduction of fossil fuel use in agriculture by minimalising soil tillage by up to 60%. This also improves yields.

The barriers are the limited knowledge of the farmers, high cost and unavailability of equipment.

Section 3.3 Water Conservation

3.3.1 Role of Water in the Economy

Water is a scarce resource affecting many aspects of the nation's developmental programmes and natural environment. It is a key resource in any plan for implementing a sustainable approach to development. Vision 2016 recognises this and states that by the year 2016, Botswana must have a national water development and distribution strategy that will make water affordable and accessible to all, including those who live in small and remote settlements. It further says that Batswana must use water as efficiently as possible through water efficient technologies and various water conservation techniques, such as water harvesting from rooftops. Botswana must play a full part in negotiating and promoting international agreements concerning water usage and storage at the regional level, to provide a buffer against localised drought, which is a common phenomenon in Botswana.

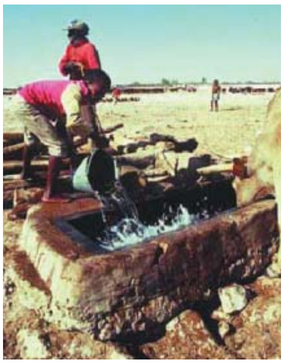

Figure 11:

Water is a scarce resource in Botswana (Photo: Illustrative Options)

During NDP8 [13], Government had two aims in the water sector:

- To meet the water requirements of the population through the provision of a clean, reliable and affordable water supply, which is available to all, and;
- To meet water requirements for industrial, mining, agriculture, wildlife, commercial and institutional users in order to achieve the major aims of rapid economic growth and sustained development.

These aims will continue to be valid throughout the NDP9 [14] as they are in perfect alignment with Vision 2016.

3.3.2 Overview of the Water Sector

The Ministry of Minerals, Energy and Water Resources (MMEWR) has overall responsibility for policy in the water sector. Within the ministry, the Department of Water Affairs (DWA) has the responsibility for national planning and water allocation. This task involves making decisions about which next major source of water should be brought on line and which parts of the country should next be supplied.

[13] NDP 8 period 1997/98 to 2002/03

[19] NDP 9 period 2003/04 to 2008/09

Through a bilateral corporation project between the Botswana and Danish Governments carried out in the NDP8, DWA has been designated the national focal point for water conservation in Botswana.

In the area of water resource development (i.e. construction of dams and well fields, water transfer from source and water reticulation to the user point), Water Utilities Corporation is responsible for the water supply to urban centres and other areas as may be designated by the minister, while the responsibility in rural villages is mainly shared by DWA and the Ministry of Local Government (MLG) through district councils. The Ministry of Agriculture is responsible for the construction of small dams targeted mainly for agricultural use.

In NDP8, DWA was responsible for the development of sources of water supplies (dams and well fields), supported by the Department of Geological Surveys (DGS) in the case of well field development, for almost all rural villages. MLG's main responsibility remained concentrated on operating and maintaining small village water supply schemes through district councils under the Water and Wastewater Department.

The Water Quality, Protection and Conservation Project was commissioned during NDP8 to assess the social acceptability and economic and technical viability of wastewater re-use. The project considered the utilisation of treated wastewater effluent as a potential resource in the process of national planning. This was also emphasised in the National Water Master Plan (NWMP) study completed in 1992, but under review in 2004.

The first phase of the Water Quality Management Project was completed in the NDP8. The project addressed two main components, namely improvement in the water quality monitoring functions of DWA and water conservation activities. As a follow-up to the Water Quality Management project, a water conservation and water demand management project was also developed and commenced towards the end of NDP8. This project is aimed at addressing issues of public awareness and education, as well as improved availability of water-saving technologies, techniques and measures.

The results emanating from the Water Quality and Conservation Project were successful piloting of the prepaid meter system in Tlokweng village and retrofitting fixtures at the Botswana Police College. During NDP9, plans are to phase out the old standpipes in 17 major villages and to replace them with the prepaid ones.

During NDP8 the Botswana Bureau of Standards (BOBS) developed the national drinking water quality standards (BOS 32: 2000), which were launched towards the end of NDP8. These standards replace and are more stringent than the old DWA drinking water quality guidelines.

The Department of Sanitation and Waste Management (DSWM) has assessed the re-use potential of wastewater in Botswana through the development of the National Master Plan for Wastewater and Sanitation (NMPWWS). The treated effluent re-use potential in Botswana is not optimised, because effluent is not seen as a water resource, but rather as waste to be disposed off.

3.3.3 Water Treatment Technologies

The need for water conservation is emphasised in the National Development Plans (NDP8 and 9). This is due to the alarming rate at which water is being depleted. The increase in the demand for water indicates that crucial measures need to be put in place to conserve water.

Insufficient waste management contributes to most of the water resource pollution. Without preventive measures and tight control systems, high risks of water pollution become prevalent. It is, however, of great importance to identify appropriate technologies to treat both potable water and wastewater to protect this finite resource in Botswana.

For plants, animals and humans, pure and adequate water is a prime need. Without water life is not possible. Plants and animals need water to maintain the functions of their bodies. The human body consists of 60% water, and an adult requires for his or her good health a daily consumption of 2 to 5 litres of water, dependent on his or her activities and climatic conditions. The crucial role of water is closely related to the physical and chemical properties of water.

Since earliest times, people have been aware of the importance of the availability of clean water. Sanskrit medical lore and Egyptian inscriptions afford the earliest recorded knowledge of water treatment (Baker, 1948). The recorded methods comprised of exposing water to sunlight, boiling it, and filtering it through sand, coarse gravel, or charcoal.

In the ancient civilisations of India, Egypt, and classical Greece and Rome, the gods oversaw the well being of the oceans. These gods were respectively Varuna, Sebek, Neptune and Poseidon. Today, modern civilisation ascribes humans as the caretakers of water, including the management and control of water quality.

The technologies for water treatment are categorised into two types: the treatment of potable water and wastewater. These technologies bring about the benefits of conserving the scarce and finite water resource by bringing it to an acceptable quality to support plants, animals, humankind, and industrial activities.

The use of technologies to treat both potable and wastewater creates an economic good. Treating water for potable use applies techniques that convert water that had impurities, thus facilitating its safe use for drinking or other domestic applications.

The treatment of wastewater involves removing contaminants which occur in the forms of micro-organisms, chemicals, sewage, and industrial or other wastes, so that it is fit for its intended use or applications. Wastewater, if properly treated, becomes a resource that compliments the available resources of both surface and groundwater.

Water treatment technologies for potable use vary depending on the type of raw water and the nature of the impurities in the raw water. Technologies available in Botswana to treat potable water for both drinking and industrial applications are as follows:

- Reverse osmosis;
- Polymer technology;
- Demineralisation.

These technologies are used in different applications to treat water that has impurities of varying mineral constituents.

Reverse Osmosis

Osmosis is a natural process that involves the exchange of water and minerals through cell walls. When a semi-permeable membrane separates water with different concentrations, the weaker solution will be forced through the membrane to dilute the higher concentration until a measurable pressure is created. This pressure is called the osmotic pressure.

Reverse osmosis occurs as a reverse process of the natural osmotic pressure by creating such a high pressure on the concentrated side that the osmotic pressure is overcome. The solution of high concentration is then forced through the membrane in the reverse

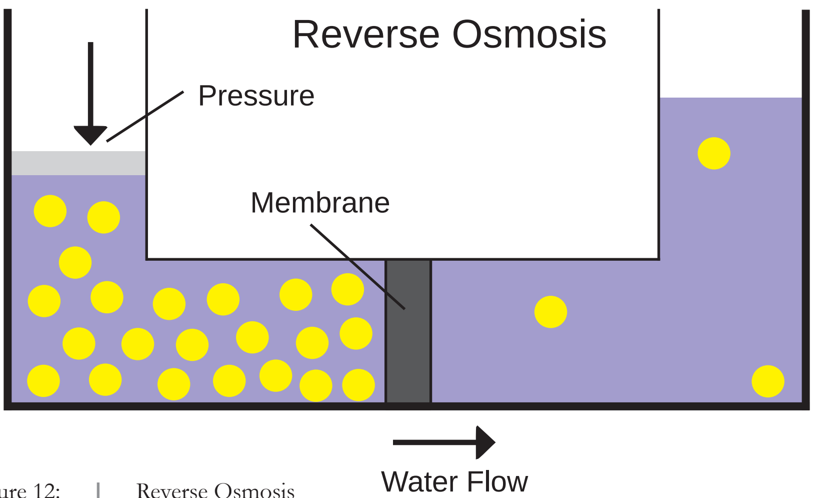

Figure 12: Reverse Osmosis

direction with only the solvent water passing through not dissolved substances. The membrane [15] functions as an ultra-fine filter, which is capable of separating even superior molecular substances such as viruses, bacteria and pyrogenes. (See Figure 2: Reverse Osmosis)

The Department of Water Affairs and the District Councils have installed a number of these technologies across the country in places such as Bokspits, Tsabong, Mahotswane, Hunhukwe, Zutshwa, Ramotlabaki, Sehithwa, Makalamabedi, Kachikau and Moreomaoto. The technologies to treat potable water for community use are supplied by ODIS (Pty.) of Israel and Envirg of Botswana.

The barriers to the uptake of this technology are high capital investment, high running costs, maintenance needs, and lack of skilled manpower.

Currently there are no alternative technologies in Botswana to improve the quality of brackish water. RIPCO (B) tried solar stills in Zutshwa, but the production rate was very minimal such that it could not be used for a village water supply.

The cost of water plants varies depending on the volumes and types of water to be treated. The installation of a plant to treat 15m3/hr, inclusive of ponds, costs BWP4 million. Maintenance costs for a plant producing 60m3/day is BWP121,300 per month (DWA pers.comm.).

Demineralisation

This technology treats water to remove solids in the form of cations (sodium and calcium). Water treated using this technology is used mainly in boilers for the production of steam for power generation at Morupule Power Station. The capacity of the demineralisation plant at Morupule Power Station is 700m^3/day. The running cost of the plant at Morupule Power station is approximately BWP90,000 per year (BPC pers. comm.). ESMIL, a French company, supplied the plant for the Morupule Power Station.

Other water uses are for food processing, manufacturing, pharmaceutical, and other industrial activities. Sud-Chemie supplied plants to Kgalagadi Breweries Limited (Pty). Reverse osmosis can be an alternative technology.

A barrier to the uptake of this technology is high capital costs.

Polymer Technology- Scale Formation Inhibiting

Long chain polymers react with hardness, forming ions to inhibit the formation of scale due to hard water. This is applied in the treatment of water to be used in boilers, such as at Kgalagadi Breweries Ltd, hospitals, Botswana Vaccine Institute, abattoirs, etc. Sud-Chemie of South Africa supplies the technology. Phosphate technology can be used as an alternative technology.

A barrier to adopting this technology is that it is not common and therefore needs aggressive marketing and trials to prove its effectiveness.

[15] In Botswana the technology of reverse osmosis is used to treat water with highly dissolved substances such as salts and other minerals. A reverse osmosis plant is not only for removal of salts from salty water, but it is also used to treat water with some other impurities such as fluoride, manganese, iron and colour.

3.3.4 Wastewater Treatment Technology

Technologies for wastewater treatment range from conventional treatment plants (activated sludge) to non-conventional treatment (waste stabilisation ponds, constructed plants, lime and limestone treatment). The installation of each plant is characterised by the prevailing situation in terms of wastewater generated (quantity and quality).

Activated Sludge

This is a conventional type of wastewater treatment system. The treatment plant is highly mechanised and is highly efficient if operating at nominal design capacities. In Botswana there are plants constructed at Thamaga Hospital, Orapa and Gaborone. The Gaborone plant is the biggest one; it treats all the sewage generated from Gaborone and the surrounding villages. It has been designed to treat 40,000m^3/day of wastewater, and was constructed by China State Construction under the supervision of Stewart Scot consultant.

At the treatment plant, large amounts of biomass are collected during the treatment process, resulting in the production of methane. The methane is captured and re-used in the treatment process. Excess methane gas is flared.

The barriers to adoption are the high costs of operation and maintenance and the need for highly skilled personnel.

Waste stabilisation ponds were used for the treatment of wastewater prior to the construction of the Gaborone Activated Sludge Plant. However, now they are used to hold effluent water after treatment from the plant to further improve the quality of treated water.

The investment cost of the plant was BWP86 million, and the annual running cost is BWP3 million.

Trickling/Percolating Filter

This is another conventional method of wastewater treatment. In Botswana, this system is only found in Francistown. The design capacity of this plant projected up to 2010 is 15000m^3 per day and at present is at 45% utilisation. The cost of this plant was BWP60 million and Steffaun and Breffan constructed it. At the treatment plant large amounts of biomass are collected during the treatment process, resulting in the production of methane. The methane is captured and used to incinerate solids trapped by the screens. Slurry from biogas digesters is collected in the sludge drying beds and incinerated. Alternative technologies are activated sludge and stabilisation ponds.

The barriers to the uptake of this technology are the costs of construction and maintenance.

Vacuum Sewerage System

This technology is for the collection and disposal of sewage to treatment systems. This is a relatively new technology in Botswana and Africa as a whole. Old installations of these technologies are found in Europe (Germany and the Netherlands are good examples). The technology is relatively good and effective in places of flat terrain, as it does not need water for the flow of sewage. The flow of sewage is effected by the creation of a vacuum pressure within the mains of the sewer.

Vacuum Sewerage Systems are found at Shoshong in the Central District. The systems are still new and not yet operational. The system's advantage to the ordinary gravity sewer system is that it saves huge amounts of water. The capacity of the system is dependent on the needs of the prevailing local situation. Orbit Pumps Botswana supply this technology. The cost for the Shoshong project is BWP14 million. Gravity sewers are the most common in Botswana and can be used as an alternative.

The main barrier to adoption is that there is a lack of knowledge, as the technology is still new in Africa and Botswana.

Rotating Bio-Contactors

The Rotating Bio-Contactor is another conventional method of wastewater treatment found in Botswana. The technology is mechanically operated with horizontally rotating bio-discs.

This type of technology can be found at Kanye Seventh Day Adventist Hospital (KSDAH), the new prison in Moshupa and Otse Police College. In Kanye, at KSDAH the effluent water is recycled and re-used for irrigating trees and lawn. The one at the new prison in Moshupa has also been designed for the re-use of wastewater for irrigation purposes. The supplier of the plant at the new prison in Moshupa is Orbit Pumps Botswana; it costs BWP1.5 million.

This type of technology is commonly used to treat wastewater discharges in large institutions, but it does not commonly handle wastewater discharged from large municipalities.

There are no major barriers to the adoption of this technology.

Alternative technologies are sewage ponds, activated sludge, and trickling/percolating filters.

Waste Stabilisation Ponds

Waste Stabilisation Ponds use the natural process of oxidation of organic matter during the treatment process. The ponds are designed such that wastewater flows in by gravity from one pond into another, and during this period micro-organisms or bacteria digest organic matter.

The systems are designed to treat large flows of wastewater for institutions, villages or towns. The systems that were visited and which were still in operation were in Ramotswa and at the Botswana Meat Commission (BMC) in Lobatse. The Ramotswa wastewater stabilisation ponds have been designed to treat wastewater in excess of 5000m^3/day. The ponds at both Ramotswa and Lobatse were constructed by Stock and Stocks Botswana under the supervision of Group Consult Botswana. The extension of the Ramotswa Stabilisation Ponds and the sewer line cost BWP68 million. The running cost is BWP3.6 million per annum. Alternative technologies are bio-filters and activated sludge plants.

The main barrier to adoption is that the technology requires a large area of land.

Constructed Wetland Systems for Wastewater Treatment

Constructed Wetlands are man-made systems designed to simulate nature to treat wastewater through physical and biological processes. The technology is used to treat wastewater for small (household) to large municipal size treatment systems.

In Botswana, the systems in place are at the Jwaneng Mine, Kanye Prison, Ramatea Vocational School in Kanye, and the Tlokweng College of Education. All these systems have been designed to treat wastewater for re-use in irrigation (e.g. the Jwaneng Mine Wetland is used to polish effluent water from the town stabilisation ponds and the water is used to irrigate the golf course).

The Jwaneng Mine Wetland is designed to treat about 50m^3/day of wastewater. The Kanye Prison is designed to treat 25m^3/day, and the Ramatea Vocational School and Tlokweng College of Education are designed to treat about 20m^3/day respectively. The cost of constructing the Jwaneng Mine Wetland was BWP700,000 and the running costs are BWP10,140 per month.

A private contractor constructed the Jwaneng Mine Wetland. The Kanye Prison, Ramatea Vocational School and Tlokweng College of Education were all designed and constructed by RIPCO (B). Alternative technologies are stabilisation ponds and rotating bio-contactors.

The major barrier to adoption is that the technology requires large areas of land.

Lime/Limestone Neutralisation

This is a technique used for treating wastewater discharged after the treatment of ore at the Selibe Phikwe mine. Lime/limestone is used to neutralise acid water that was used in the cleaning process of the ore. A lime/limestone plant treats 100m^3/hr of wastewater, and for nickel precipitation the rate is 250m^3/hr. The limestone treatment technique is supplied by

CSIR of South Africa while lime treatment is done in-house by BCL mine.

The cost of the limestone plant was BWP5 million; the lime plant cost BWP500,000. The running cost of the limestone plant is BWP1 million per year, and the cost of lime neutralisation is BWP400,000 per year. An alternative technology is constructed wetland for the treatment of acid water.

A barrier to adoption is the scaling of pipes, which is frequently caused by the limestone.

3.3.5 Rainwater

Botswana is a semi-arid country with limited water resources. The annual rainfall pattern ranges from less than 250mm in the extreme southwest of the country to more than 650mm in the extreme north. The rainfall is erratic and mainly concentrated in a rainy season lasting from October until April. Evaporation rates are very high, exceeding 2000mm/annum in most areas (Bhalotra, Y.P.R, 1985).

Due to Botswana's flat topography and sandy pervious soils, surface water sources are limited. Permanent surface water is rare in Botswana, although a few ephemeral rivers have been dammed to create reservoirs to serve major towns and villages. The lack of suitable rivers and dam-sites means that surface water resources are inappropriate for rural water supplies in most areas in Botswana. Because surface water resources are not feasible, boreholes are the most appropriate source.

Good quality groundwater is available in some areas in Botswana, but in a number of areas groundwater is too deep, unreliable and/or too saline to provide an acceptable supply for potable use. In these areas, alternative sources have to be found or water has to be transported in bowsers from long distances at great expense. In such locations, rainwater collection is the most cost effective option.

Rainwater catchment systems can also play an important role in helping to conserve water in towns, villages and settlements. In villages and settlements, rainwater catchments can provide an invaluable supplementary or back-up supply. A supplementary or back-up supply could be used during the breakdown of water mains, or when maintenance work is carried out, or during severe droughts when supply boreholes have dried out. Rainwater catchments systems, especially in the form of individual roof catchment tanks, play an important role in remote and isolated homesteads.

In rapidly growing urban centres in Botswana, such as Gaborone, Francistown and other major villages, rainwater catchment systems offer the potential to reduce the water demand from the mains supply. Rainwater catchments systems, if properly implemented, allow for enough time to find alternative sources of supply in periods of drought.

Rainwater catchment systems can also be used in villages with existing reticulated boreholes or dam supplies to act as a supplementary back-up supply at times when the main system is not functioning. Villages and remote settlements suffering from periodic water shortages and which are currently being supplied by costly means of supply, such as bowsers, should be targeted as priorities to increase the rainwater catchment systems.

3.3.5.1 History of Rainwater Catchment Systems in Botswana

Traditionally in Botswana, people have been collecting rainwater running off ground surfaces in excavated pits and from the eaves of thatched roofs for centuries. This practise may still be prevalent in some rural areas of the country.

The use of more formalised rainwater catchment systems such as roof catchment tanks probably dates back to the turn of the twentieth century. The first major research study on rainwater catchment in Botswana was carried out in Radisele in the Central District in 1966. The publication of this research finding was done by the Intermediate Technology Development Group (ITDG) in 1969.

The ITDG report outlined the project's installation of ground catchment tanks, which were intended to collect surface run-off and which could be stored and used for irrigating vegetable gardens. Follow-up reports by ITDG (1971), Farrar and Pacey (1974), Pacey and Cullis (1987) concluded that although the project failed, partly as a result of the high labour requirements involved, it had given impetus to the inception of the Arable Lands Development Programme's (ALDEP) Tank Programme, which started a decade later.

The biggest scheme responsible for rainwater tank construction in Botswana has been ALDEP, administered by the Ministry of Agriculture. Through their water tank package, which provided subsidy to small farmers, more than 700 sub-surface ferrocement ground tanks were built from 1979 to 1991. Most of these used traditional threshing floors or compacted surfaces as catchment aprons. Between 1991 and 1993 more than 200 of 7m^3 polyethylene surface tanks connected to roof catchment systems were installed.

Ground Catchment Tanks

ALDEP tanks were originally designed to provide water for draught animals at the lands to allow for early ploughing at the start of the rainy season. In addition, people used the water for domestic purposes, including drinking (Ainley 1984).

The major barrier to adoption is that these ground catchment systems use traditional mud/dung threshing floors as catchment areas. As a result, the quality of water in most of these catchment systems has been found to be poor, due to contamination by faecal matter.

In response to this, the Ministry of Agriculture developed a raised corrugated 40m2 iron sheet catchment area and a 7m^3 polyethylene tank, (Visscher and Lee 1991). The replacement of the ground catchment by the roof catchment improved the quality of rainwater, thus making it suitable for drinking.

Roof Catchment Tanks

Roof Catchment Tanks are a common sight in many primary schools in Botswana, and they are also found at clinics and some government buildings in many villages. In most cases the District Councils construct and maintain the tanks. The tanks found in councils and government premises are constructed from corrugated galvanised sheets, bricks, and polyethylene material.

The common barrier that has been identified is that these tanks leak. Leakage is a serious problem, especially with the corrugated galvanised sheets and the brick tanks, and is due to poor design and workmanship resulting in the development of cracks.

Some private households have been investing in the roof catchment tanks, especially in the rural areas where the traditional grass roof thatching is gradually being replaced by the modern corrugated roof sheets and tiles.

The Botswana Technology Centre (BOTEC) and RIPCO (B) undertook a training programme on the construction of ferrocement rainwater catchment tanks in different localities in the southern part of the country. The training emanated as a result of the study conducted by BOTEC in the 1980's whereby a number of problems, due to poor workmanship, inadequate training, and ineffective supervision (Gurusamy 1991), were identified.

A ferrocement tank construction programme commenced on the 2nd July 1996 and was completed on the 12th December 1996. It had been initiated by the Ministry of Local Government, Lands and Housing (MLGLH) in cooperation with the Ministry of Agriculture (MOA). The Botswana Technology Centre was assigned to implement the project and RIIC was engaged as a sub-contractor.

A total number of 16 ferrocement tanks with sizes ranging from 10 – 46m^3 have been constructed as part of the training. These tanks were constructed within a radius of 80km from Kanye at the following locations: Moshaneng, Moshupa, Polokwe (between Kanye and Moshupa), Kanye and Ranaka. The aim of the project was to run an intensive training in ferrocement tank construction to train trainers and builders. The programme participants were from the Brigades, the District Councils, the Ministry of Agriculture and the Botswana Defense Force.

This project was phased out in two phases: these were implemented at different stages as shown on Page 40.

The main advantages of the rainwater catchment systems are that they can be built anywhere in the country and can provide good quality water sources.

The barrier to the uptake of this technology is the high cost per unit.

PHASE 1

Part I	National ferrocement survey
Part II	Rainwater catchment systems workshop
Part III	Pre-feasibility, fact finding mission and initial design

PHASE 2

Stage I	Training course ferrocement tank development project (theoretical training)
Stage II	Practical training and construction of 16 ferrocement tanks

The future development of rainwater catchment systems can only succeed if the government puts in place programmes that support and fund the technologies for rainwater harvesting.

Section 3.4 Social Acceptability of Wastewater

3.4.1 Introduction

Re-using treated wastewater is beneficial in that it aids in conserving water. In many locations where the available supply of fresh water has become inadequate to meet water needs, it is clear that the once used water collected from communities and municipalities must be viewed not as a waste to be disposed of, but as a resource that must be re-used. It is commonly accepted that access to water is a basic human right. The Dublin Conference in 1992 asserted that "... it is vital to recognise first the basic right of all human beings to have access to clean water and sanitation at an affordable price." (ICWE, 1992)

Figure 13:

CBM Discharge Pipe and Trench (Photo: Kuipers)

Many societies believe that water has special cultural, religious and social values, which marks it off from other economic goods. In many cultures, goals other than economic efficiency influence the choice of water management institutions. However, the focus on water's special status tends to obscure the fact that, in most societies, only a tiny fraction of water consumption is actually for drinking and preserving life. A large portion of urban water is used for convenience and comfort. The value of water to particular users depends crucially on its location, quality and availability. Water's location determines its accessibility and cost. Its quality affects whether it can be used at all, and at what treatment cost. The time when it is available governs its reliability and its relative value for power, irrigation, and environmental or potable uses.

Water is a key commodity in food production, processing and preparation. Water is a limited resource in Africa in both quantity and quality. Yet many parts of Africa experience torrential rain whereby vast quantities of water are allowed to wash away soil into the rivers and oceans, when it could be harvested for more effective uses, such as in irrigation and associated food processing activities. Water scarcity leads to unsanitary conditions thus putting foods at high risk of contamination. According to the World Water Council, a global think tank on water issues, by the year 2050, water shortages are forecast in more than 70 countries, including 35 in Africa and several in the Caribbean, which could result in what is called 'water stress' (Anon, 1998).

Botswana's water supply is a critical issue for its future, regardless of climate change, and will become an even greater challenge if in the future the earth's climate becomes warmer and drier (BINC). Wastewater is recognised as an important water resource that could be used more extensively. The ephemeral nature of the surface water supplies, and Botswana's increasing dependence on these sources, increase the country's vulnerability to drought and climate change (Zhou and Masundire, 1998).

Current Status

Currently some 12,380 Ml/year of "new water" is produced in Botswana. The bulk (80%) of this water (11,200Ml/yr), is produced by five urban wastewater treatment works (WWTW) at Gaborone, Francistown, Selibe Phikwe, Lobatse and Orapa. Some 7,300 Ml/yr of this "new water" is re-used, representing 29% of flows entering WWTW country-wide.

A study on the social acceptability of wastewater was carried out in 12 areas; the sample size is shown in the table on page 42. Due to time and budget constraints the study managed to cover 158 households and 3 institutions; the topic was the usage of wastewater.

Year	Estimated "New Water" Volumes	
	m^3 / d	Ml / year
2001	33,700	12,200
2010	83,000	30,000
2020	144,000	52,400
2030	200,000	73,000

Source:
Department of Sanitation and Waste Management (NMPWWS, 2003)

Table 3: New Water for Re-use

3.4.2 Findings

Three institutions were interviewed: Mokolodi Nature Reserve, Botswana Meat Commission and South East District Council.
The study found that a lot of wastewater is currently produced in households, and it is just being thrown away, i.e. 52% of the respondents interviewed said they just throw used water on the ground, 34% throw it in pit latrines and the rest use it in gardens, or it goes in septic tanks and soaks away. Of those interviewed, 52.5%, said they know about wastewater

recycling and only 32.9% use wastewater in their gardens.

Many households have access to clean water; 87.3% of those interviewed said they get their water from the dam, 11.4% from boreholes and the rest did not know. A majority of the households had water in their yards, i.e. 60.8 %, while 13% get their water from public standpipes. Sixty-seven point one per-cent (67.1%) of the respondents said they could use wastewater in their households as long as it is treated. Most of the respondents preferred

Town / Village	Sample
Gaborone	20
Tlokweng	15
Mogoditshane	15
Metsimotlhabe	15
Kumakwane	16
Gabane	13
Mmopane	15
Oodi	16
Matebele	10
Mochudi	5
Ramotswa	13
Serowe	5
TOTAL	158

Table 4: Sample Sizes

that wastewater be used for horticulture, brick-making, cleaning and gardening, since they think it is dirty and not good for human consumption.

The study also found that 64.6% of the respondents prefer grey water to black water because they think black water has a lot of germs and causes diseases, believing it contains human waste. The respondents also suggested that it would be better if they are not told where the treated water or the supplied water comes from. They preferred not to be told about the source of the water, because if the source was revealed that would determine whether or not they would accept the treated wastewater.
Table 5 shows that 60% of those interviewed in Gaborone said they would not use wastewater in their households. However, in other areas most respondents said they can use wastewater in their households; 46% of the total respondents said they would use wastewater in their households, except for cooking and drinking. Therefore, we can conclude that wastewater usage is accepted in households as long as is not for cooking and drinking.

Town	Description	HHWW		Total
		Yes	No	
Gaborone	Count	8	12	20
	% within Town	40.0%	60.0%	100.0%
	% of Total	5.2%	7.8%	13.0%
Tlokweng	Count	11	4	15
	% within Town	73.3%	26.7%	100.0%
	% of Total	7.1%	2.6%	9.7%
Mogoditshane	Count	9	6	15
	% within Town	60.0%	40.0%	100.0%
	% of Total	5.8%	3.9%	9.7%
Metsimotlhabe	Count	11	4	15
	% within Town	73.3%	26.7%	100.0%
	% of Total	7.1%	2.6%	9.7%
Mmopane	Count	10	5	15
	% within Town	66.7%	33.3%	100.0%
	% of Total	6.5%	3.2%	9.7%
Gabane	Count	9	4	13
	% within Town	69.2%	30.8%	100.0%
	% of Total	5.8%	2.6%	8.4%
Kumakwane	Count	10	3	13
	% within Town	76.9%	23.1%	100.0%
	% of Total	6.5%	1.9%	8.4%
Ramotswa	Count	10	2	12
	% within Town	83.3%	16.7%	100.0%
	% of Total	6.5%	1.3%	7.8%
Oodi	Count	12	4	16
	% within Town	75.0%	25.0%	100.0%
	% of Total	7.8%	2.6%	10.4%
Matebele	Count	10	0	10
	% within Town	100.0%	.0%	100.0%
	% of Total	6.5%	.0%	6.5%
Mochudi	Count	4	1	5
	% within Town	80.0%	20.0%	100.0%

Table 5: Usage of Wastewater in Households in Towns

Most of the respondents interviewed were females (71.5%), as women usually do domestic work and use a lot of water. The study found that even though households pay a lot for water, they do not have a good understanding or good practises on how to save water or use water effectively. Only 32.9% said they re-use water in their gardens. Some respondents (30.4%) said they derive some benefits, like cost and water saving from re-using wastewater in their gardens.

Most people asserted that there are advantages to treating and using wastewater; 38.6% said it will conserve water. Only 31.6% did not think there are any advantages to re-using water because they thought used water is filthy and cannot be re-used. Some respondents said in

		Frequency	Percent (%)
Valid	Yes	106	67.1
	No	48	30.4
	Total	154	97.5
Missing	System	4	2.5
Total		158	100.0

Table 6: Summary of Usage of Household Wastewater

their cultures used water is waste and it should be thrown away. A majority of respondents (52.5%) said that the recycling of wastewater would have an impact on the fresh water supply, as it would save water and costs (Refer to Annex 8.7).

The study also found that most households do harvest rainwater during rainy seasons; the main problem is that they don't have tanks to store rainwater. Therefore, people need to

		Frequency	Percent (%)
Valid	Water Conservation	61	38.6
	Cost Saving	7	4.4
	Avoid Diseases	23	14.6
	Water & Cost Saving	10	6.3
	Avoid Disease & Conserve Water	4	2.5
	All	3	1.9
	No advantage in using WW	50	31.6
Total		158	100.0

Table 7: Advantages of Treating and Using Wastewater

be educated on the importance of harvesting rainwater and they should be provided with technologies that can store a lot of water to be used over a long period of time.

The three institutions interviewed are involved in wastewater recycling. They prefer using grey water, because black water will need more purification, while grey water can be treated without the use of chemicals. Grey water can be treated with wetlands. They do recycle water, because they want to conserve water and also educate students on wastewater recycling, e.g. at Mokolodi Nature Reserve.

The public need to be educated about conserving fresh water and the usage of wastewater. Many respondents did not know that wastewater can be used. According to their cultures and norms, they believe that used water is waste, and it cannot be re-used. Therefore, a lot of work has to be done to make the public aware of the benefits of re-using wastewater and the safe and healthy technologies that are now available.

A major social constraint is that many people have an aversion to the idea of handling and re-using treated effluent in certain applications, such as irrigation. There may also be objections to certain practises on the basis of religion, for instance the Islamic faith. Hence the awareness and participation processes with any proposed re-use scheme are very important. Issues of public concern must be properly and sensitively addressed. Education programmes need to be set up (NMPWWS, Vol. 7, 2003).

As the population of Botswana increases, there will be a rapid increase in water demand. Therefore, water re-use must be considered as a viable option. Water conservation, the efficient use of existing water supplies, and new water resource development and management are other alternatives that must be evaluated.

Section 3.5 Agriculture

3.5.1 Overview of the Agricultural Sector

Agriculture is responsible for about one fifth of the overall anthropogenic greenhouse effect. However, the relative importance of methane and nitrous oxide emissions is greater than in other sectors. This assessment of mitigation options confirms the earlier Inter-Governmental Panel on Climate Change (IPCC) estimates and quantifies the potential contributions by agriculture to reduce greenhouse gas emissions. Botswana is not an exception to this (BINC 2001).

Between 200 and 600 Tg C [16] per year could be sequestered world-wide in agricultural soils by implementing appropriate management practises to increase productivity and corresponding carbon inputs, to reduce tillage, and to restore wasteland soils. However, soil C sequestration has a finite capacity, over 50-100 years, until a new equilibrium level of soil organic matter is established (Batjes 1998).

Biofuel production on 10-15 % of the land area currently in agricultural use or in agricultural set-asides could offset from 300 to 1300 Tg of fossil fuel C per year (Derpsch 1998).

[16] Tg C means Terragram (g12) Carbon

The Botswana livestock farming systems are based on the grazing of ruminants outdoors all year round, and the waste products of digestion are deposited directly onto pastures; thus they produce very little methane. It is estimated that 99% of the methane produced by ruminants is attributed to enteric fermentation.

Enteric methane arises as a by-product of the fermentation of feed in the rumen. The rumen contains a large and diverse population of micro-organisms that break down the feed to produce volatile fatty acids (VFA), carbon dioxide (CO2) and methane. The micro-organisms responsible for the production of methane are methanogens, which synthesise methane from hydrogen. The VFA produced in the rumen are absorbed and used as an energy source, but most of the CO2 and CH4 are removed from the rumen by eructation (Clark 2001).

The amount of methane produced in the rumen varies with factors such as diet type, level of feeding, size, age and species of animal. As a percentage of the gross energy consumed, between 2-15% is lost as methane (Johnson & Ward 1996). Therefore, reducing the amount of methane produced by ruminants has implications both for the concentrations of GHGs in the atmosphere and the efficiency of conversion of dietary energy into animal products.

The energy intensity of agriculture has decreased greatly since the 1970's. Fossil fuel use by agriculture in industrialised countries, although constituting only 3-4 % of overall consumption, can be further reduced by for example, minimum tillage, irrigation scheduling, solar drying of crops, and improved fertiliser management (Allmaras & Dowdy 1995).

Farmers will not voluntarily adopt GHG mitigation techniques unless these can be shown to improve productivity and profitability. Some of the technologies listed below are not necessarily climate change technologies, but are also meant to provide guidance and a sample of what is globally available. Some of the technologies listed also present information on what climate change researchers are doing in other countries. This illustration may facilitate adoption of other techniques proposed in this chapter. Proposed options for reducing GHG emissions are consistent with increasing agricultural productivity.

3.5.2 Agriculture Technologies Identified

3.5.2.1 Livestock

Reducing Livestock Numbers

This technology requires farmers to reduce livestock numbers and by so doing reduce enteric fermentation methane emission to the atmosphere.

The barriers for adoption are the resistance from farmers and the resulting reduced income.

Improving Animal Productivity

Improvements in the efficiency of conversion of feed into animal products will reduce the amount of methane emitted per unit of product. This requires selecting and breeding animals with higher feed conversion efficiencies.

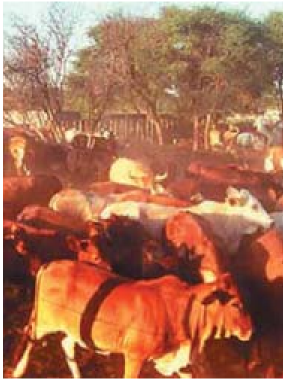

Figure 14:

Cattle rearing continues to be a significant source of income for many Batswana (Photo: Illustrative Options)

The genetic merit of animals has to be encouraged. This should be allowed to increase through selective breeding, and the widespread distribution of genetic material from exotic breeds. Improved management techniques should be developed and adopted as well. These measures will decrease the amount of methane produced per unit of product (Ministry for Environment New Zealand 2000).

Whether increases in productivity per animal arising out of these processes would be enough by themselves to reduce Botswana's total enteric methane emissions needs to be further investigated.

The current barriers are a dearth of work in this area and limited knowledge. Additionally, the costs of breeding may be high.

Ionophores

This technology involves the administration of antibiotics called ionophores to livestock in order to reduce methane emissions and improve feed conversion efficiency.

Overall, because of their dual impact on methane production, the feeding of ionophores does show promise as a tool for reducing methane. However, more consistent measuring of methane emissions from grazing ruminants needs to confirm potential; and the long-term effects of ionophores on methane output need to be studied.

The barriers are that some people are concerned about the long-term implications of the routine feeding of antibiotics to animals; and that ionophores need to be fed at frequent intervals. There is also concern that unless a slow release delivery device can be used, the ionophores would only be suitable for dairy cattle and intensive beef cattle. The lack of local knowledge and awareness are other barriers.

Probiotics

Probiotics are microbial feed additives developed primarily to improve animal productivity by directly influencing rumen fermentation.

Wallace and Newbold (1993) reviewed data from trials involving dairy cows and cattle fed high concentrate diets; they calculated that probiotics improved productivity by 7-8%. This would imply a reduction in the amount of methane produced per unit of product. Interest in probiotics as a potential technology to reduce methane stems from the additional finding that in-vitro they can directly reduce methane production (Frumholtz et al. 1989).

The barriers are that since probiotics are feed additives that are given daily, they would appear to be only suitable for systems where feed supplements are given on a routine basis or for animals, such as lactating dairy cows, where supplementation via such means as the water supply is straightforward. The lack of knowledge and awareness are other barriers.

Improved Forage Quality

At similar levels of intake, forages that increase the animal's productivity also decrease the amount of methane produced. Additionally, certain forages (e.g. those containing condensed tannins) directly reduce the amount of methane per unit of intake (Davenport et.al. 1989).

Cultivars of perennial ryegrass containing high levels of water-soluble carbohydrates are also available, and these have been found to increase animal performance (IGER 2001).

A lack of awareness and implementation in this area are the main barriers to date; no direct tests on the amount of methane produced by animals grazing these forages or any forage in Botswana have been carried out.

Manipulating Nutrient Composition

Manipulating the nutrient composition of the ruminants' diet can directly reduce methane output. For example, a high proportion of concentrates (grain based feeds) in the diet tend to reduce the protozoal population in the rumen, reduce rumen pH, alter the acetate: proportionate ratio and decrease the amount of methane produced per unit of feed intake (Blaxter & Clapperton 1965).

The barriers are that concentrates are fed daily; they would appear to be only suitable for systems where limited grazing or zero grazing is practised. A lack of knowledge and awareness are other possible barriers.

Animal Breeding

This technology involves the use of smaller numbers of higher genetic merit animals (lower emitters) to produce a given amount of product, and hence would therefore be beneficial in terms of methane emission mitigation.

It is also possible that some animals have lower methane emissions per unit of intake than others at the same level of performance. In trials with grazing sheep, Pinares-Patino et. al. (2000) identified in a single trial some animals as 'high' and other animals as 'low' emitters per unit of feed intake. They then confirmed in a second trial that these differences persisted when the same type of diet was fed. The reasons why particular animals emitted less methane per unit of feed intake are not known, but the study does raise the possibility of genetic differences in methane production in different animals.

The major barrier to adoption of this technology is that not much is known about this technology in Botswana.

Livestock Methane Vaccine

This technology involves vaccinating animals to ensure that methane-producing organisms are not active and thereby reducing the methane produced per unit (Ministry for Environment New Zealand 2000).

For grazing animals in the livestock industry, researchers are testing vaccine formulas that will stimulate antibody production in sheep and cattle against methane-producing organisms. Vaccines are a standard part of farm procedure in the grazing industries and are used to protect animals against a range of diseases.

The major barriers to adoption are that the vaccine is not available in Botswana, and the local industry does not know about it. In addition, even if it was well known, methane abatement may not be a priority to the industry.

3.5.2.2 Conservation Tillage

Conservation Tillage

Figure 15:

Technological and management intervention for crop production (Photo: Illustrative Options)

Zero tillage, apart from saving energy, reduces the release of soil carbon, increases soil moisture retention, resulting in improved yields (Allmaras et.al. 1995).

Sanitas Botswana are doing experimental farming and have demonstrated that ripping to a 1 metre depth enables plants to grow with minimum water, to grow healthier and to yield more. Elephant grass is used for mulching to retain soil moisture. Such practises conserve water and retain soil moisture. In some instances plant stalks are buried for 6 months before ripping for nitrogen and mulching purposes.

Animal-powered versions of conservation tillage used in developing countries can also reduce the manual drudgery. The cost of uptake in Botswana is around US$31 – 38/tC [17] saved. Globally 150-175MtC [18] /yr sequestration is possible (Zhou 1999).

The possible barriers to adoption would be the cost of implements and the lack of extension agencies and marketing.

Soil Carbon Uptake

Typical agricultural soils contain 100-200tC/ha to 1m depth. The over-use of soils leads to degradation, salinisation, erosion, desertification, and lower organic matter contents, with consequent carbon emissions (Lal & Bruce 1999). Changing the land use of intensively

[17] tC means tons carbon

[18] MtC means million tons carbon

cultivated soils could result in increased organic matter and carbon sequestration until the soil finds a new balance. The total sequestration potential of the world's cropland is around 750- 1000MtC/yr for 20-50 years from: erosion control (80-120MtC/yr), restoration (20-30MtC/yr), conservation tillage and crop residue management (150-170MtC/yr), reclamation of saline soils (20-40MtC/yr), improved cropping (180-240MtC/yr) and C offsets through energy crop production (300-400MtC/yr) (Takahashi & Sanada 1998).

A possible barrier is limited land for rotation and soil conservation.

Tractor Operation and Selection

The correct operation of tractors and matching the sizes of machinery to the job to be done could improve tyre life, reduce soil compaction, and save time. Behaviour change through driver education is required (Sims et al. 1998).

To improve tractor efficiency (fuel saving), a tractor has to move in the same tract and this will avoid compaction of the soil for root penetration. At the same time, less fuel is used because there is little or no resistance on the track. Sixty percent (60%) of fuel is wasted in loose soil, 20% is wasted if the soil is not loose, or after driving on the same track more than once (Visage pers. comm. 2004).

The major barriers are the limited knowledge of farmers, high cost and the unavailability of equipment.

Section 4

Priority Technologies

Prioritisation was done for the identified technologies presented in Chapter 3.

The process involved workshop group work, and the stakeholders who attended the workshop did the prioritisation for the energy, water and agriculture sectors.

For each sector a maximum of three technologies was selected as part of this prioritisation process. The prioritised technologies are presented below:

Section 4.1

Energy Priority Technologies

Some technologies, such as solar, wind, biomass, fuel cells, were not selected during the stakeholder workshop. The major reasons mentioned were that technologies are costly, and some stakeholders had limited knowledge of some of the technologies.

4.1.1 Supply Side

Information on **Supply Side** energy priority technologies can be found in Tables 8 - 10.

TECHNOLOGY: Coal Washing				
Barriers to Adoption	**National Actions To Remove Them**	**Additional**	**Needs (Capacity, Policy/Law), Financing**	**Responsible Institution & Stakeholders**
1. Limited awareness by stakeholders	Promotion and education, public addresses	Demonstration sites, adverts in public media	Flexible financing mechanisms	Institutions, Private Sector, NGOs, Govt.
2. Non-availability of washed coal	Coal beneficiation feasibility	Support to the entrepreneurs, commercialise washed coal	Emission standards	Govt., CEDA, NDB, BDC, BOBS
International Support Needed and Stakeholders	Funding, SIDA, World Bank, African Development Bank, Training			
Expected Benefits and Beneficiaries	Power can be increased instantaneously; Reduction of GHG emissions; Power can be sold at the same current market price; Export of power			

Table 8: Coal Washing Technology

TECHNOLOGY: Coal Bed Methane				
Barriers to Adoption	**National Actions To Remove Them**	**Additional**	**Needs (Capacity, Policy/Law), Financing**	**Responsible Institution & Stakeholders**
1. Lack of conviction that CBM can be an alternative fuel	Tax holidays, subsidies	Information dissemination to the public	Policy to liberalise power industry	BPC, BGC, Govt.
2. Competition from conventional fuels	Promotion	Create a market for CBM	Policy and financing	Govt., Parastatals, Private Sector
3. No supporting infrastructure for CBM	Importation of infrastructure	Grid extension, roads and telecommunications	Policy and financing	Govt., Parastatals
4. Lack of equipment and machinery	New project	Funding for research	Financing	RIPCO, BOTEC & others
5. No expertise for exploitation	Training of trainers by BGC	Technology transfer	Capacity build and financing	BGC, RIPCO, BOTEC & others
6. Expensive training	-	Embedded in curriculum	-	Govt.
International Support Needed and Stakeholders	Funding, SIDA, World Bank, African Development Bank, Training			
Expected Benefits and Beneficiaries	Power can be increased instantaneously; Reduction of GHG emissions; Power can be sold at the same current market price; Export of power			

Table 9: Coal Bed Methane Technology

4.1.2 Demand Side

Information on **Demand Side** energy priority technologies can be found in Table 11.

Section 4.2 Water Priority Technologies

4.2.1 Wastewater Treatment

The following technologies were not selected as priorities during the stakeholders' workshop: vacuum sewerage system, rotating bio-contractors, constructed wetlands and lime/limestone neutralisation. The main reason they were not selected was lack of knowledge by the stakeholders. For more information See Tables 12 - 14.

4.2.2 Water Treatment

Technologies that were not prioritised were: demineralisation and polymer technology, the major reasons being high capital costs and lack of knowledge about certain technologies. For more information see Table 15.

TECHNOLOGY: Biofuels				
Barriers to Adoption	**National Actions To Remove Them**	**Additional**	**Needs (Capacity, Policy/Law), Financing**	**Responsible Institution & Stakeholders**
1. Lack of raw materials/ resource base	Non-existent	Encourage production of biofuels through pilot projects	Policy to support the use of biofuels	Private Sector, RIPCO (B), NGO, BOTEC, Govt.
2. Lack of technological expertise	Workshops on the potential of various biofuels	Technology transfer, demonstration sites	Should be infused into energy master plan	Parastatal, NGOs, Govt.
3. Adverse weather conditions for some	Encourage artificial farming NAMPAADD Small Dams Programme	Identify suitable biofuel crops for Botswana conditions	Support for the production of biofuel crops incl. through biotechnology	CBO, NGOs, Parastatal, Govt.
International Support Needed and Stakeholders Expected	Collaboration research; Funding; Training (SANITAS, Brazil, China, etc)			
Benefits and Beneficiaries	Diversification of the economy; Reduction in import of fuel; Employment creation; Reduction of GHG emissions			

Table 10: Biofuels

TECHNOLOGY: Energy Efficiency and Management				
Barriers to Adoption	**National Actions To Remove Them**	**Additional**	**Needs (Capacity, Policy/Law), Financing**	**Responsible Institution & Stakeholders**
1. Limited awareness / education on the part of potential beneficiaries / low priority	Education Research DANIDA - supported project	Promotion of energy saving devices; Promoting energy efficient building designs; Promotion of institutional/ household energy audits. Promoting behavioural change	Phase out / converting incandescent bulbs / energy wasting appliances	DOE Retailers Consumers NGOs
2. Lack of standards and limited labelling	Non-existent	Training of commercial staff to know what they are selling	Enforcement of devices labelling	BOBS DOE
3. Affordability	-	Subsidies/incentives/ disincentives	Price control	Govt.
International Support Needed and Stakeholders	Funding; Collaboration with other international organisations			
Expected Benefits and Beneficiaries	Improved energy savings; Cost reductions; GHG reductions			

Table 11: Energy Efficiency and Management

TECHNOLOGY: Activated Sludge				
Barriers to Adoption	**National Actions To Remove Them**	**Additional**	**Needs (Capacity, Policy/Law), Financing**	**Responsible Institution & Stakeholders**
1. High capital cost	Nothing is being done	Identification of alternative technologies Research	Attract multi-lateral financing, Donor agencies, Govt.	Government, parastatal, NGO, Private Dev. Agencies
2. Need highly trained personnel (Engineers, Biochemists)	Training	Technology transfer	Financing	Government, Aid Agencies, & Private.
3. High costs of operation	Trading of effluent	Recycling of effluent e.g. by installing a phosphate removal plant that can allow treated wastewater to be pumped back to dams	Implement National Master Plan for Wastewater & Sanitation (NMPWWS), NAMPAADD	MOA, DSWM, DWA
International Support Needed and Stakeholders	Funding; African Development Bank (ADB), GEF, UNDP, DANCED, SIDA, CIDA			
Expected Benefits and Beneficiaries	Restoration and environmental protection, effluent re-use (Agric, Aqua-culture), sludge use (fertiliser), Methane production (energy source). Can also be recycled for potable use (pumped back to dams); The use of methane as an energy source will eliminate direct emissions to the atmosphere.			

Table 12: Activated Sludge

TECHNOLOGY: Waste Stabilisation Ponds				
Barriers to Adoption	**National Actions To Remove Them**	**Additional**	**Needs (Capacity, Policy/Law), Financing**	**Responsible Institution & Stakeholders**
1. Requires large areas of land	Use of alternative technologies (e.g. Activated Sludge Plant)	Where possible reserve land	NWMP, NMPWWS,	Government
International Support Needed and Stakeholders	No international support needed			
Expected Benefits and Beneficiaries	Protection of the environment (no stream/groundwater pollution), re-use of effluent (irrigation), Use of sludge as fertilisers, Low costs of operation and maintenance (System uses natural biological process, therefore no human interferences); Minimum industrial activities result in less production of methane since most of the treatment process for wastewater is aerobic.			

Table 13: Waste Stabilisation Ponds

TECHNOLOGY: Trickling/Percolating Filter				
Barriers to Adoption	**National Actions To Remove Them**	**Additional**	**Needs (Capacity, Policy/Law), Financing**	**Responsible Institution & Stakeholders**
1. High Capital Costs	Nothing is being done	Identification of alternative technologies Research	Financing	Government
2. Need skilled manpower (Engineers, biochemists, technicians)	Training	Technology transfer	Financing	Government Aid agencies
3. High costs of operation and maintenance	Trading of effluent (Installation of a phosphate removal plant)	Re-use of effluent water (Can be pumped back to dams)	NWMP, NMPWWS NAMPAADD	Government
International Support Needed and Stakeholders	Funding African Development Bank (ADB), GEF, UNDP, DANCED, SIDA, CIDA			
Expected Benefits and Beneficiaries	Restoration and environmental protection, Effluent re-use (Agric, Aqua-culture), Sludge use (fertiliser) Methane production (energy source). Can also be recycled for potable use (pumped back to dams). The use of methane as an energy source eliminates direct emissions to the atmosphere.			

Table 14: Trickling/Percolating Filter

Section 4.3 Agricultural Priority Technologies

4.3.1 Livestock

Some technologies, such as ionophores, probiotics, livestock methane vaccine, improved forage quality, were not selected during the stakeholders' workshop. The reasons were limited knowledge and awareness and the high costs associated with animal breeding. For more information see Tables 16 - 17.

4.3.2 Conservation Tillage

Soil carbon uptake, tractor operation and selection technologies were not prioritised, due to a lack of understanding by the stakeholders. For more information see Table 18.

TECHNOLOGY: Reverse Osmosis				
Barriers to Adoption	**National Actions To Remove Them**	**Additional**	**Needs (Capacity, Policy/Law), Financing**	**Responsible Institution & Stakeholders**
1. High capital costs	Nothing is being done	Need for more research	Government subsidies	Government
2. Need skilled personnel	Training	-	Funding	Government
3. High costs of operation and maintenance	Use of durable membranes	Coverage by the expansion of the national grid	Subsidise electric connections	Government
International Support Needed and Stakeholders	Funding African Development Bank (ADB), GEF, UNDP, DANCED, SIDA, CIDA			
Expected Benefits and Beneficiaries	Derived use of brackish water, improved industrial activity and economic growth; Optimum utilisation of water resources; The use of the national grid system for powering plants results in less emission of green house gases.			

Table 15: Reverse Osmosis

TECHNOLOGY: Animal Breeding				
Barriers to Adoption	**National Actions To Remove Them**	**Additional**	**Needs (Capacity, Policy/Law), Financing**	**Responsible Institution & Stakeholders**
1. Limited knowledge on the part of farmers	Cross breeding awareness	Awareness/education Research work	Financing	Government
2. High cost of breeding	Nothing is being done	Government subsidies	Farmers Bank	Government
International Support Needed and Stakeholders	Biomedical engineering research on animal breeding; FAO			
Expected Benefits and Beneficiaries	Less methane generating cattle breed; Breeds that are adaptive to our environment (resistant to droughts, common diseases; etc)			

Table 16: Animal Breeding

Section 4.4 Project Selection Mechanism

The development of the project selection mechanism was based on the premise that projects must fulfil the development objectives as stipulated in Vision 2016, national development plans or other national development policies.

TECHNOLOGY: Reduce Livestock Numbers				
Barriers to Adoption	**National Actions To Remove Them**	**Additional**	**Needs (Capacity, Policy/Law), Financing**	**Responsible Institution & Stakeholders**
1. Revenue decline	Fencing Policy	Establish feed lots, implement carrying capacity policy	Policy implementation strategies	Government
2. Opposition from farmers	Persuasion	Awareness	Professional advice	Government
International Support Needed and Stakeholders	No international support needed			
Expected Benefits and Beneficiaries	Reduced overgrazing; Good range management practises; Improved animal quality			

Table 17: Reduce Livestock Numbers

TECHNOLOGY: Conservation Tillage Technologies				
Barriers to Adoption	**National Actions To Remove Them**	**Additional**	**Needs (Capacity, Policy/Law), Financing**	**Responsible Institution & Stakeholders**
1. Not widely known to farmers	NAMPAADD Nothing is being done	Training and dissemination	Minimal Subsidy	Government
2. Chemical weed control	NAMPAADD	Awareness	Farmers Bank	Government
3. Special farming implements	-	Avail special farming implements	Financing	Government
International Support Needed and Stakeholders	International Funding not needed			
Expected Benefits and Beneficiaries	Improved Farming and Increased Revenue			

Table 18: Conservation Tillage Technologies

The projects which may not have been clearly mentioned in the national objectives could also be considered, provided they will result in clear development benefits. Any project, whether mentioned or not, should present development benefits with clear socio-economic indicators. Projects that would only be implemented to reduce GHG emissions would therefore not receive high priority, e.g. destruction of HydroFlouroCarbons (HFC) gases, as they have little or no sustainable development benefits.

The projects that present a critical development impact are then considered for environmental benefits, such as reducing GHGs, local environmental impacts, etc. This is a necessary step but one that cannot stand alone.

Projects that qualify for both developmental benefits and environmental benefits have to be evaluated for their potential to be successfully implemented. It is possible to have a good project that cannot immediately be undertaken due to limited capacity in the country.

Projects that do not meet some or all of these criteria will not receive high priority support when decision-makers are endorsing projects.

The framework used to select projects is summarised in Figure 3.

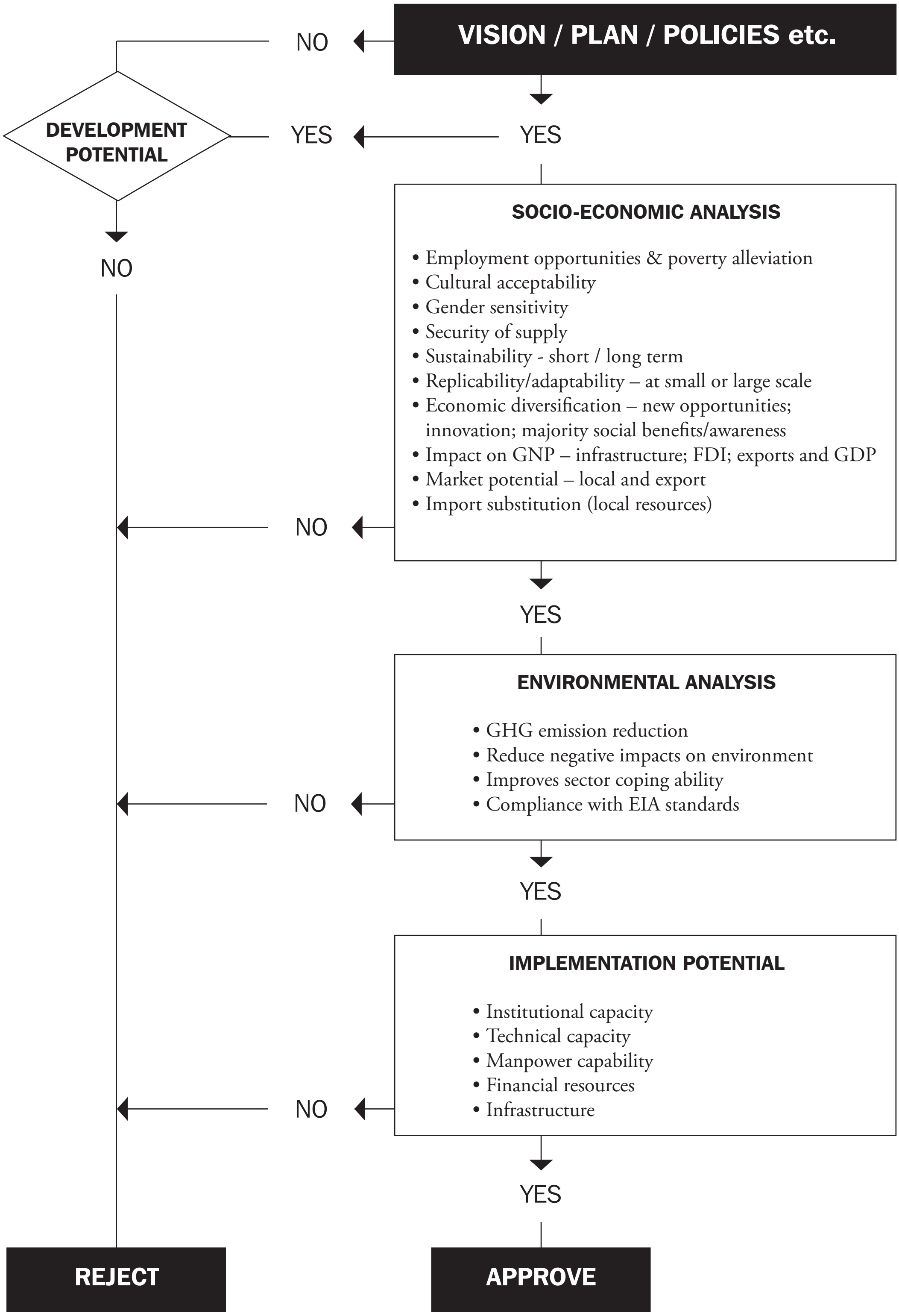

Figure 16: Project Selection Mechanisms

Section 5

Implementation Aspects

Section 5.1

Policy Framework

The Policy Environment provides a signal of what socio-economic outcomes the Government is planning to achieve, and the selected technologies which will effectively and efficiently utilise Government resources.

The Policy Environment also has the objective of making a contribution to national development. Alignment, therefore, with the National Development Plans, the Vision 2016 and relevant policies is of critical importance. The development imperatives stipulated in the Vision and NDP have already been provided under the development agenda.

The policies to consider in selecting the technologies are: the Botswana Energy Master Plan, the Industrial Development Policy, the Privatisation Policy, the Revised Rural Development Policy, the National Master Plan on Arable Agriculture and Dairy Development (NAMPAADD), the Citizen Entrepreneurial Development Agency (CEDA), the Training Policy, the Science and Technology Policy, the National Water Master Plan and the National Master Plan on Wastewater and Sanitation.

Environmentally-sound technologies that could respond to these policies will contribute to Botswana's development objectives.

5.1.1 Botswana Energy Master Plan

The Botswana Energy Master Plan sets out the appropriate policies, regulatory mechanisms and institutions to guide the energy sector in reaching the national economic and social goals. One of the policy goals is to maintain an appropriate level of engagement with international developments involving the global environmental impacts of the energy sector. Within the Energy Master Plan, further policy recommendations include promoting the efficient use of energy, diversification of energy supplies and including social and environmental costs in the price of energy. National energy programmes include, among others, the Rural Electrification Project, which promotes the use of both grid and solar energy. Botswana aims to achieve a balance between the import of electricity from the southern African power pool and its local generation. In 2003, the ratio of local electricity generation to import was 30:70, and the aim is to shift to 70:30 (BEMP 2004). Such dependence on external sources makes Botswana insecure in terms of energy supply.

Vision 2016 sees tremendous potential for solar energy and envisages Botswana becoming a centre of excellence in solar energy technology.

There is a Programme to exploit Botswana's large coal reserves rather than use the natural woodlands and to apply coal beneficiation to improve the quality of coal. There are also plans to continue exploration for coal bed methane in the coalfields of Botswana. Previous efforts have emphasised natural gas and oil in the Nossop-Ncojane Basin, and assess the hydrocarbon potential of the Ngamiland region.

5.1.2 Industrial Development Policy

The principles of the Industrial Development Policy encourage highly productive and efficient export industries, based on local resources, and integrated with the deployment of technologies for foreign markets. The policy also aims to promote and expand efficient support services and component manufacturers in the SMEs category. Finally, the policy aims to provide assistance to small-scale rural entrepreneurs through involving NGOs and local communities in the development of business activities and opportunities in rural villages.

5.1.3 The Privatisation Policy

The Privatisation Policy aims to improve efficiency, increase productivity and attract investors with resources and technology. Its other objectives include: stimulating entrepreneurship and increasing citizen participation in the economy, and relieving Government's financial and administrative burdens in undertaking and maintaining services and investments in infrastructure. In order to attract new financial resources, selected technologies should have a high market potential if the private sector is to invest.

The policy offers opportunities to utilise technologies that can contribute to national productivity and create robust citizen businesses.

5.1.4 The Revised National Policy for Rural Development

The Revised National Policy for Rural Development is in place and provides opportunities for enterprise building in rural areas. With regard to land and natural resources, the issue of unclear property rights was found to be a hindrance to development in rural areas. The revised policy will streamline and make transfers of land rights easier. The policy requires the multiple or integrated use of land for different enterprises rather than allocating separate areas of land for each and every business undertaking (Budget Speech, 2002).

Access to productive resources, employment and other opportunities in rural areas were found to be skewed in favour of men, so the gender balance needs to be addressed.

With regard to poverty, it was realised that communal rain-fed agriculture based on current practises will not alleviate/eradicate poverty, so the focus should be on a variety of rural economic pursuits in addition to communal arable agriculture. The National Poverty Reduction Strategy (UNDP, Draft Report 2002) is making a contribution to this effort. The strategy is expected to achieve the objective of sustainable economic diversification in rural areas in order to curb rural-urban migration.

Among the programmes proposed by the Draft National Strategy on Poverty Reduction are:small-scale horticulture, rain-fed crop production, small stock production, community based management programmes, rural tourism and capacity building of small and medium citizen businesses.

5.1.5 National Master Plan for Arable Agriculture and Dairy Development (NAMPAADD)

NAMPAADD introduces a business-oriented scheme for agriculture; this differs from past schemes that were welfare-oriented. NAMPAADD is therefore expected to succeed in providing several economically viable business opportunities in improved rain-fed crop production, irrigated agriculture/horticulture and dairy production. Whilst Botswana is only able to produce 12% of its cereal requirement, under NAMPAADD cereal production per hectare is expected to go up from 300kg to 1 - 3 tonnes under rain-fed arable agriculture (NAMPAADD, 2002).

Large farms of 150-1000 ha which can utilise mechanised equipment and new technologies are being proposed for the plan. It is expected that Botswana will produce vegetables for national consumption, irrigated flowers and fruit for exports, and some other crops irrigated with reclaimed water. Dairy farming, animal feeds and appropriate rearing and milking technologies are being proposed to increase milk production from the current 2000l/cow/year to 6000l/cow/year.

5.1.6 The Citizen Entrepreneurial Development Agency (CEDA)

CEDA is a new financial assistance programme that has incorporated the objectives of the SMME policy and FAP. The focus is on the development of citizen owned business enterprises through the development of entrepreneurial and management skills. CEDA is implemented through interest subsidy, training, monitoring and mentoring rather than outright grants, as was the case under FAP.

The 1998 SMME Policy aimed to develop dynamic and self-sustaining small, medium, and micro enterprises through appropriate funding, training and other institutional support. Assistance was directed towards marketing and the adoption of appropriate technology.

FAP resulted in high failure rates and the abuse of the scheme by beneficiaries. Seventy-five per-cent (75%) of small, 45% of medium and 35% of large enterprises assisted through FAP did not survive beyond the period of assistance. FAP also only managed to deliver 15-20% of national vegetable and 24% of fruit requirements (NAMPAADD, 2002). The objectives of FAP have been incorporated in CEDA.

5.1.7 Science and Technology Policy

The Science and Technology (S & T) Policy has as its overall objective to achieve sustainable social and economic development, and uplift the quality of life through the application of Science and Technology. The S & T policy stipulates the need for development, adaptation, the application of appropriate technologies for small to large scale processing and manufacturing (in rural and urban areas), including the promotion of traditional, new and innovative technologies. The S & T policy also aims to create centres of excellence, science parks, and business incubators in strategic S & T disciplines.

5.1.8 Botswana National Water Master Plan

As part of its National Water Master Plan (NWMP), Botswana would like to enhance water conservation and demand management. On the supply side, opportunities for rainwater and run-off capturing are seen as means that could complement the conventional surface and groundwater resources.

In view of the rapidly rising water demands in all sectors, and the need to develop a regional and national approach to water development, Government embarked on the formulation of a National Water Master Plan during NDP6. NWMP, which was completed in 1991, had the following objectives:

- To provide Government with a number of alternative strategies aimed at meeting Botswana's growing water demands at the lowest possible cost over a 30 year planning horizon;
- To analyse the economic, social, environmental, legal and administrative implications of alternative strategies.

5.1.9 Botswana National Master Plan for Wastewater and Sanitation

The overall objective of the Master Plan is to evaluate the current scenario on wastewater generation and disposal, on-site sanitation facilities, and their impact on the environment, and to develop planning and implementation strategies for regulating the generation, collection and disposal of wastewater in an environmentally friendly and acceptable manner.

In effect, the Master Plan provides a sound strategy for the effective implementation of the National Wastewater and Sanitation Management Policy of the Government of Botswana.

Section 5.2 Legal Framework and Standards

Botswana's legal environmental framework is based on the 1990 National Conservation Strategy. The National Conservation Strategy (NCS), which is a cross-cutting policy that addresses all aspects of the environment across government portfolios.

The NCS aims to pursue policies and measures to increase the effectiveness of natural resource use and management and to integrate the work of the many sectoral Ministries and interest groups throughout Botswana. Fulfilling development and conservation goals requires that development be designed so as to minimise environmental costs and to enhance environmental quality. Issues addressed within the NCS include:

- Growing pressure on water resources;
- Degradation of rangeland pasture resources;
- Depletion of wood resources;
- Over-use or exploitation of some natural veld products;
- Pollution of water, air, soil and vegetation resources.

The intention to reduce global emissions of gases, such as CO_2 and NO_x, will also reduce the local emissions. The National Conservation Strategy aims to reduce rangeland and pasture degradation, the depletion of wood resources and the dumping of waste – all of which ultimately impact on climate change.

The protection of woodland resources, and the continued sustainable use of biomass fuels, are important for maintaining Botswana's current favourable greenhouse gas emission status.

As Botswana becomes more affluent, industrial and urbanised, the control of vehicle emissions will become an emerging issue. Provisions to control vehicle exhaust emissions have been made through the Road Traffic Act (revised 1987). There are also suggestions that air pollution may be controlled through the introduction of metered parking in certain urban areas. There is a policy to promote the use of mass transit transport or non-motorised transport. The transportation sector is the country's largest consumer of petroleum products, which are imported from neighbouring countries.

The 1998 Waste Management Act requires that waste management plans be prepared, and where possible, that waste be recycled. Local authorities are obligated to license all landfills, most of which are being rehabilitated or redesigned. Replacing the the ventilated, improved pit latrines with dry compost technology will also reduce groundwater pollution. Sanitation technologies are being assessed and implemented under the new Department of Sanitation and Waste Management.

The Atmospheric Pollution (Prevention) Act regulates the emission of gases into the atmosphere. Registration certificates are issued before certain industrial processes may be conducted. Air pollution control is the responsibility of the Department of Mines and is focused on major industrial sources. Intensive air quality monitoring takes place in some locations such as Gaborone and Selibe Phikwe (DOM, 1999). There are national environmental laboratory facilities with an expanded network of stations in major settlements.

The Mines and Minerals Act (1999) requires that mining areas be rehabilitated and that wasteful mining practices be avoided. Regulations are in place to ensure the protection of the environment, this includes the restoration of topsoil after mining. The required Environmental Impact Assessment for planned projects has been introduced in the Mines and Minerals Act.

The Forest Act (1980) provides for the better regulation and protection of forests and forest produce in Botswana. The Act prohibits the setting of fires, stock grazing, crop cultivation and the damage or removal of forest produce within State-proclaimed forest reserves.

Crop cultivation, livestock grazing and watering, vegetation clearing and afforestation are regulated within the Agricultural Resources (Conservation) Act. The maximum number of stock per stock class that may be kept in an area is also controlled under this legislation.

Section 6

Conclusions & Recommendations

Section 6.1

Conclusions

Botswana has significant potential for environmentally sound technology (EST) application in coal/coal bed methane, biogas and biofuels.

6.1.1 Energy

A general assessment of these technology applications is provided below:

a. The biggest opportunities for EST are in coal washing - to improve the quality and exploitation and the utilisation of CBM for power generation and as transport fuel. Coal washing is hindered by high costs and a lack of potential investors to establish this industry. The CBM industry is hampered by a lack of infrastructure to exploit, distribute and utilise the CBM.

b. There are a number of technologies that can be adopted by Botswana to utilise land fill waste, abattoir waste, and manure in order to generate biogas for energy for domestic, institutional and industrial use. The current barrier is a lack of investment capacity and resources for carrying out feasibility studies to attract potential investors.

c. Biofuel technology application in Botswana is generally limited by climate and hence a limited biofuel resource base. However, there are some plants, such as Jetropha, that have the potential to grow and produce biodiesel. Pilot projects are required to establish how best to exploit this resource.

The applications of solar, wind, and other biomass (elephant grass) are limited in scope.

a. Solar PV technologies (for water pumping, as off-grid electricity supply) are still too expensive to adopt large scale. Therefore, these technologies can only be disseminated through a government subsidy, but such a subsidy should directy benefit the poor. There is also a limited application of solar cooling and passive designs, due to limited expertise and the high cost of designs in those areas. There is the potential, however, to widely disseminate solar water heaters in the country and to improve the current technology performance. In this regard, there are already new SWH technologies being developed in Botswana and in other countries. Solar cooking will face competition from the use of LPG that is entrenched in the country.

b. Similarly, elephant grass requires further feasibility studies to establish its potential use in Botswana.

c. Although wood fuel still remains the most affordable source of energy for the majority of Batswana, and would contiune to contribute substantially to the national energy demand, the adoption of biomass briquettes is limited by an inadequate resource base.

The use of other energy technologies has varied potential.

a. LPG is well adopted and there are minimal barriers to its uptake.

b. Off-grid decentralised diesel electricity generation is being gradually replaced by national grid connections.

c. Fuel cell application that can be used for a decentralised electricity supply and for powering vehicles is not yet a mature technology.

d. Wind technologies are only applicable for water pumping in shallow boreholes, but they are not sufficient for electricity generation with technologies on the market.

e. There are considerable energy efficiency improvements and efforts; their potential applications are being investigated through various projects.

6.1.2 Water

The emphasis on water conservation is through proper resource management. The principle of integrated water resource management in Botswana is very appropriate, since this takes into consideration all the forms of water resources available.

a. The types of treatment plants available in Botswana were identified as:

- Reverse osmosis, demineralisation, polymer technology and solar stills for potable water;
- Activated sludge, bio-filters, waste stabilisation ponds and constructed wetlands for wastewater treatment;

b. The advantages of conventional systems (activated sludge) over non-conventional systems (stabilisation ponds) are that they can treat high volumes of wastewater over a short period of time and produce an acceptable quality.

c. Contrary to the advantages of conventional systems, non-conventional systems have high costs associated with maintenance.

d. The potential for reusing effluent in Botswana is for agricultural activities, such as forestry, fodder, horticulture, and landscaping.

e. Water conservation in the form of rainwater catchment systems has been practised in Botswana, but constraints have been due to poor system design, lack of training and supervision, and the high cost of the units. The technology still has the potential to be further exploited in both the urban and rural areas of Botswana, and it offers a good option to conserve water and save costs in developing water resources.

f. During the survey on the social acceptability of wastewater, it was found that some people in areas visited do collect rainwater, but they do not have technologies to store water for future use; therefore it is recommended that people should be provided with rainwater harvesting technologies and should be trained in their use.

g. The majority of the respondents (64.6%) in the wastewater social acceptability survey preferred treated grey water for re-use rather than black water. The survey results indicate that the majority of Batswana are willing to use treated wastewater, but will need to be educated regarding the quality and safety of the resource.

6.1.3 Agriculture

The most suitable technologies for agriculture in Botswana have been identified. They require further refinement to turn them into marketable products that could be adapted to the local industry.

This study has identified several technologies; only three were taken as priorities. The technologies would reduce livestock numbers, for example through culling, improve animal breeding, for example through cross breeding, and conserve tillage, for example by limiting the number of tillage cultivators.

The potential for each is as follows:

a. There is great potential to reduce livestock numbers and improve livestock quality with the range fencing policy. It would have the added advantage of protecting pastures from overgrazing and degradation.

b. The breeding of animals that are "lower emitters" would be advantageous, as they have a higher feed conversion efficiency. Thus, the breeding of "lower emitters" would not only protect the environment but also produce high outputs.

c. Besides climate change, conservation tillage in Botswana has the added advantage of moisture conservation. The NAMPAADD pilot project at the Barolong farms is advocating the use of sophisticated limited tillage equipment to increase crop yields.

Section 6.2 Recommendations

It is recommended that Government support the following follow-up activities to implement the prioritised technologies in each of the sectors studied.

6.2.1 Energy

Support for the following activities is required in order to implement the prioritised technologies in each of the energy sectors:

a. For the coal bed methane, there is a need to establish a resource base and a potential market for CBM use.

b. On the policy side, Government would have to liberalise the energy market to allow other players that might provide CBM based energy services.

c. Research and capacity building in relation to exploitation and utilisation of CBM technologies ought to be pursued.

d. In relation to coal beneficiation, the feasibility for coal washing should be completed and the results disseminated to attract potential entrepreneurs and to energise the market. The potential benefits in the power sector, industry and household sectors need to be explored.

e. Government can support promising entrepreneurs with funding from sources such as CEDA, BDC and NDB.

f. There is a need to identify biofuels and related crops that can be produced in Botswana, and to undertake pilot projects to produce those biofuels.

g. Government can encourage through policy the use of biofuels and include the policy in the Botswana Energy Master Plan.

5. Little has been done in Botswana in the areas of energy efficiency and management. Few buildings have been constructed according to efficient energy management concepts. There is no legislation to control energy management in construction, and it is clear that this institutional framework is needed to guide stakeholders.

6.2.2 Water

On wastewater, the Government should create an environment that will ensure that the resource is exploited for various end uses. This could include the following:

a. Creating an awareness of the scarcity of water and the safety of treated wastewater;

b. Developing an infrastructure for the distribution of treated wastewater;

c. Enforcing wastewater treatment standards;

d. Providing subsidies for the adoption of reverse osmosis technology.

6.2.3 Agriculture

The following recommended technologies should be considered by relevant organisations for adaptation and dissemination:

a. Animal breeding for methane abatement is currently not being done; however, some work on high productivity animals is being carried out by DAR. It is recommended therefore that DAR should disseminate its research results to farmers.

b. It is recommended that the Botswana Agricultural Union take an active part in encouraging farmers to reduce their livestock numbers in order to attain high quality livestock and to protect pastures from overgrazing and degradation.

c. Conservation tillage is being tried in the country, namely by Masedi Farms in Pandamatenga, NAMPAADD in Barolong Farms and RIPCO (B) in association with MODIMP of the Republic of South Africa. It is therefore recommended that NAMPAADD disseminate reduced tillage methods and include its advantage as part of the purpose for implementation.

Figure 17:

Agricultural activities such as ploughing and fertilizing influence emissions of greenhouse gasses (Photo: Illustrative Options)

General Recommendations

a. Many of the technologies identified need to be adapted to be compatible with the social, cultural, economic and environmental priorities of Botswana.

b. The role of the private sector will be vital in the identification and adoption of environmentally sound technologies and should continue to be engaged in future TNA activities.

c. Technology needs will continue to change, and Government should ensure that this TNA report is frequently updated and new action plans developed for implementation.

d. There should be training for organisations, which will manage technologies and conduct the environmental impact and risk assessments.

e. General stakeholder participation should be ensured in the technology transfer process.

f. Indigenous capacities should be developed, as an exclusive dependence on imports can prove harmful in the future.

g. There is a need to undertake project life cycle confirmation studies to determine the methane mitigation potential for each technology identified.

Section 7

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Section 8

Annexes

Section 8.1

Technology Options and Suppliers

Technology Options	Interviewed Stakeholders	Comments
Wood chip briquetting	Timber Companies e.g. Nata Timbers	No company in Botswana doing briquetting
Abattoir/chicken manure biogas digesters	RIIC	To be investigated further
Diesel-decentralised generation-Multi-platform	DBES, Electrical Services	Decentralised generation decreasing but back-up installations increasing.
LPG	EasiGas, BP	LPG organisation being formed
Natural gas	DGS	Info search on-going
Smelter efficiency	Mining (BCL)	No response from the stakeholder
Passive solar design	BOTEC, DOE, DBES	No supporting regulations, some buildings used the concept
Energy management systems	BOTEC, DOE, DBES	Some companies are trying the concept
Compact Fluorescent Lights	Somarelang Tikologo; DOE, BPC	A number of companies and households are using CFLs
Solar Water Heaters	MLG, RIIC, Solarpower, BHC, DBES	Many in the market, no promotional policy

Section 8.2

List of Contact Persons in Energy

Organisation	Subject matter	Contact person
Botswana Gas Corporation	Coal bed methane	Mr. P. Bateman
Solarpower	Solar water heaters - high pressure	Mr. M. Abdekenari
Solar International	Solar mini-grids and integrated PV for buildings	Mr. G. Jacobs
G4	Coal beneficiation	Mr. B. Gubago
UB Faculty of Engineering and Technology	Solar cooling, energy management	Prof. T. Oladirin
Gaborone City Council	Landfill gas	Mr. K. Jain
Somarelang Tikologo	Energy conservation	Ms. Jo Wall
Caltex	Fuel quality	Ms. P. Moremi
Sangfroid	Sewerage biogas Abattoir waste biogas	Mr. J. Khupe
Energy Affairs	Coal beneficiation Biomass technologies	Mr. Seretse Mr. S. Bok
Sanitas	Elephant Grass Tillage	Dr. G. Neilsen

Section 8.3

Interviewees for Water Study

No	Institution/Organisation	Type of Water
1	Department of Water Affairs	Potable water
2	Department of Waste & Sanitation Management	Wastewater
3	SEDC- Water & Wastewater Department	Wastewater
4	Gaborone City Council – Sewage Department	Wastewater
5	Kgalagadi Soap Industries	Wastewater
6	Kgalagadi Breweries Limited	Potable water
7	Botswana Power Corporation	Potable water
8	Botswana Meat Commission	Wastewater
9	Sud Chemie	Potable/Wastewater
10	Debswana	Potable/Wastewater
11	BCL	Potable/Wastewater
12	Orbit Pumps	Potable/Wastewater
13	Botswana Technology Centre	Wastewater
14	KSDA Hospital	Wastewater

Section 8.4

List of Contact Persons in Agriculture

Organisation	Subject matter	Contact person
Ministry of Agriculture (DAR)	Agricultural Technology Research	Dr. G.S. Maphanyane
Ministry of Agriculture (DAR)	Animal Nutrition	Dr. J. Macala
Ministry of Agriculture (DAR)	Range and Pasture Management	Dr. W. Mphinyane
Ministry of Agriculture (DAR)	Animal Breeding	Ms. L. Phiri
Ministry of Agriculture (NAMPAAD)	Crops and Forestry	Mr. Sebolao
MODIMP	Tillage Technologies	Mr. A. Visagie
RIPCO (B)	Animal Feed Production	Mr. D. Disele

Section 8.5

List of Workshop Participants

Name of Participant	Company/Organisation
Dr. S. Maphanyane	Dept of Agricultural Research
Mr. P. Bateman	Botswana Gas Corporation
Mr. Mokgweetsinyana	Electrical & Mechanical Services
Mr. K. Jain	Gaborone City Council
Mr. T. Das	Gaborone City Council
Mr. L. Ramokate	Dept of Geological Surveys
Mr. M. Odireng	Kgalagadi District Council
Ms. S. Mophuting	Liquifire
Ms. G. Ramothwa	Dept of Meteorological Services
Ms. D. Masisi	Dept of Meteorological Services
Mr. D. Lesole	Dept of Meteorological Services
Mr. B. Gopolang	Dept of Meteorological Services
Mr. A. Visagie	MODIMP
Mr. R. Mclaggan	Orbit Pumps
Mr. M. Coubrough	Pumpco
Mr. J. Van Graan	Rand Transmission Company (RSA)
Mr. K. V. Morei	RIPCO (B)
Mr. P. P. Maribe	RIPCO (B)
Mr. D. Disele	RIPCO (B)
Mr. J. Khupe	Sangfroid
Mr. Opelo	DSWM
Mr. M. Abdekenari	Solar Power
Ms. J. Wall	Somarelang Tikologo
Mr. Malaba	Sud –Chemie
Mr. R. Rapelana	DWA
Ms. K. Moremedi	DCPF
Mr. D. Nelson	Rand Transmission Company
Mr. D. Molefha	GCC
Mr. S. Kabasia	GCC
Mr. I. Pilane	Farmer
Mr. A. Mohamed	Green Heat Liquifire
Mr. M. Abdurahman	Green Heat Liquifire
Mr. T. Stone	Somarelang Tikologo
Ms. C. Macheke	DMS
Ms. K. Monaka	DMS
Mr. S. Lebang	DSWM

Section 8.6

Social Acceptability of Wastewater Re-use

Questionnaire Number: ____________

Start time: ____________

Finish time: ____________

PART I: HOUSEHOLD

A. Administration

1) Town/Village: ____________

2) Name of Respondent: ____________

3) Contact Number: ____________

4) Date: ____________

5) Sex: Female ☐ Male ☐

6) Age: ____________

B. Water Requirements/Usage:

7) What is your source of water?

a) Borehole ☐

b) Well ☐

c) River ☐

d) Dam ☐

e) Mogobe ☐

8) How do you access water?

a) Public Standpipe ☐

b) Yard Connection ☐

c) House Connection ☐

d) Other (Specify) ☐

10) Do you pay for your water supply? Yes ☐ No ☐

11) If yes what is your average monthly payment? ____________

12) What activities require water in your house?

a) Cooking ☐

b) Washing ☐

c) Cleaning ☐

d) Gardening ☐

13) From the above activities which ones use more water?

a) Cooking ☐
b) Washing ☐
c) Cleaning ☐
d) Gardening ☐

14) Which activities use recycled water?

a) Washing ☐
b) Cleaning ☐
c) Gardening ☐

15) Do you know anything about wastewater recycling? Yes ☐ No ☐

If No go to question 20

16) If yes, which activities in your house use recycled water?

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17) Do you derive any benefits from the usage of recycled wastewater?

Yes ☐ No ☐

18) If yes what are the benefits? Explain?

---

19) Where do you collect wastewater for recycling?

a) Septic tank ☐
b) Bathroom ☐
c) Collector tank ☐

20) How do you collect wastewater for recycling? Explain

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21) How do you dispose of wastewater?

a) Septic Tank/Soak Away ☐
b) Central Sewer System ☐
c) Pit Latrine ☐
d) Other Specify ☐

22) What do you think is the difference between treated and untreated wastewater?

---

23) Do you know any method of wastewater treatment? Yes ☐ No ☐

24) If yes, which one do you know?

____

25) What do you think are the advantages of treating and using wastewater?

____

26) What are the sources of wastewater that you know?

a) Kitchen ☐
b) Bathroom ☐
c) Toilet (Flush) ☐

27) Would you use wastewater in your household? Yes/No
Explain:

____

28) Which type of wastewater would you prefer to use?

a) Grey water (Bathroom and Kitchen) ☐
b) Black water (Toilet) ☐

29) Why? Explain:

____

30) What impact do you think wastewater recycling has on the fresh water supply?

a) Cost saving ☐
b) Water saving ☐
c) Other - Specify ☐ ____________________

Section 8.7

Statistical Package for Social Scientists

Water Access		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Public standpipe	21	13.3	13.3	13.3
	Yard connection	96	60.8	60.8	74.1
	Other	2	1.3	1.3	75.3
	Yard & house connection	39	24.7	24.7	100.0
	Total	158	100.0	100.0	

Benefits		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Cost saving	18	11.4	37.5	37.5
	Water saving	17	10.8	35.4	72.9
	Cost water saving	12	7.6	25.0	97.9
	Control smell	1	0.6	2.1	100.0
	Total	48	30.4	100.0	
Missing	System	110	69.6		
Total		158	100.0		

Household Waste Usage		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	106	67.1	68.8	68.8
	No	48	30.4	31.2	100.0
	Total	154	97.5	100.0	
Missing	System	4	2.5		
Total		158	100.0		

Wastewater Impact		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Cost saving	26	16.5	17.6	17.6
	Water saving	37	23.4	25.0	42.6
	None	2	1.3	1.4	43.9
	Both	83	52.5	56.1	100.0
	Total	148	93.7	100.0	
Missing	System	10	6.3		
Total		158	100.0		

Wastewater Preference		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Grey water	102	64.6	69.9	69.9
	Black water	1	.6	0.7	70.5
	None	13	8.2	8.9	79.5
	Both	30	19.0	20.5	100.0
	Total	146	92.4	100.0	
Missing	System	12	7.6		
Total		158	100.0		

Recycling Activities		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Washing	2	1.3	1.3	1.3
	Cleaning	5	3.2	3.2	4.5
	Gardening	52	32.9	33.3	37.8
	Brick-making	4	2.5	2.6	40.4
	None	91	57.6	58.3	98.7
	Gardening & cleaning	1	0.6	0.6	99.4
	Washing & cleaning	1	0.6	0.6	100.0
	Total	156	98.7	100.0	
Missing	System	2	1.3		
Total		158	100.0		

Sex of Respondents		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	113	71.5	71.5	71.5
	Male	45	28.5	28.5	100.0
	Total	158	100.0	100.0	

Water Sources		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Borehole	18	11.4	11.5	11.5
	Dam	138	87.3	88.5	100.0
	Total	156	98.7	100.0	
Missing	System	2	1.3		
Total		158	100.0		

Town Frequency		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Gaborone	20	12.7	12.7	12.7
	Tlokweng	15	9.5	9.5	22.2
	Mogoditshane	15	9.5	9.5	31.6
	Metsimotlhabe	15	9.5	9.5	41.1
	Mmopane	15	9.5	9.5	50.6
	Gabane	13	8.2	8.2	58.9
	Kumakwane	16	10.1	10.1	69.0
	Ramotswa	13	8.2	8.2	77.2
	Oodi	16	10.1	10.1	87.3
	Matebele	10	6.3	6.3	93.7
	Mochudi	5	3.2	3.2	96.8
	Serowe	5	3.2	3.2	100.0
	Total	158	100.0	100.0	

Water Treatment Advantages		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Water conservation	61	38.6	56.5	56.5
	Cost saving	7	4.4	6.5	63.0
	Avoid diseases	23	14.6	21.3	84.3
	Water & cost saving	10	6.3	9.3	93.5
	Avoid disease & conserve water	4	2.5	3.7	97.2
	All	3	1.9	2.8	100.0
	Total	108	68.4	100.0	
Missing	System	50	31.6		
Total		158	100.0		

Water Payment		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	135	85.4	86.0	86.0
	No	22	13.9	14.0	100.0
	Total	157	99.4	100.0	
Missing	System	1	.6		
Total		158	100.0		

Wastewater Re-use Benefits		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	48	30.4	60.8	60.8
	No	31	19.6	39.2	100.0
	Total	79	50.0	100.0	
Missing	System	79	50.0		
Total		158	100.0		

Wastewater Disposal		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Septic tank/soak away	29	18.4	18.4	18.4
	Central sewer system	17	10.8	10.8	29.1
	Pit latrine	34	21.5	21.5	50.6
	Gardening	11	7.0	7.0	57.6
	Throw away	52	32.9	32.9	90.5
	Septic & throw away	1	0.6	0.6	91.1
	Pit & throw away	3	1.9	1.9	93.0
	Pit & gardening	5	3.2	3.2	96.2
	Gardening & throw away	6	3.8	3.8	100.0
	Total	158	100.0	100.0	

Wastewater Recycling		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	83	52.5	52.5	52.5
	No	75	47.5	47.5	100.0
	Total	158	100.0	100.0	

Wastewater Re-use		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Horticulture	1	0.6	1.0	1.0
	Brick-making	4	2.5	4.1	5.2
	Garden	36	22.8	37.1	42.3
	Cleaning	5	3.2	5.2	47.4
	All (including drinking)	46	29.1	47.4	94.8
	Brick & garden	1	0.6	1.0	95.9
	Brick & livestock	1	0.6	1.0	96.9
	Horticulture & livestock	3	1.9	3.1	100.0
	Total	97	61.4	100.0	
Missing	System	61	38.6		
Total		158	100.0		