TECHNOLOGY TRANSFER NEEDS ASSESSMENT IN ZIMBABWE

2004

CONTENTS

LIST OF MAPS, TABLES AND BOXES

ACRONYMS AND ABBREVIATIONS

AREX	Agricultural Extension Services
AIJ	Activities Implemented Jointly
AWOS	Automatic Weather-Observing Stations
BNR	Biological Nutrient Removers
BS	British Standards
CCC	Canadian Climate Centre
CDM	Clean Development Mechanism
COP	Conference of Parties
DCP	Data Collection Platform
DDF	District Development Fund
EMA	Environmental Management Act
GM	Genetically Modified
GOZ	Government of Zimbabwe
HYCOS	Hydrological Cycle Observing System
IPCC	Inter-governmental Panel on Climate
ITCZ	Intertropical Convergence Zone
ENSO	El Nino – Southern Oscillation
NRZ	National Railways of Zimbabwe
UNFCCC	United Nations Framework Convention on Climate Change
UNITAR	Untied Nations Institute of Training and Research
RETIM	(Satellite Distribution System)
SAS	Southern African Association
SADC	Southern Africa Development Community
SADIS	Satellite Distribution System
SAZ	Standard Association of Zimbabwe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
Wedis	Aviation Software
WHYCOS	World Hydrological Cycle Observing System
WRMS	Water Resources Management Strategy
ZINWA	Zimbabwe National Water Authority
ZESA	Zimbabwe Electricity Supply Authority

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This comprehensive report "Technology Transfer Needs Assessment in Zimbabwe" was borne out of collaboration among many different expects spread across in different sectors of the country. Various individuals and institutions have over the past two years worked together to come up with the technology transfer needs assessments. Experts attended workshops, exchanged ideas and concepts, and contributed to the write-up of this document. Various institutions and industries made many documents available to enable the partners in this initiative make this report as current as possible.

Two workshops were organised in order to collect as many ideas and as much information from the experts and stakeholders. The participants are listed elsewhere in this report.

The Ministry of Environment and Tourism (Climate Change Office) would like to thank all the expert individuals and organisations which made time and their expertise available to enable us to successfully accomplish this project.

Foreword

Zimbabwe, through the years, has demonstrated its willingness to preserve the global climate for the good of the present and future generations. Zimbabwe was one of the first countries to sign the United Nations Framework Convention on Climate Change at the United Nations Conference on Environment and Development, held in Rio de Janeiro in June 1992.

Since 1993 Zimbabwe has carried out several activities under the collaborative modalities with various donors. All the previous efforts were focused on compiling greenhouse gas inventories as well as raising awareness on mitigation, vulnerability and adaptation to climate change. The focus of this project "Expedited financing of climate change enabling activities Part II", which was funded by United Nations Environment Programme prepares the country for climate change adaptation and mitigation strategies. This aspect is very important, as the risks of adverse effects of climate change on agriculture and water resources, especially in Zimbabwe, which is characterized by more frequent and prolonged droughts, become life threatening.

Water resources are expected to dwindle and the evergreen forests of the Eastern Highlands of Zimbabwe may be reduced to seasonal forests. From the foregoing, it is clear that the impacts of climate change on Zimbabwe could negatively impact on our efforts to achieve sustainable development.

The focus of the technology assessments prepares the country for mitigation through identification of feasible energy efficiency options and barriers to their implementation. A number of technologies need to be revised or changed in order to reduce emissions of greenhouse gases. Another aspect coming out is the need for the use of renewable resources in whichever areas possible.

Finally, I would like to thank the United Nations Environment Programme for providing funds and technical guidance on the project.

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EXECUTIVE SUMMARY

1. Background

Greenhouse gas concentrations in the atmosphere are increasing globally. Since 1800, the atmospheric concentration of carbon dioxide, methane and nitrous oxide have increased approximately 30 percent, 145 percent, and 15 percent respectively (IPCC, 1996). The prevailing scientific opinion is that increased levels of greenhouse gases in the atmosphere may cause global warming or other forms of climate change. Some results due to global warming directly relevant to Zimbabwe could be the loss of biodiversity and changes in forest composition; changes in pest and disease epidemics; changes in rainfall distribution and increased storm frequency and intensity; and shifts in agricultural production patterns.

The Government of Zimbabwe views global climate change as a serious issue. As a result, Zimbabwe signed and ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 after the Rio Earth Summit. By signing the UNFCCC, Zimbabwe became Party to the Convention. Being Party to the Convention carries with it certain obligations like curbing the growth of greenhouse gases, preparation of National Communications and enunciating climate change policies. National climate change policies are both a function of national priorities as well as trends in the international debate on global warming. Zimbabwe is in the process of finalising the papers pertaining to the signing of the Kyoto Protocol.

The Climate Change Office, which was established in 1996 in the Ministry of Environment and Tourism, has conducted several studies on climate change and climate-related issues. This project on Climate Change Technology Transfer Needs Assessment is the latest project to be implemented by the office as a follow up of several others, which mainly concentrated on inventories of greenhouse gases and mitigation studies.

Zimbabwe like most other developing countries are very much concerned with the potentially serious impacts that global climate change might have on the country. At the Rio'92 conference it came out clearly that the Parties to the UNFCCC recognized the importance of environmentally sound technologies as well as high-quality data of greenhouse gases and climate-related information and have noted that, in many instances that, either the geographic coverage, quantity or quality of the data produced by current global and regional observing systems are inadequate. Most of these problems occur in developing countries, where lack of funds for modern equipment and infrastructure, inadequate training of staff, and continuing operational expenses are often major constraints.

Zimbabwe is contrained by its inability to put appropriate measures in place in order to respond to climate change requirements because of lack of human, institutional and financial resources. However, Zimbabwe has continued through the years to support the United Nations efforts to curb the escalation of greenhouse gas emissions. The issue of climate change has now been included in the National Environmental Policy of Zimbabwe.

The technology transfer needs assessment project is in response to several pertinent decisions of the Conference of Parties (COP) and the obligations of each country under the UNFCCC as stated in the Article 4.5 of the convention. Article 4.5 of the UN Framework Convention on Climate Change (UNFCCC) states that developed countries **"shall take all practicable steps to promote, facilitate, and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention."** In this context, technology transfer is designed to assist the Zimbabwe with responding to climate change through the diffusion and use of appropriate climate change mitigation and adaptation technologies.

It is with the above background that the Ministry of Environment and Tourism (Climate Change Office), with funding from UNEP, hosted a technology transfer study inception workshop on 23 April 2004 with various stakeholders and experts/scientists. The central goals of the inception workshop were to review the identified needs in the Initial Communication, as the first step to technology transfer needs assessment in Zimbabwe. Secondly, to identify priority sectors and sub-sectors to be studied. The third goal was to clarify and confirm terms of reference of technology transfer needs assessment consultants. The three principal sectors that were agreed upon for investigation were the agriculture, industry/mining and energy sectors.

2. Agriculture Sector

Agriculture is a strategic sector in Zimbabwe, yet it is directly affected by climatic variability and change. Agriculture's adaptation to climate change will require the following priority technologies:

- New genetic stocks for crops and livestock
- Improved water harvesting, water conservation and irrigation efficiency
- Improved soil nutrient management.

Current knowledge of adaptation and adaptive capacity is insufficient for reliable prediction of adaptations and evaluation of planned adaptation options. Research in many sectors and regions indicates an impressive human capacity to adapt to long-term mean climate conditions but less success in adapting to extremes and to year-to-year variations in climatic conditions. As a result, adaptations designed to address changed mean conditions may or may not be helpful in coping with the variability that is inherent in climate change.

Agriculture in Zimbabwe can contribute modestly towards greenhouse gas emission mitigation through:

- Carbon sequestration in soils and forests
- Ruminant diet improvement to reduce methane emissions.
- Better soil nutrient management to reduce nitrous oxide emissions.
- Manure to methane fuel conversion.

The effectiveness of technology transfer in the agricultural sector in Zimbabwe would depend to a large extent on the suitability of transferred technologies to the socio-economic and cultural context of the recipients.

A number of barriers will need to be overcome to facilitate technology transfer for the agricultural sector in the country in the context of climate change. Key among these are:

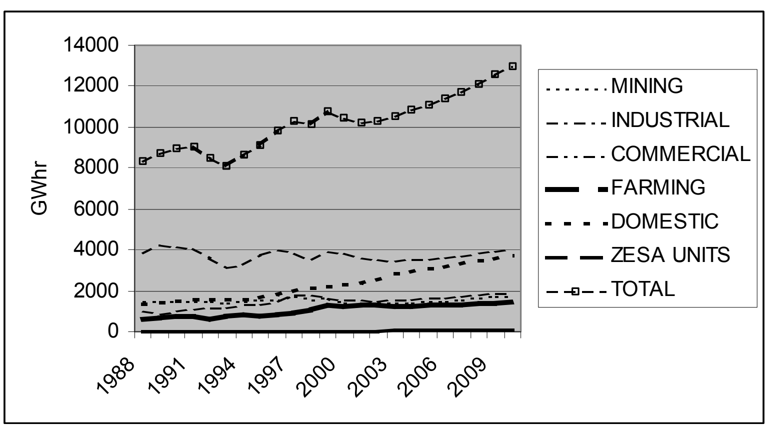
- Unrestricted movements of innovations between countries, as was the case with the Green Revolution.
- Education and information lie at the heart of technological transfer.
- Policy
- Financial constraints

3. Energy and Industry

The energy sector is dominated by coal. There are hydro resources as well as solar energy, which have been developed, but to a limited extent. Most of the energy is used in industry with the majority of the population having poor access to modern energy.

Energy demand growth continues to be positive even though there is a slow down in terms of economic activity. The growth in energy demand seems to be driven by the growth in households. Indications are that suppressed demand is playing a major role in limiting demand growth but the situation can change in a very short time.

Fig 1: Projected Energy Demand Growth



The looming shortage of capacity on the regional grid is a major factor influencing energy planning at the present moment. Effort is being made to find new sources of electricity to meet demand after 2007. Coalbed methane is a major option but energy efficiency improvement continues to be an attractive option.

4. Technology Transfer

Several projects have been carried out that identified opportunities for energy efficiency improvement or technology upgrading. Given the reliance of the energy sector on hydro electricity and the climate change impacts of coal use, opportunities for climate mitigation tend to link closely with opportunities for climate change adaptation. The following table shows some of the technologies that have been identified in Zimbabwe.

Table 1: Technology Options for Climate Mitigation

Technology	Description of Option
Domestic lighting	High efficiency lamps
Electric water heaters	Solar water heaters, usage regulation
Electric motors	High efficiency motors, speed control, Power factor control.
Industrial boilers	Steam use co-ordination, insulation improvement, flue gas heat recovery
Industrial furnaces	Plasma arc furnaces
Foundries	Waste heat steam boilers
Diesel tractors	Low tillage agriculture
Road transport	Ethanol-Gasoline blending
Low Carbon Fuel	Coalbed methane
Renewable Energy	Wood waste power generation Solar water heaters PV Power Crop waste gasification Wind farm for electricity Wind pumps Solar cookers Solar crop dryers Solar refrigeration Biogas digesters
Soft technology	Industrial audits Integrated resource planning Rural electrification master-plan Power Pool Analysis

Source: UNEP Abatement Costing Studies

Several barriers exist that limit the rate of technology transfer. These barriers include;

- Lack of awareness on more efficient technologies
- Limited capital resources
- Low skills for energy efficiency planning
- Poor policy environment
- Lack of appreciation of benefits of energy efficiency improvement

Barriers tend to be intertwined hence it is difficult to separate one from the other. For example limited skills for project development may actually appear like limited availability of loan finance because the proponent fails to make a convincing argument for finance.

Barrier removal is therefore a complex process that requires careful assessment and design of the measures.

4. Transferable Technologies

The study focused on a sample of technologies that can be implemented in Zimbabwe. These include;

- Electricity from sewage gas
- Energy from sawdust
- Efficiency improvement in cement production
- High efficiency lighting
- Variable motor speed drives
- Solar water heating

Table 2 Previous Technology Transfer Initiatives

Year	Initiative	Funding	Objective
1994 – 2000	GEF PV Pilot Project	UNDP-GEF	To promote PV solar home systems and PV Power
	SADC-CTI Project	OECD-CTI	Promote investment in cleaner energy technologies in SADC
	National Climate Change Assistance Program	Dutch Government	To assess barriers to adoption of energy efficient technologies and to propose barrier removal options
1996 – 1997	Willowvale Industrial Park Project	UNDP – Public Private Partnership Program	To introduce an industrial park level energy and waste management scheme
	SADC Industrial Energy Management Program	CIDA	Promoting Industrial Energy Management and Capacity Building
	GEF – Small Grants	UNDP- GEF-SG	Promote adoption of climate friendly technologies

Previous activities have achieved varying levels of success which need to be considered in future activities. The activities were at different times during the years 1990 to 2000 therefore the institutional memory for these activities is limited.

5. Conclusions and Recommendations

Technology adoption decisions in the energy and industry sectors are based on individual priorities. Energy production and supply maybe in the national realm in terms of investment and regulation but energy end-use is centred on individual decisions. It is therefore apparent that programs to promote technology upgrading in the energy sector have to be structured so as to influence individual decisions. This implies a wide range of high cost activities, which need careful consideration to promote success. Integration of technology transfer objectives into current policy objectives can help in minimising cost. The Environmental ACT is one policy vehicle that can be used to promote technology upgrading. It is however important that the ACT is analysed for opportunities where technology transfer can support the objectives of the legislation whilst instruments available to the ACT can be used to promote technology transfer. The types of technology that can be transferred range from local soft technologies that can be transferred between local organisations, local hardware, to imported hardware and soft technologies. In all cases the benefits of the technology need to be measured in terms local economic priorities, local environmental priorities as well as global environmental benefits.

The national energy mix is critical to energy security. Given the potential impacts of climate change on the energy sector it is important to build an energy supply system that has sufficient diversity to safeguard the economy against climate induced energy shortages. Out of the 1800MW of installed capacity in Zimbabwe, 750MW is hydro supplied by the Kariba Power Station. Electricity is also imported from Mozambique and Zambia both of which are hydro dependent. Efficiency improvement through technology upgrading would reduce the potential impact of failure of the regional hydro resources. If the potential impact of the hydro resources is estimated to within reasonable limits the required level of technology upgrading to minimize the impact of climate change on the economy can be defined. This would lead to the development of appropriate policy to guide the expansion of the energy supply system.

The productive sector is continuously being driven to produce for the export market. Issues of quality, quantity and environment are key to local industry meeting demands for export goods. In the centre of this criteria is the availability of appropriate technologies. The market for export goods and the local capacity to produce such goods are usually analysed separately. If the two parameters are analysed together there would be a clearer guide for industrial policy that would link up with other technology related policies as well as energy supply policies. A program to define the local technology market in relation to requirements for production could be established with the key Ministries being Ministry of Industry and International Trade, Ministry of Energy and Power Development and Ministry of Environment and Tourism. Such a program would link up with any climate related policies and benefit from UNFCCC mechanisms.

CHAPTER 1: NATIONAL OVERVIEW

1.10 Weather and Climate

Zimbabwe's atmosphere

Zimbabwe lies in a semi-arid and arid region in which rainfall is variable and unreliable, impacting on rain-fed agriculture and other sectors of the economy. The country, which has a seven-month dry period annually, has in the recent past been experiencing frequent droughts. There is also evidence of increased frequency of floods especially in the low-lying areas of the Zambezi and Limpopo basins. These events have resulted in loss of life and property.

Rainfall totals on average decrease from north to south. Apart from the general effects of global climate change and several local factors, rainfall over Zimbabwe is also influenced by El Nino – Southern Oscillation (ENSO). The climate of Zimbabwe does not exhibit the traditional summer-autumn-winter spring seasonal cycle as in mid latitude weather regimes but is characterized by the following seasons:

Cool season: mid May to August
Lowest temperatures are recorded during this season. The season is also characterised by cold nights with occassional frost, clear skies, dry air and calm conditions. It is the least rainy time of the year.

Hot season: September to mid-November
High temperatures characterize this season with low humidity especially in September. However, thunderstorm development starts towards the end of October and in some years, progresses into November.

Main Rain Season: mid-November to mid-March
The character of the rainy season is largely depended on the behaviour of the Intertropical Convergence Zone (ITCZ), a result of the convergence of the Congo Air and the southeast Trade winds. Tropical cyclones also bring significant rains into the country once in a while. The cessation of the rainy season is quite variable in different years. At times it may end abruptly and at other times the rains may peter out gradually as the air near the surface and aloft gradually become drier

Post –Rainy season: mid – March to mid – May.
This is the transition period between the main rainy season and the cool season. Days become progressively hotter during the first half of the transition period. Thereafter a fairly steady downward trend in temperatures sets in. Many people regard this as the most pleasant time of the year as the weather is mild and sunny.

The mean annual temperature varies from 18ºC in the highveld to 23ºC in the lowveld. The highveld experiences some frost in June or July in most years and temperatures rise up to 30ºC around October. In the lowveld region, temperatures rarely fall below 2ºC in winter but can rise to over 40ºC in summer. An attempt was made to analyze temperature changes in Zimbabwe and the results tend to agree with the regional and global warming trends. The preliminary results of the above analysis show that there are indications that minimum temperatures are gradually increasing as the number of cold days is decreasing. The number of days with maximum temperatures below the 10percentile is also decreasing by not less than 7days/100years for the analyzed stations. The same result was observed for Africa from the 1980s' to 2000 when the mean temperature anomaly started increasing.

National Climate Change Highlights

A set of climatic extremes for some selected meteorological stations in the Zimbabwe were analysed for search of evidence of climate change. Daily data records for rainfall, minimum and maximum temperatures are analysed using RClimdex software.

From the analysis, it has been observed that the monthly highest daily maximum temperatures (TXx) for most of the stations are on the increase, by about 2ºC per century (see an example on Fig 1a). The percentage of days when minimum temperature is below the 10^{th} percentile (TN10p) shows us whether the number of clod days is increasing of decreasing. From the analysis, the indices for 80% of the stations imply that the number of cold days is decreasing at the rate of about 15 days/century. The model explains about 33.2% of the variance in the Belvedere trend, 29.9% for the Goetz variance and 25.6% for Beitbridge (for Beitbridge see Fig. 1b).

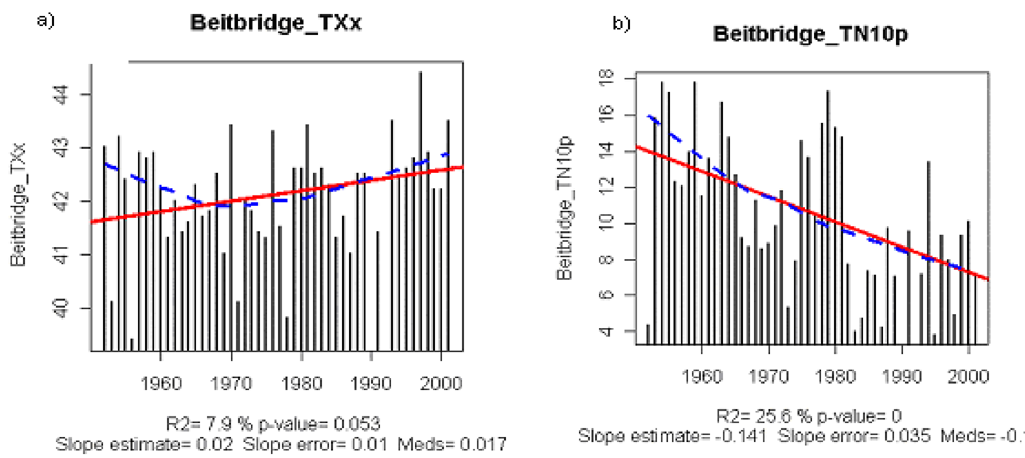


Figure 1: Graph showing the Least Linear Square for maximum a) and minimum b) temperatures for Beitbridge

Climate observing systems in Zimbabwe

Meteorological observations are the backbone of climatological studies among other uses. The Zimbabwe meteorological station network comprises of 64 stations and around 46 are manned by meteorological staff and the rest are part time stations, meaning that they are manned by the relevant institution where the equipment is installed and these are mostly agricultural research stations.

Apart from the conventional equipment, which is installed at meteorological stations, the Department of Meteorology also operates seven automatic weather-observing stations (AWOS) around the country, with a project to have 20 AWOS by 2005. Other available additional observation/transmission tools used as forecasting aids are 4 weather radars, a PDUS Meteosat receiver, and Synergy system.

The network also includes aviation stations with which use other communication systems such as SADIS, RETIM AFRICA and Wedis. The department has three upper air stations, which can do both the radio-sonde and balloon ascents besides the pilot balloons, which are done by other 10 stations using the theodolite.

State of the equipment

The department embarked on a modernization programme during the period 1999 to 2000. The idea was to replace all the old standard equipment more than forty years old with new technology. The project was done with sponsorship from the European Union and the Spanish Government, and was supposed to be in two phases.

The first phase included supply of 25 stations with standard equipment and the rest was supposed to be done in the second phase. So about 23 stations out of the 64 have new equipment, which was supplied in 2000. The second phase is still pending due to financial constraints. It means that out of the 64 stations only 25 are going to have equipment, which is less than 5 years old. The other problem on the equipment is shortage of consumables like fibre tipped pens, tracing ink, special lubricating oil, heat sensitive paper and lack of spare parts to repair the faulty equipment. The department needs to replace all its upper air stations, which were using the RS80 sonde, which will be phased out at the end 2004.

The Department of Meteorology needs to open more stations in order to improve the coverage of data.

Technological Transfer Barriers

Financial constraints of the Zimbabwe economy is the major barrier to technology transfer. Some of the challenges facing the country are that whenever funding for procurement of new equipment is sourced it is difficult to include the training component for the maintenance of the equipment. The other barrier is that the resources accessed are enough to procure technology without backup spares that require outsourcing expertise for maintenance.

Recommendations

In order to satisfy the basic requirements of the World Meteorological Organisation, and consequently for the country to fulfill its obligations to the United Nations Framework Convention on Climate Change (UNFCCC), the following recommendations are suggested:

- To make available spare parts for the instruments
- Replacement of old equipment with new equipment should be done at once for all stations in order to maintain uniform standards of instrument sensitivity.
- Training of instrument technicians should be enhanced with donor funding.

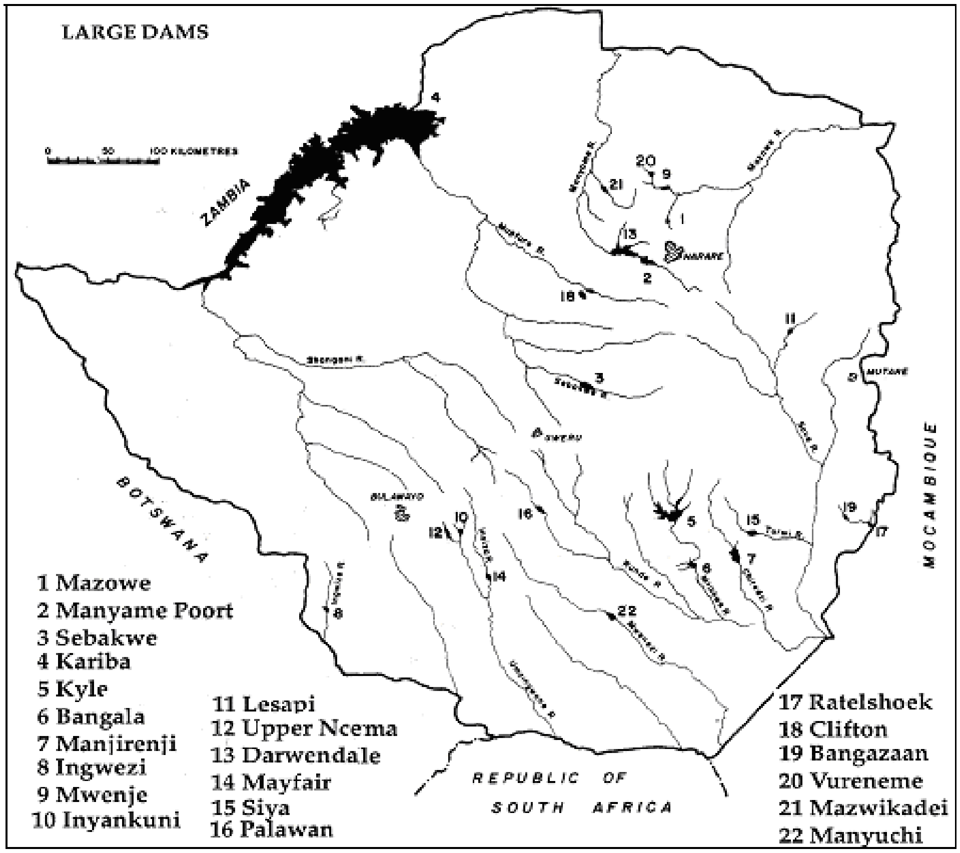
- Comprehensive metadata will assist analysts of data to interpret data trends correctly.
- Equipment for ozone and pollution measurement should be acquired for installation as soon as possible since currently there is virtually none.
- The observational network, both surface and upper-air needs further expansion.
- Equipment to measure greenhouse gases should be installed in strategic industries and other relevant institutions in order to achieve regular observations countrywide.

1.20 Water Resources

Scientific evidence that has been gathered over the past 30 years from numerous and climatically diverse parts of the world shows that there is increasing but intensified variability in the hydrological cycle. It is highly probable that the variability is going to intensify as further global warming adds to the ever-present climatic turbulences whose main aspects are extreme droughts, floods, heat and freezing cold spells. Extreme weather records continue to be broken, e.g. the devastating 2000 extreme floods that affected Mozambique and Zimbabwe, which were caused by cyclone Eline. The regional drought of 1991/92 resulted in enormous damage to the economies of southern Africa.

Water resources in Zimbabwe

The semi-arid nature of Zimbabwe's climate entails that quite a significant number of rivers dry up during the annual dry season that stretches from April to September. Rivers also dry up and cease to flow during prolonged dry year-on-year droughts. In order to sustain water supplies to diverse demand users, Zimbabwe relies on an extensive network of over 10 000 small, medium and large dams (Ndamba et al, 2000). Refer to **Map 1** for some of the large dams in Zimbabwe. The country relies on surface water resources for 90% of its requirements while groundwater supplies the remaining 10%.



Map 1: Some of the large dams in Zimbabwe

An estimate water balance for a normal year in Zimbabwe shows that the country receives approximately 253 million cubic metres of water from a mean annual rainfall of 650mm. Of this amount, 231 million cubic metres is lost to evaporation from surface water and transpiration from vegetation. It is an estimated 20 million cubic metres that forms runoff into rivers and then forms the main source of water for demand uses such as irrigation, urban, industrial, mining and other primary as well as secondary purposes (Nilsson and Hammer, 1996; Ndamba et al., 2000). Of the estimated total runoff, the potential yield is around 11 million cubic metres of which 75% or 9 million cubic metres can be actually exploited. Of the exploitable potential, about 5 million cubic metres is currently committed and this leaves a total of around 4 million cubic metres for future uses.

With Zimbabwe having a total population of 11.3 million people, the theoretical amount of water available per capita is around 2000m^3 annually when compared to a world average of 7700m^3 and an African average of 6500m^3. Agriculture uses up to 80% of available surface water resources while the rest of the other demands use the remaining 20%.

Overall, Zimbabwe has the technological capacity to design and construct various dam types that include the double-curvature concrete arch, single-curvature concrete arch, concrete buttress, concrete gravity, earth and rockfill embankments as is fairly represented by the dams in existence.

Groundwater resources contribute around 10% of water requirements in Zimbabwe. While groundwater is not a significant source of water for irrigation and most economic production purposes, it is the major source of portable water supplies for 70% of Zimbabwe's population, which lives in the rural areas. The National Action Committee on Rural Water Supply and Sanitation has it on record that a total of 20 000 boreholes and 10 000 deep wells sustain rural communities throughout Zimbabwe (Ndamba et al., 2000). The estimated groundwater abstraction is 28 to 35 million cubic metres per year for rural water supplies. A general estimate of Zimbabwe's groundwater puts the figure at between 1 000 and 2 000 million cubic metres.

Groundwater is mainly for domestic water supplies, which include drinking and bathing, stock watering, small-scale gardening and horticultural production. The main technologies in use for groundwater exploitation include hand pumps, bucket pumps, electric and diesel powered pumps.

Legal and institutional framework for water management in Zimbabwe

The Water Act (1998) is the single most important legislative tool that guides water resources planning, development, distribution, pollution control, conflict resolution and day-to-day management in Zimbabwe. Of relevance to the issue of climate change is that the Act actually addresses weather extremes that are droughts and floods as national development limiting factors that require special attention from water managers and decision-makers. The act addresses the integrated water resources management framework as the guiding philosophy for the development and management of water resources in Zimbabwe. The act addresses stakeholder participation in water resources development and management. It also acknowledges that the environment is a water demand user that should be included in all water resources development and management activities. However, the act is silent on climate change per se.

Other importance aspects of the act are that the water right system was replaced by a water allocation system, which in turn addresses the issue of equitable access to water, by all demand users. The act also addresses water shortages through a presidential issued decree. Thus water shortages that may arise as a function of climate change induced weather extremes can be adequately addressed through the Water Act. The integrated approach to water management provides a platform from which to mobilise both surface and ground water resources to satisfy diverse demands during climate change induced periods. Inherent to this is the use of appropriate technologies to deliver services to water users.

Despite Zimbabwe having embarked on the development of a Water Resources Management Strategy (WRMS) in the latter part of the 1990s, the output is not implementable with respect to such aspects as equitable water allocation, water pricing, demand management, quantification of resources and demands, management guidelines, investment strategies, technologies, capacity building and legislation.

The institutional framework for the Zimbabwe water sector has a large number of actors that are involved in different aspects of water development and management. The Ministry of Water and Infra-structural Development has responsibility over water policy issues. The Zimbabwe National Water Authority (ZINWA) is tasked with the actual development and management of water resources. Stakeholders participate in water policy implementation activities through Catchment Councils.

Other actors include the District Development Fund (DDF), which is into the development and management of primary water sources for domestic and small-scale irrigation in rural and re-settlement areas. The Ministry of Health is into the development of primary water sources especially for nutritional purposes through the establishment of small vegetable gardens. The Department of Agricultural Extension Services (AREX) has responsibility over the development of smallholder irrigation schemes in the country.

Framework to meet climate change induced challenges in the Zimbabwe water sector

Although Zimbabwe is a water scarce country by virtue of the semi-arid nature of the natural environment and the ever-increasing demands of water to satisfy a diversity of uses, it can be safely concluded from the preceding sections that an enabling environment exists for handling some climate change induced challenges. There is already elaborately developed water infrastructure that includes numerous dams, boreholes, water and wastewater treatment facilities, and water conveyance systems. The legal, policy and institutional frameworks for dealing with weather extremes such as droughts and floods exist although it is silent on climate change as a threat per se.

For the socio-economic and environmental systems of Zimbabwe to survive, copying strategies are essential. The use of appropriate water management technologies with the objective of sustaining viable economic production activities and dependent quality human livelihoods in a pristine natural environment is inherent to any copying strategies.

Of fundamental importance is the need to have such water management technologies available as well as information on those that can be sourced from outside the country for the purposes of copying with the adverse impacts of climate change. It is therefore imperative that key water using activities are addressed in this document. Although there is discretisation of technology types, it has to be noted that an integrated approach to addressing climate change impacts on water is likely to yield positive benefits from the survival strategies chosen.

Agricultural crop production in Zimbabwe is primarily rainfed especially for the indigenous population in rural and resettlement areas. However, the commercial farming sector is dependent on both the natural rain and supplementary irrigation. Irrigated agriculture uses up to 80% of water in reservoirs. In studies carried out by FAO, it was found that current irrigation efficiencies are on average at 30% of their designed capacities. Thus 70% of the water goes to waste. Thus it is necessary to have water management technologies that sustain agricultural production in worst-case scenarios. Various technologies could be used in order to mitigate as well as adapt to climate change. The issue of technologies transfer is thus pertinent in this regard. Chapter 2 discusses in detail the technologies to be transferred in the agriculture sector.

Water scarcity in dry areas of Zimbabwe is a perennial crisis in which people need information and the know how of capturing and using every available drop of water efficiently. Research work and field trials are currently being done on various water harvesting technologies in the dry areas of Zimbabwe.

A dead contour with zero slope is demarcated between two contours of equal height. Five to ten meter length pits are dug along the dead contour. Each pit is then paved with variable clay thicknesses in order to facilitate infiltration of water into the crop field. To avoid losses to evaporation, the pits are covered with slabs, which have small openings on top that facilitate withdrawal of water from the pit using buckets if the need arises. Thus the pits act as water storage reservoirs while facilitating controlled soil moisture infiltration into the field for crop growth.

Dead contour water management technology could be used in conjunction with appropriate soil-water management techniques and drought tolerant seed varieties, yields of such crops as sorghum, rapoko and finger millet. Finger millet that produces up to 3 tonnes of yield per hectare has been successfully tried and compared to around 1 tonne per hectare under dryland farming. Such improved production levels have been recorded in the marginal dry areas of Chivi, Mudzi and Mutoko where field trials are taking place.

This technology has been demonstrated to be significantly efficient in achieving higher crop yields with only 200mm of rain and is considered quite ideal in situations of climate change. This technology is easily transferable to areas of Zimbabwe with gentle to mild slopes. Training requirements will be needed for target areas in terms of building capacity at village user level.

Technologies from outside Zimbabwe

Tied ridges could also be used as and adaptive measure. These are similar to the normal contour ridges but have soil bunds across the trench sections at given intervals. They catch all flow into them and retain the water, which then infiltrates into the adjacent field for crop moisture benefits.

Fanya juus are right the opposite of contour ridges. The soil from the trench is heaped up slope while that for contour ridges, the soil is heaped down slope. The resultant ridge has the effect of keeping water within the levelled field so as to facilitate infiltration for the benefit of the crops. Research and field trials so far carried out in the drier areas such as Mudzi and Chivi have been achieving crop yields of up to 3 tonnes per hectare where dryland farming normally achieves around a tonne per hectare.

The two technologies outlined above are being implemented in Kenya and Tanzania. If experiments are carried out extensively in Zimbabwe, the results could benefit the community in the wake of climate change.

Proper soil management techniques could also be used as adaptive measures to climate change. The need for appropriate land management techniques in combination with water harvesting technologies as well as the application of manure for the purposes of optimising on soil moisture for crop benefit cannot be over emphasized.

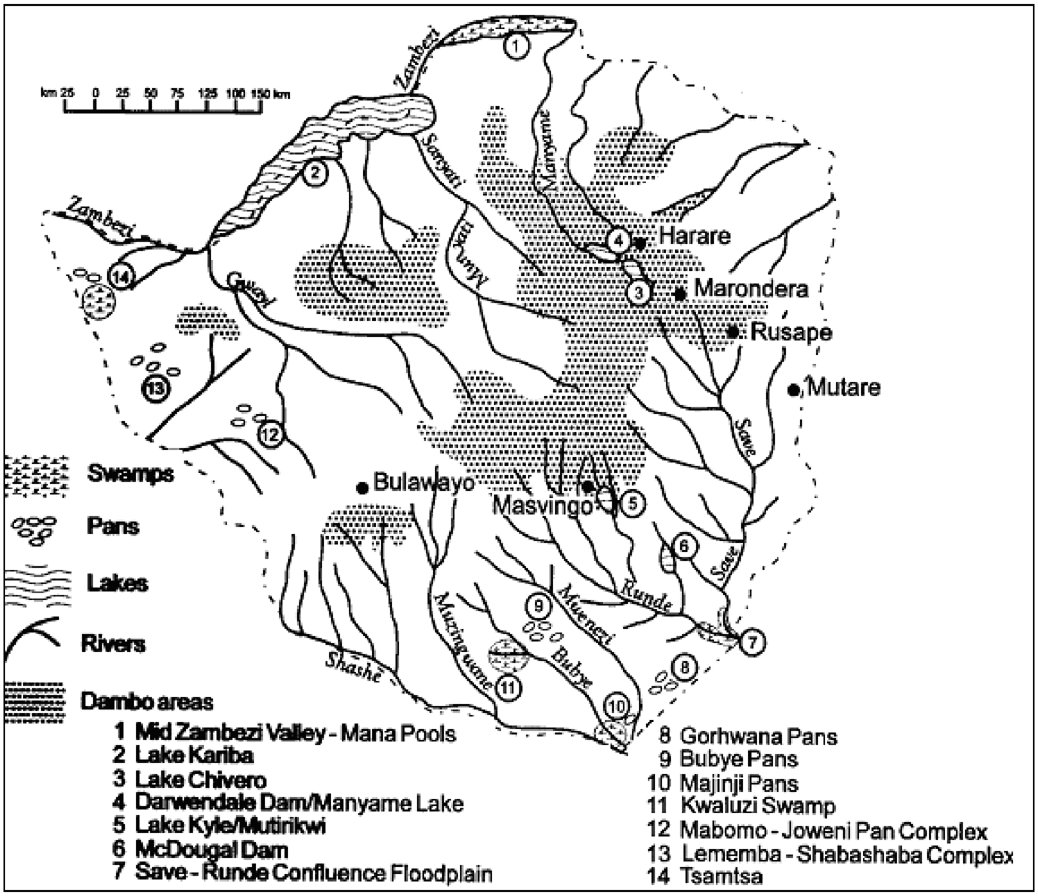
It is worth noting that the naturally dry or desert environments survive on very efficient water harvesting and utilisation technologies that are deemed to be of relevance if ever Zimbabwe is affected by climate change. Examples are Egypt, Tunisia, Yemen, Israel, Libya and Morocco. The objective would be to catch as much rainfall and runoff as possible in the face of unavoidable losses to evaporation. Some of the technologies that will need to be investigated for transfer to a potentially drier Zimbabwe are:

- Micro-catchment systems in which runoff is caught and directed to an adjacent agricultural area with say tree crops. In this case, runoff flows over very short distances and the root zone is the storage reservoir.
- On-farm micro-catchment systems whereby all water controls structures are constructed inside the farm boundaries. Structures include contour ridges, semi-circular and trapezoidal bunds, small pits, eyebrow terraces, runoff strips, contour bench terraces and small farm water harvesting reservoirs for supplemental irrigation.

These systems concentrate on mainly the catchment areas, storage facilities and target recipient areas. Some of the issues to be addressed when considering for transfer to Zimbabwe include stakeholder participation to ensure acceptability and ownership, socio-economics, applicability to targeted areas of the country and impacts on the natural environment.

Zimbabwe is endowed with wetlands that are called dambos. Research on the ecological functions of wetlands shows that wetlands play very important roles in nutrient retention and export, groundwater recharge and discharge, flood control and flow regulation, sediment retention, erosion and salinity control, water treatment, micro-climate and ecosystem stabilisation.

Dambos are a major source of rural livelihoods in the dry areas of Zimbabwe as well as during the annual dry periods. When utilised in conjunction with water management technologies such as bunds, they yield high volumes of food crops. During the 1991/92 drought, most dambos remained viable and wet. Thus they have to be included in the strategies for copying with the adverse impacts of climate change. The management of these delicate features is still an issue that needs significant investigation as well as the appropriate technologies to use.



Map 2: Occurrence and distribution of wetlands in Zimbabwe
(Source: Chabwela, 1991)

The use of drip irrigation systems is being tried in the field in the drier areas of Zimbabwe such as Mudzi, Chivi, Gwanda and Mutoko. Drip systems are being applied to the production of horticultural crops such as fruits and vegetables. The sizes of the plots range from $100m^2$ to $500m^2$.

A special feature of these drip systems is that they are operated on low variable head with water supply drums being on stands that are 0.5 to 1.0 m above the ground. The drip systems include Plastro and Netafim from Israel and IDE from India.

The Ministry of Agriculture's Zimbabwe Irrigation Technology Centre and the University of Zimbabwe are involved in testing and adapting the imported irrigation technologies before releasing them onto the Zimbabwe market. The extensive use of these systems is being hampered by lack of financial resources.

Other technologies that are being tested include micro-sprinklers, micro-jets and low volume sprayers. It has to be pointed out that a range of these water conservation technologies proved to boost horticultural production when used in conjunction with green houses.

Thus this combination of technologies has to be considered for transfer to agricultural producers with stakeholder participation. These technologies are producing very good production results. Some of the issues to consider when transferring the technologies from say Israel and India include considering the setting up of manufacturing and back up services in Zimbabwe; acceptance by stakeholders; affordability in terms of costs to the user; copying with variable water quality across the country; and overall issues of sustainability.

Otherwise some of the technologies have been proved to be efficient in producing horticultural products with 200mm of water in dry areas. Hence the technology is transferable from the manufacturing countries to Zimbabwe. The fact that they use small amounts of water makes them most ideal for crop production in water scarce environments in the event of climate change.

A major output of all urban areas and *growth points* with piped water supplies are the large volumes of wastewater. This effluent is in most cases considered a significant source of water supplies. The major problem is the quality of this effluent. Of related importance is the need to produce high quality effluent without adverse effects on the recipient environment. Zimbabwe has serious problems with poor effluent quality, as the wastewater treatment facilities are obsolete.

Cities such as Harare, Chitungwiza and Marondera implemented effluent polishing facilities called Biological Nutrient Removers (BNRs) as end of pipe technologies. The resultant effluent is still of poor quality as the facilities are overloaded. Handling of wastewater is an area demanding significant investments in technologies.

Countries such as Canada are quite advanced with BNR technologies to the point of recovering phosphates for fertilisers. Thus Zimbabwe will need the know-how of wastewater handling technologies from such countries as Canada and Namibia.

A strategy that involves on-site waste treatment by effluent producing industries and upgraded waste treatment by local authorities will assist in recycling effluent as a means of copying with scarcities caused by climate change.

Finally, use of demand management techniques e.g. low volume flushing systems, pressure reduction, punitive tariffs, and public awareness – a combination of these measures will achieve water conservation, in view of the changing climate and the consequent anticipated reduction of precipitation.

Hydrological observing systems in Zimbabwe

Adequate information is essential for water resources management. Unfortunately, at the global scale, the ability to provide information about the status and trends of water resources is declining. Any developing countries (including Zimbabwe) are unable to maintain their systems for acquiring water-related data, and for disseminating them to decision-makers, engineers, resource managers and the public.

The World Hydrological Cycle Observing System (WHYCOS), which was developed by the World Meteorological Organisation, is composed of regional systems called Hydrological Cycle Observing System (HYCOS), implemented by cooperating nations. It is expected to compliment national efforts to provide the information required for effective resource management. The WHYCOS project is expected to be a vehicle for disseminating high-quality information and also build the capacity of National Hydrological Services so that they are ready to face the demands of 21st century. The information to be gathered should help in monitoring the trends of climate change.

Out of the 50 Data Collection Platforms (DCPs) proposed for the first phase of SADC HYCOS, 43 were installed, giving an average achievement rate 86%, which is quite high. Zimbabwe had all the proposed 5 DCPs installed. Currently, 3 stations out of 5 are working at Manyame at Nyakapupu, Mazowe at Old Mazowe Bridge and Save at Save Gorge. Mwenezi at Malipati Bridge and Mzingwane at Doddieburn are not working. An evaluation of the SADC HYCOS project that was recently carried out found out that there was a problem of breakdown of the stations in almost all the SADC countries.

Water resources-climate change scenarios

The CCC was used to develop temperature and precipitation scenarios for the doubling of CO_2 case. Estimating water demand to year 2075 was based on population projections and average growth rates in water usage from 1950 to 1995 (Zimbabwe National Communication under the UNFCCC, 1998). Rainfall-runoff simulation for the doubling of CO_2 scenario showed that a 15%-19% decrease in rainfall and a 7.5%-13% increase in potential evapotranspiration will result in a 50% decrease in runoff. This means that there is some scope for water conservation through the planning of appropriate adaptation strategies.

CHAPTER 2: AGRICULTURE SECTOR

2.10 Introduction

Zimbabwe cannot solve the potential problem of increases of global greenhouse gas emissions on its own. However, the country can act in conjunction with other nations to limit output of these gases and take advantage of the benefits relating to energy conservation, improved waste and material management, and improved air and water quality through reductions in pollutant emissions. Evidence from elsewhere suggests that this is best achieved through mainstreaming and integrating climate responses into development and poverty eradication programs. This study assesses technologies available to address both mitigation and adaptation activities in agriculture.

Atmospheric concentrations of key anthropogenic gases (i.e. carbon dioxide (CO_2), methane (CH_4), Nitrous Oxide (N_20) and troposphere ozone (O_3) reached their peak in the 1990s (IPCC, Third Assessment Report, 2001). The rise is attributed to combustion of fossil fuels, agriculture and land use changes. Greenhouse gas emissions from Zimbabwe agriculture as of 1994 are presented in Table 2.1. Furthermore, IPCC projects an increase in climate variability and some extreme events whose impacts will fall disproportionately upon developing countries and poor persons. Reducing (mitigating) emissions of GHGs to stabilize their atmospheric concentrations would delay and reduce damages caused by climate change. Adaptation at all scales is also a necessary complementary strategy, which together can contribute to sustainable development objectives.

Table 2.1 Greenhouse gas emissions from Zimbabwe Agriculture as of 1994 ***(Source: Ministry of Mines, Environment and Tourism, 1998)***

GHG Source or sink	Carbon Dioxide (CO_2) *Gg*	Methane (CH_4) *Gg*	Nitrous Oxide (N_2O) *Gg*	CO_2 equivalent *Gg*
i. Agricultural waste	-	0.93	0.03	**135.82**
ii. Ruminant enteric fermentation	-	179.82	-	**4405.54**
iii. Manure management	-	7.09	-	**173.71**
iv. Savanna burning	-	49.00	-	**8673.90**
v. Landuse change & deforestation (Sink)	-62269.00	1.26	0.01	**-62171.75**
Total Agric Emission (Gg)	-62269.00	236.84	2.39	
% of National Emissions	0%	**66%**	**25%**	

Global climate change and variability raise major socio-economic development challenges for Zimbabwe. Short-term development goals and the mitigation of existing social, economic and environmental problems may need to be balanced against the need for long-term environmental security. Agricultural productivity is highly correlated with climatic conditions. Our understanding of the climate change mitigation potential of the agriculture sector has improved. It is becoming clear that agriculture can make a significant contribution to reduction of GHG emissions, both in the short and medium term. The attractive feature of managing agriculture for GHG mitigation is that GHG management practices are consistent with general conservation or "Beneficial Management Practices" and result in improved economics and efficiencies for producers and processors, in addition to the obvious public benefits. However, major challenges exist at the science-policy interface in dealing with GHG management and adaptation to climate change and variability in the Agricultural Sector.

It is generally accepted that agriculture is not the major source of greenhouse gases. However, four main points motivate agriculture to be involved in efforts to reduce greenhouse gas emissions.

- Agriculture releases substantial amounts of methane and nitrous oxide.
- Agriculture has a large potential to enhance absorption of Greenhouse Gases by creating or expanding sinks through better management practices.
- Agriculture may provide products which substitute for Greenhouse Gas Emissions, and
- Agriculture may find itself operating in a world where commodity and input prices have been altered by Greenhouse Gas Emissions related policies of trading partners.

Agriculture needs to adapt to climate change for the following main reasons.

- Climate is changing and production techniques need to change with it.
- Policy may change to assist Zimbabwe in meeting its UNFCCC commitments.
- More importantly, farmers need to maintain a livelihood to support their families and to continue producing food and other raw materials for industry.

By adapting to climate change now, agriculture will be able to capitalize on the immediate benefits of the expected climate while minimizing potential adverse impacts of the change. Adapting to changing climate and developing relevant climate policies requires information. Adaptation has successfully taken place in agriculture in a number of ways over the course of its development in Zimbabwe. Farmers have successfully adapted their production and management practices to a variety of changes, such as technology, policy and weather, but not all adaptation techniques are sustainable or successful. Most significantly, for agriculture to adapt to climate change, there is need for the redirection of policy affecting agriculture. Zimbabwe needs to outline its climate change strategy to provide the agricultural community an idea of what it needs to adapt to.

2.20 Climate adaptation and mitigation technologies

There are two strategies for responding to predicted climate change: mitigation and adaptation. Mitigation attempts to address the causes of climate change and can be classified into three broad areas: reducing sources of GHGs; maintaining existing sinks of GHGs; and expanding sinks of GHGs. Adaptation is concerned with responses to the effects of climate change. It refers to any adjustments that can be undertaken to ameliorate the expected or actual adverse effects of climate change. It has been argued that adaptation succeeds if it seeks to reduce the vulnerability of the poor to existing climate variability, while also building in the potential to anticipate and react to future climate changes.

2.2.1 Adaptation technologies

There are 5 broad categories of adaptation measures:

- **Prevent the loss** - adopt measures to reduce vulnerability to climate change.
- **Tolerate the loss** - do nothing to reduce vulnerability and absorb the losses.
- **Spread or share the loss** - do not reduce vulnerability, but rather spread the burden of losses across different systems or populations.
- **Change the activity** - stop activities that are not sustainable under changed climate, and substitute with other activities.
- **Change the location** - move the activity or system

Zimbabwe's agriculture is highly vulnerable to climatic extremes particularly drought and floods. In a drought year, maize yields may fall by as much as 70% and about 60-70% of the country's population of about 11.8 million may require food relief assistance at phenomenal cost. Shocks in agriculture are felt throughout the country's agro-based economy.

The need for agriculture to adapt to current climate variability and future climate change cannot be overemphasised. Good technology and effective policies and programs will be needed to stimulate Zimbabwe agriculture's potential to adapt to climate variability and climate change.

The following were identified as key **problem areas** for Zimbabwean agriculture in the context of climate variability and change:

- Poor crops and livestock genetics
- Poor soil fertility management
- Lack of water
- Poor quality of animal feed

2.2.2 Mitigation technologies

In order to mitigate greenhouse gas (GHG) emissions from the agriculture sector, Zimbabwe's interventions should focus on enteric fermentation, manure management and carbon sequestration. Priority must be given to enteric fermentation and Carbon sequestration.

The efficiency of digestion in the rumen requires a diet that contains essential nutrients for the fermentative micro-organisms. When the available feed lacks these nutrients, digestion will be less efficient, lowering productivity and raising methane emissions per unit product. Improving production efficiency is therefore the most effective methane reduction strategy in livestock. Because Zimbabwe is striving to increase production from ruminant livestock, improvement in production efficiency will help to have these goals realised while simultaneously avoiding increases in methane emissions. Economic benefits of methane reduction should be emphasised to encourage farmers to adopt best management practices.

Factors supporting methane reduction projects

The study that was carried out in Zimbabwe revealed that economic development benefits derived from improving production efficiency in livestock can be the driving force behind investments undertaken to reduce methane emissions. Shortage of beef associated with decline in national livestock herd demands that there be further investments in the sector to enhance production efficiency. Sufficient infrastructure must be available to more individual producers to get product to market. These include transportation, processing and retailing facilities. The infrastructure must provide a reliable and cost effective link between producers and consumers. Livestock resources must be capable of improved production efficiency. In some cases improved genetic potential for production is needed to improve the local livestock resource base. The livestock must be well suited to their production environment, which often require significant contribution of genetics from the indigenous breeds. Local resources must be available for improving production efficiency including feed resources, credit for establishing advantageous cash flow conditions and expertise. Efforts that require costly imports are unlikely to succeed.

2.2.3 Transferable technologies for both adaptation and mitigation

The following techniques for improving livestock production efficiency and methane reduction can be suggested for Zimbabwe:

1. Improved nutrition through mechanical and chemical food processing. This involves wrapping and preserving straw to enhance animal digestibility, chopping straw to enhance animal intake, and Alkali treatment of straw to enhance digestibility. These options may reduce methane emissions by 10-25% while increasing digestibility by 5%.

2. Improved nutrition through strategic supplementation for the purposes of provision of critical nutrients such as Nitrogen and important minerals to animals on low quality. Also, provision of microbial and/or bypass protein to the animal, as well as molasses/urea multinutrient blocks and bypass protein techniques can reduce methane by up to between 25-75% accompanied with substantial increases in production efficiency.

3. The use of bovine somatotropin and anabolic steroids for enhancing production has an emission reduction potential of 5-15%.

4. Continued improvements in genetic potential will increase productivity and thereby reduce methane emissions per unit product.

5. Large portions of the herd of large ruminants are maintained for the purposes of producing offspring. Methane emissions per unit product can be significantly reduced if reproductive efficiency is increased and fewer animals are required to provide the desired number of offspring. Technology Options that address reproduction directly are:
    - Artificial insemination
    - Twinning
    - Embryo transplants.

6. Inadequate management of grazing lands may hamper production efficiency. Better matching of livestock grazing loads to seasonal grazing resources will help improve production efficiency and reduce emissions. Encourage high protein high digestibility rye grass.

Methane emissions from anaerobic digestion can be recovered and used as energy by adapting manure management and treatment practices to facilitate methane collection. This methane can be used directly for on-farm energy, or to generate electricity for on-farm use or for sale. The other products of anaerobic digestion, contained in the slurry effluent, can be utilized in a number of ways, depending on local needs and resources. Successful applications include use as animal feed and aquaculture supplements, in fish farming, and as a crop fertilizer.

The controlled bacterial decomposition of the volatile solids in manure reduces the potential for contamination from runoff, significantly reduces pathogen levels, removes most noxious odours, and retains the organic nitrogen content of the manure.

The selection of successful methane emissions reduction options depends on several factors, including climate; economic, technical and material resources; existing manure management practices; regulatory requirements; and the specific benefits of developing an energy resource (biogas) and a source of high quality fertilizer. Because most of the manure facility methane emissions occur at large confined animal operations (primarily dairies and pig farms), the most promising options for reducing these emissions involve recovering the methane at these facilities and using it for energy. The primary approaches for recovering this methane include the following:

Large Scale Digesters: Large-scale digesters are engineered vessels into which a mixture of manure and water is placed. To keep the cost of the vessels low, the vessels are engineered to provide an average retention time for the manure of about 20 days. To facilitate as much gas production as possible during this relatively short retention time, the digester is heated to about 60° C. The gas is drawn off and used for energy.

The two main digester designs are Complete Mix and Plug Flow.

A Complete Mix digester is a large temperature-controlled insulated tank with a mechanical mixing mechanism. A Plug Flow digester is typically a long temperature-controlled insulated tank, with no mixing mechanism. Manure is added regularly to each digester (e.g., daily). In the Plug Flow design, the manure takes about 20 days to flow the length of the digester, from the inlet to the outlet. Large dairies and pig farms with significant energy requirements will typically find these systems to be cost effective. The amount and price of the energy displaced by the recovered methane are the main determinants of the profitability of these systems.

Small-scale livestock producers can also use digesters, albeit on a smaller and less complex scale. Small-scale digesters typically require a small amount of manure to operate and are relatively simple to build and operate. As such, they are an appropriate strategy for producers with technical, capital, and material resource constraints. Due to the rising cost of commercial fertilizers, the recovery of high quality fertilizer from digesters can be an even more important benefit than the energy supplied from biogas. A number of different digester designs have been developed. These small-scale designs typically do not include heating the digester.

Figure 2 Biodigester at a pig-production unit.

A transgenic crop plant contains a gene or genes, which have been artificially inserted instead of the plant acquiring them through pollination. The inserted gene sequence may come from another unrelated plant or from a completely different species: transgenic Bt corn for example, which produces its own insecticide, contains a gene from a bacterium. Plants containing transgenes are often called genetically modified or GM crops although in reality all crops have been genetically modified from their original wild strains by domestication, selection and controlled breeding over long periods of time. Desirable genes may provide features such as higher yield, improved quality, pest or disease resistance, tolerance to heat, cold and drought. Transgenic technology enables plant breeders to bring together in one plant useful genes from a wide range of living sources, not just from within the crop species or from closely related plants. This is not possible from traditional cross-pollination.

The following transferable **adaptation technologies** were proposed as priority for the agricultural sector:

- Gene technology
- Soil fertility management
- Water harvesting and conservation

- Improved and cost effective irrigation systems
- Improved digestibility of animal feed

2.30 Market assessment of technologies

2.31 Technology transfer already in place

Agricultural sector is unique in that a global network of research, development and technology transfer has already been in place for a number of decades. Sustainable agricultural development is an ongoing priority for Zimbabwe. The country has developed agricultural technologies in relative isolation. However, Zimbabwe has since established strong links with the international system to help solve important problems.

Case Study 1. Use of Digestive Modifiers as dry season browse enhancers in Zimbabwe

The environment is subject to seasonal changes, during the wet season there is green grazing and nutrition is good. During the dry season grazing is dry and nutritive value declines. Indigenous animals tend to survive better in this environment as opposed to exotic ones. Hunger sets in due to the nutrient deficit and animals try to adapt by increasing browsing activity, which will be limited due to presence of anti nutrients. The options under this scenario will be to:

- ✓ Modify the environment - Plant pastures and forage crops. This works but is expensive
- ✓ Modify the diet - Feed the animal manufactured feeds. Effective but expensive
- ✓ Modify the animal - By breeding an animal that can live in the environment. Expensive and time consuming

The best option would be to modify the animal's digestive processes, which is instant and cost effective. Agricura (a private company) had a Browse Plus trial in Mopani Ranch, Mwenezi in 1995. Browse Plus is a digestive modifier, which does the following:

- ✓ Bonds with C tannins liberating the protein for utilization
- ✓ Bonds with H tannins preventing toxicity.
- ✓ Prevents rumen lesions.
- ✓ Increases rumen microbes

Its effect is to:

- ✓ Increase browsing - more protein
- ✓ Increase the level of by-pass protein
- ✓ Increase consumption of dry unpalatable grass
- ✓ Speed up digestion - increases intake

It has the following advantages

- ✓ Achieves more balanced use of the food source
- ✓ Reduces dependency on a single aspect of the food source – grass
- ✓ Enables utilization of low cost "environmental" protein
- ✓ The concept is environmentally friendly
- ✓ No negative impact on other life forms such as dung beetles

Efforts are underway to improve digestibility of animal feed. Studies have shown that for every 10kg of grass eaten by an animal, 7% of the energy from the grass is lost as methane. By improving animal diet, making it more digestible one automatically reduces the 7% of the energy lost from animal feed as methane. Hence efforts are underway to control or lower methane production bacteria as a means of enhancing energy conversion efficiency in livestock.

Recycling of organic waste from dairy cows is currently being undertaken at Henderson Research Station, situated to the north of Harare, as good manure management practices. Liquid livestock manure is collected from the sewer systems mixed with water and pumped to the fields to irrigate pastures. The practice is cheap and very effective in that it reduces the use of commercial fertilization of the pastures.

Biogas production for use as fuel in homesteads is another example of manure to energy programs implemented on different scales in different parts of the country. This has been possible with assistance of donor funding. The fermentation process in biodigesters produces methane, which is then pumped through pipes to homesteads for use in cooking, lighting or to power fridges. The constraints with biogas include low pressure, which limits, the number of houses that can be supplied from one source, difficulties in maintenance and the corrosive nature of the gas.

In Zimbabwe gene technology has already been applied successfully in the poultry industry. What is critical for Zimbabwe is to support culturally acceptable forms of genetic modification, whilst also taking care of health and environmental concerns.

2.31.1 Current limitations and responses

Uncertainty of climate change affects the course of technology transfer for any country, particularly for adaptation. Several barriers have been identified. These include barriers with respect to technology transfer from developed to developing countries, technology transfer between Zimbabwe and other developing countries, private sector barriers, barriers at farmer level, country level barriers, market barriers and barriers at the development partner level. A more detailed account of these barriers e.g. given below.

Barriers at developed country-to-developing country level

These barriers include:

- Inadequate technological information from local sources.
- High cost of the technology and shortage of capital.
- Conflicting priorities
- Decline in funding for agricultural research imply reduced availability of new technologies for climate change mitigation and adaptation.
- Disparities in socio-economic conditions may render some of the available technologies in the developed countries inappropriate in a developing country such as Zimbabwe.
- Limited linkages between developed and developing country institutions.
- Patents

Barriers to technology transfer between Zimbabwe and other developing countries

- High levels of inflation and lack of significant infrastructure increase risks for domestic and foreign investors.
- Lack of capital result in the purchase of used equipment resulting in higher energy use and/or GHG emissions, as well as higher production costs
- National trade and investment policies may limit flow of foreign capital into agriculture.
- Obtaining information about and assessment of technologies provided by foreign suppliers is more difficult for local investors in developing countries.
- Inadequate environmental policies may reduce demand for environmental sound technologies
- Lack of training

Private Sector Barriers

- Concern about absence of protection for intellectual property
- Lack of access to cheap credit and foreign currency
- Limited market for certain technologies

Barriers at farmer level

- Differences in socio-economic and cultural context particularly between the North and South.
- Declining support and role of public extension services
- Some technologies may require more labour.
- Some technology options require more capital investment.
- Small farm sizes render some technology options non-viable, particularly for smallholder farmers.
- Limited access to cheap credit.
- Risk aversion.
- Inadequate information and/or lack of access to information in appropriate language.
- Lack of demonstrated local success stories.
- Absence of or inadequate supporting infrastructure and complementary back-up services.
- Inadequate incentives to adopt new technology.

Country level Barriers

- Lack of clear economic incentives to overcome the challenges of climate variability. In Japan, land scarcity motivated the development of agricultural technology, which requires less land such as, higher yielding varieties, better irrigation and land terracing.
- Lack of a clear national position on climate change scenario(s) to adapt to.
- Declining funding for agricultural research and extension.
- Limited institutional capacity on agricultural research.
- Macroeconomic instability
- Limited foreign currency

Barriers at the Development Partner level

- Limited levels of financial support for climate change mitigation and adaptation programs.
- Limited support for research projects in developing countries.

Market barriers

- Lack of capital
- Shortage of foreign currency
- High inflation
- Inhibitive prices

Table 2.2 Summarized barriers for a few selected technologies.

Technology Option	**Constraints/Barriers**
Irrigation Efficiency	- Requires large investments and national commitment - Requires technology transfer to the farm level - Requires co-operative community action
Substitution of traditional crop varieties with improved varieties	- Less preferred grain quality - New pest problems in some areas - Changed management
Conservation tillage	- Risk of reduction of yield - Different machinery needs, crop varieties, soil moisture and climatic conditions - Requires intensive weed control
Modification of animal feed	- Ammonium sulphate is more expensive than urea
Large scale biogas digester	- More investments - Complex to operate and maintain

From the above analysis, the following crossing-cutting gaps are apparent:

- Information and skills

There is inadequate information on climate change and available mitigation and adaptation technologies. Successful adaptation requires recognition of the necessity to adapt, knowledge about available options, the capacity to assess them, and the ability to implement the most suitable ones.

- Education

Scientific knowledge on climate change takes too long to filter into the formal education system.

- Policy

Climate issues have not been mainstreamed into national economic development agenda.

- Research

Local funding for agricultural research is declining.

- Infrastructure

Adaptive capacity of a system is a function of *availability of* and *access to* resources by decision makers, as well as vulnerable sub sectors of a population.

- Institutions

Institutions are a means for holding society together, giving it sense and purpose and enabling it to adapt. Countries with well-developed social institutions have greater adaptive capacity than those with less effective institutional arrangements. The role of inadequate institutional support is frequently cited in the literature as a hindrance to adaptation.

- Equity

The adaptive capacity of a system is a function not only of the *availability* of resources but of *access* to those resources by decision-makers and vulnerable sub sectors of a population. In the case of technological innovation, the differential distribution of information within an organization can impose constraints on adaptation strategies. Differentiation in demographic variables such as age, gender, ethnicity, educational attainment, and health often are cited in the literature as being related to the ability to cope with risk.

CHAPTER 3: ENERGY SECTOR

3.10 Introduction

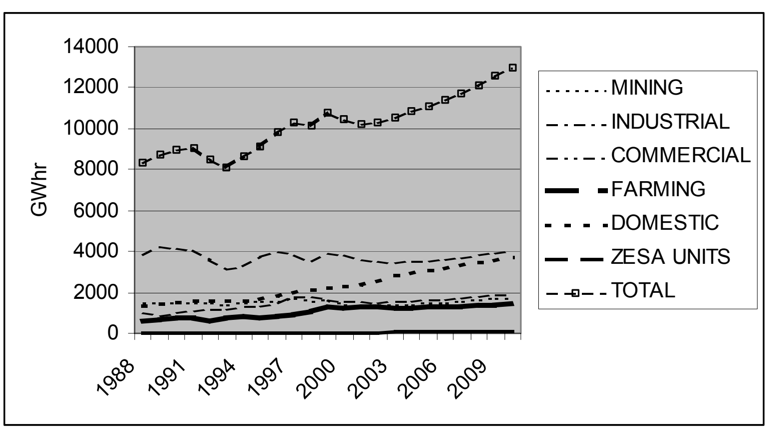
The electricity sector in Zimbabwe is dominated by ZESA, a government owned utility. The organisation has now been split into various business units each specialising in one of the main business areas of the former utility. These units are;

Generation,
Transmission,
Distribution and
Communications.

These units are owned by a holding company, which is a government owned entity headed by an Executive Chairman. A regulator is set to be appointed for the energy sector. At present the regulator's office has been set up but temporary appointees are running it. Energy efficiency improvement remains a key option for the electricity supply industry. Zimbabwe has a history of foreign exchange constraints, which have limited the rate of capital upgrade in industry and commerce. It is not uncommon to find 20 year old vintage equipment in the productive sector. This equipment operates side by side with more modern equipment in the same sector. The effects of such a technology mix is overshadowed by the perceived benefit of limited investment expenditure. However the inefficiency in terms of energy use is a cost to the supply industry and in turn to the energy users.

Zimbabwe continues to face a high level of electricity demand growth. The main reason being extension of the grid to new customers. It is common for developing country electrical energy demand growth to follow an exponential growth pattern due to the extension of the grid. Recent projections by ZESA show the growth rate as in Fig 3 below.

Figure 3: Electricity Demand Growth and Projection



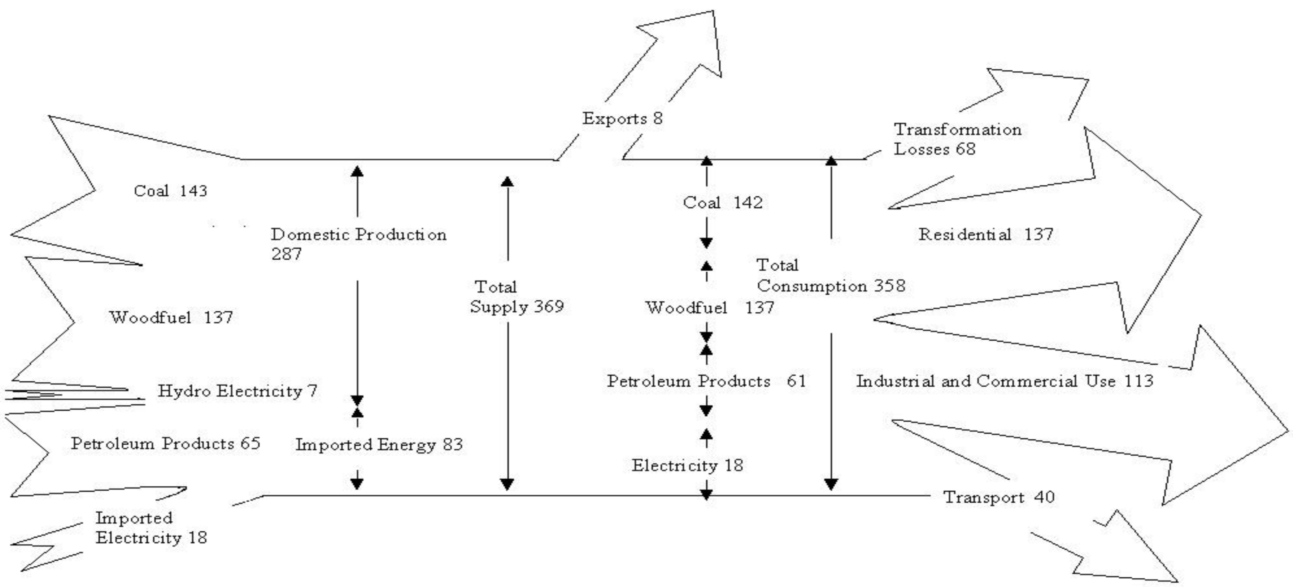
Source: ZESA

The growth of the residential sector is showing a trend similar to the total growth. This confirms the fact that growth is driven more by grid extension than by economic growth.

Fig 4 shows the energy flows in Zimbabwe. It is apparent that the residential sector consumes most of the energy used in the country. This includes both commercial energy and biomass fuels. If only commercial energy is considered then the industrial sector accounts for the bulk of the energy. According to the 1998 energy balance produced by The Ministry of Energy and Power Development the residential sector is dominated by woodfuel to the extent that the commercial energy used is insignificant as represented in the sanke diagram, Fig 4.

Figure 4: Zimbabwe Energy Balance

Source: Southern Centre



* Shares may not sum to totals due to rounding : Source Ministry of Energy & Power Development, Energy Balance 1998

3.20 Climate Adaptation and Mitigation Technologies

The energy sector is dominated by coal and biomass fuels. Hydroelectricity is the preferred option of electricity production but is restricted mainly to sources along the Zambezi river. Climate change poses a threat on the hydro electricity resources since Southern Africa is prone to droughts and loss of water reduces the available hydroelectric resources. Unsustainable use of biomass fuels results in deforestation and soil degradation. This exacerbates the impacts of climate change since surface water resources and soil productivity fall significantly. Energy technologies that alleviate these impacts include renewable energy technologies, improved energy use efficiency and clean coal technologies. Several initiatives have been carried out that looked at promoting the use of this type of technologies for the purpose of improving sustainability of the energy sector. In most cases barriers were identified that limit the adoption of these technologies.

Mitigation technologies focus mainly on avoiding emissions from the use of carbon fuels. Given the low volume of greenhouse gas emissions from Zimbabwe it is not realistic to expect a significant reduction in global greenhouse gas emissions resulting from mitigation activity in Zimbabwe. There is however scope to improve production efficiency by avoiding future emissions of greenhouse gases, which in turn contribute towards the minimisation of the progression of climate change.

3.2.1 Adaptation and Mitigation Technologies

Several technologies have previously been identified as options for climate change adaptation in Zimbabwe. Most of these technologies also double as mitigation technologies since they help in avoiding green house gas emissions. Efficient wood stoves are more of an adaptation technology than a mitigation one since they are promoted as options to counter the shortage of fuel wood. From another perspective efficient wood stoves can reduce the rate of tree cutting hence deforestation that sets in when dry wood is no longer available for use as fuel. This would then preserve carbon sinks and reduce green house gas accumulation in the atmosphere.

3.2.2 Technologies with Potential for Transfer

Table: 3.1 Technologies for Climate Mitigation in Zimbabwe

Technology	**Description of Option**
Domestic lighting Electric water heaters Electric motors Industrial boilers Industrial furnaces Foundries Diesel tractors Road transport Low Carbon Fuel	High efficiency lamps Solar water heaters, usage regulation High efficiency motors, speed control, Power factor control. Steam use co-ordination, insulation improvement, flue gas heat recovery Plasma arc furnaces Waste heat steam boilers Low tillage agriculture Ethanol-Gasoline blending Coalbed methane
Renewable Energy	Wood waste power generation Solar water heaters PV Power Crop waste gasification Wind farm for electricity Wind pumps Solar cookers Solar crop dryers Solar refrigeration Biogas digesters
Soft technology	Industrial audits Integrated resource planning Rural electrification master-plan Power Pool Analysis

Source: UNEP Abatement Costing Studies

The above technology options have previously been analysed for climate change benefits[1]. Some studies have also analysed the barriers to implementation of the technologies. Barrier analysis is however a difficult process since the barriers may change in response to a changing economic environment. It is therefore important to update technology transfer barriers periodically.

3.30 Market Assessment of Technologies.

Variable Speed Motor Drives

Motor speed controllers are a major energy conservation option for electricity users. Their application depends on the range of speeds that is required and on the accuracy of the speed regulation. In all cases the ability to match the speed of the motor to the task at hand results in significant energy savings especially with devices such as fans and pumps where energy used depends on the rate of pumping. The original need for motor speed controllers was in industry such as textiles where the quality of the product relies heavily on the accuracy with which the motors are controlled. In addition applications requiring precise positioning of devices such as antennae pointing and elevator positioning require the ability to control the speed and position of the drive motor.

The project deals mainly with the application of motor drives as energy conservation devices. Industrial machines account for about 60% of energy use in industry. ZESA reports that industry in Zimbabwe consumes about 3453GWh of electricity per year. 60% of this figure would be 2071GWh and this would be the energy used by electric motors in industry. Not all motors can viably be fitted with speed drives since some of the motors have to run at constant speed and some of them would achieve low savings to make it viable to retrofit the speed controllers. If only 30% of these motors are fitted with speed drives with an achievement of 20% savings in each case about 124GWh would be saved per year. This is equivalent to about 66000 tonnes of coal or 42400 tonnes of carbon dioxide avoided. This estimate does not account for the energy use in coal transport or the emission of methane from coal mining. With coal transport giving a major logistical problem to industry, the savings achieved through a partial implementation of variable speed drives on industrial motors have a much wider impact than the direct energy and emission savings.

Case Studies of Energy Efficiency Improvement Using Motor Drives.

A hotel in Harare has about 200 bedrooms. The hotel has air-conditioning provided by a refrigeration unit that cools air, which is in-turn, pumped into the rooms by air handling fans. Naturally the bedrooms are not all occupied at any one time nor do those, which are occupied, need the same level of air-conditioning at the same time. The air ducts are fitted with electrically driven vanes at each vent. The occupant of each bedroom sets the required temperature by turning a dial on a thermostat. The thermostat opens or closes the vanes thereby allowing cold air into the room or restricting it.

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[1] Greenhouse Abatement Costing Studies, Zimbabwe Country Study Phase Two, Southern Centre and RISO, 1993

The air handling unit (fan) is remote to the room therefore has no direct connection to the thermostat. However as each room thermostat is set the pressure in the air duct changes. The air pressure rises as the vanes close or falls as they open. This means the air handling unit faces a higher resistance as the vanes close or a lower air resistance as the vanes open. A pressure sensor in the duct therefore changes the speed of the fan motor in response to the pressure changes.

A visit to the site revealed that the fan motors are running at about 50% load during the off peak periods and can run to full load during the peak periods when the air-conditioning demand is high. If the fan motor was not fitted with a speed drive the fan would continue to blow air at maximum pressure even when the vanes were closed. This would be a mere waste of energy. Given that the fan motor is rated about 15kW, an off peak period of about 10 hours per day corresponding to the period 9:00pm to 6:00am for three months i.e. April, May and June would save about 6825kWh. These are the months with low demand for air conditioning. Needless to say the low holiday season include months with high air-conditioning demand hence the system would continue to save energy during the low occupancy period as well.

The same air conditioning system includes a water-cooled condensing unit. The pump motor for the condensing unit does not include a speed drive. This means the pump motor runs continuously even when the demand for cooling water is low. If the pump motor were fitted with a variable speed drive the pump speed would be reduced during the low demand periods thereby reducing the demand for energy. Admittedly, the condensing unit includes a thermostat for controlling the compressor operation to limit the cooling effect on the evaporator, which then cools the air. However this operation does not match the condensing effect to the cooling effect with sufficient precision to avoid unnecessary water pumping.

In addition to regulating speed, variable speed drives allow motors to start “softly”. This means the motor gradually accelerates to full speed without the characteristic surge that motors impose on the power supply when they are started directly online. This soft start saves the motor as well as reducing the contribution of the motor to power demand.

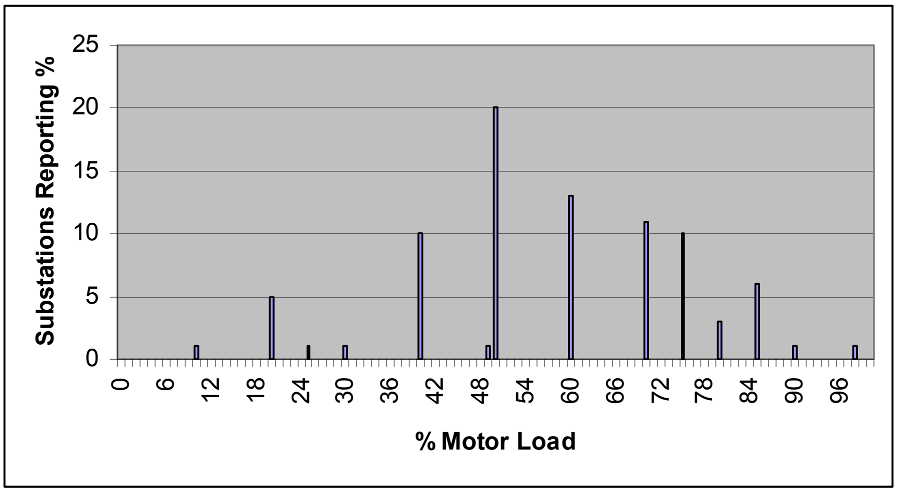
The general rule is that when fan or pump speed is reduced by 10% the flow rate for air or water is also reduced by 10% but the energy consumption is reduced by 27%. A 20% reduction in speed would reduce power consumption by 49%. This is because fluid energy is proportional to a cube of the speed.

The major drawback for variable speed drives is that all of them are now electronic and they impose stray frequencies on the power system. The characteristic on-off operation of the thyristors in the speed drive generates unfriendly harmonics (frequencies that are multiples of the power frequency). These have a heating effect on rotating machines remote to the driven motor and also introduce electromagnetic noise into space. Users with sensitive equipment would require that special filters be installed to reduce these harmonics. Utilities normally have standards for the operation of variable speed drives which if applied limit the negative effects of the stray frequencies that they generate.

Contribution of Motor Load to the System Load

A study by ZESA has estimated the percentage of load that is contributed by motors at various points on the system. The results show that the motor load ranges between 20% and 98% depending on the nature of process that is dominant in the area. 98% would be typical of a water pumping station and 20% would be typical of a high-density residential area.

Figure 5: Distribution of Motor Load by Substation in Zimbabwe



Source: ZESA

The above graph shows the nominal motor load being around 60%. This agrees with the estimate given earlier.

Methane Production from Treatment works

The City of Harare, which has, more than 2.5 million inhabitants has two main sewage treatment works from which meaningful methane production can be attained. These are Crowborough and Firle plants. The sewage waste that is received is separated into liquid and sludge in large tanks. The liquid is treated through a biological process and is released into the water system as recycled water. The sludge is fed into biodigesters where anaerobic respiration produces methane. The methane is partly used to heat the digesters to maintain a temperature between 35 deg C and 37 deg C and the excess gas is flared in the open for disposal. The Crowborough sewage works have gas-metering equipment and in 1995 the volume of gas produced was about 200 m^3 per hour. This +metering equipment is now in poor maintenance and the readings cannot be relied on. The Firle sewage plant has had no metering installed and all volumes of gas produced have been referenced to the Crowborough plant. The two plants even though using similar processes, treat different quality of sewage waste. Firle sewage works receives a large volume of industrial effluent with a higher proportion of waste water. Industrial effluent disposal regulations do not allow the disposal of toxic waste, high concentration waste especially with high volumes of food or organic waste. As a result, industries have tended to dilute their effluent as a way of avoiding penalties. Cleaner production methods and a general conscience on environment protection is now pushing most industrialist into waste management and pre-treatment. The table below shows the characteristics of waste from the two plants

Table 3.2: Characteristics of the two sewage treatment plants

Characteristic	**Crowborough**	**Firle**
Type of digester	Anaerobic	Anaerobic
Volume of raw sewage received per day	168330 m^3	130 000 m^3
Sludge in cubic meters per day	11 457	28 172
PH	5.32	5.58
Percentage total solids	5.06	2.72
Percentage mineral solids	1.32	0.92
Percentage volatile solids	3.68	1.80
Biogas produced per day in cubic meters	40 210	98 875

Note: The temperature of the digesters are maintained at 35-37 degrees Celsius

Although 168330 cubic meters of sewage are received at Crowborough plant per day 62310 cubic meters of this is released and only about 106 000 cubic meters is treated at the plant. Firle Sewage Works produces less sludge given the volume of raw sewage received because the sewage volume includes a large portion of industrial liquid waste.

Using the ratio of sludge to gas produced for 1995, when the gas production was metered, estimates of current biogas production were obtained. The 1995 UNEP studies on Zimbabwe showed that 1990m^3 of biogas was being produced from 567m^3 of sludge. Using simple proportion figures of biogas produced were obtained given the volume of sludge treated. The assumptions made here are that, the sludge composition is not significantly different and conditions then are not very different from conditions now.
These conservative estimates only indicate the potential that exists at these plants and if biogas production is optimised, more gas could be obtained.

Potential for methane production also exists in the City of Bulawayo, which is the second largest city in Zimbabwe as well as smaller towns of Masvingo, Mutare, and Gweru. In all these towns the gas is released into the atmosphere. It is important in the meantime to look at flaring the gas so that carbon dioxide is emitted instead of methane which would reduce the global warming effect of the gas as most of the carbon dioxide will be recycled by agriculture which is the source of the most of the organic matter in the sludge. Table below shows volumes of sewage treated in these towns and the estimated methane production levels. The estimates of methane released are based on population figures and the relative emissions from the plant in Harare. These figures may over estimate the biogas potential since the existing digesters do not have temperature regulation as in Harare and also are open to the atmosphere which may allow entry of oxygen into the digesters. If the digesters were closed and optimised for biogas production the indicated figures could be attained or surpassed.

Table 3.3: Methane production from sewage plants using biodigesters in Zimbabwe

Cubic meters/day	**Sewage**	**Biogas**	**Methane produced**
Mutare	30 000	1 107	554
Masvingo	16 800	621	311
Bulawayo	35 000	2 951	1 475

Figures for Gweru were not available.

Use of Biogas to Produce Electricity.

Biogas is a very lean fuel. This means it is a bulky gas with little energy in it. This is because biogas is about 50% carbon dioxide and 50% methane. It can go up to 65% in methane but the general methane concentration is 50%. This characteristic restricts the use of biogas in the ordinary internal combustion engine or gas turbine. If a reciprocating engine such as a diesel engine is to be used the biogas has to be fired as one of two fuels normal diesel and biogas otherwise the engine does not run. This in a way reduces the consumption of diesel because the engine could be successfully run at 80% biogas. However the need for diesel restricts the applicability of the biogas engine in economies where diesel is imported.

There are biogas engines that are designed to run on biogas only. These engines have a spark ignition and are often called gas engines. They are fired on biogas, gas from gassifiers or natural gas. Gas engines for use with biogas are specially designed to cope with the moisture content of biogas and the acidic nature of emissions especially the high content of hydrogen sulphide in the fuel.

Table 3.4: Example Specification of a Biogas Engine

Electrical Output	KW_{el}	143
Recoverable thermal output (150deg C)	KW	213
Energy Input	KW	416
Fuel consumption – LHV 6.4kWh/Nm^3	Nm^3/h	65
Electrical Efficiency	%	34.3
Thermal Efficiency	%	51.2
Total Efficiency	%	85.5
Heat to be dissipated (LT circuit)	KW	-
Cost – FOB (2001)	Euro	110000
Emissions	NO_x < 500mg/Nm^3 (5% O_2) CO < 650 mg/Nm^3 (5% O_2) NMHC < 150 mg/Nm^3 (5% O_2)	

Source: GE Jenbacher – Austria.

The above table shows that with the estimated production of 1600m^3 per hour of biogas at Crowborough about 3.5 MW of electricity can be produced. It is essential that the gas volumes be confirmed so as to determine much more precisely the electricity that can be produced. Similar volumes of gas are produced at Firle Sewage Works.

A quick estimate shows that the plant cost is equivalent to 769Euro per kW (925USD/kW) which is approximately 40% of the unit cost of a coal fired plant assuming 2500USD/kW for coal fired plant. The installed cost would increase the per unit cost but the equipment is delivered and operated in a container hence the final price would still be lower than conventional plant.

Cost Benefit of Sewage Gas Power Generation

Sewage gas is generated through the process of sewage treatment. The methane produced poses a fire risk within the sewage plant if it is not disposed of correctly. Disposal methods include venting of sludge tanks and collection of gas and flaring in open air.

Anaerobic digestion of sewage sludge produces an effluent that is rich in nutrients. The effluent cannot be disposed of directly in surface water systems hence it has to be used for irrigation as a way of removing the nutrients in the waste. Modern sewage systems now favour aerobic processes where sewage is passed through biological filters where the waste water is oxygenated. The biological organisms in the tank remove the nutrients and the resultant effluent is suitable for disposal in surface water systems. In all cases sewage waste increases the nutrient load in water and results in pollution. Anaerobic processes happen to yield higher levels of eutrophication hence they are not favourable where there is insufficient land for irrigation. In Harare the waste water is used to irrigate pasture.

Power generation as proposed above takes advantage of biogas that is already available at the sewage works. The power generation project therefore does not include the construction of biogas digesters or the change of the sewage treatment process. The power generation project is in a way increasing the value of waste produced by the treatment plant by converting it to electricity.

There are two possibilities for using the electricity from the sewage gas. One is to inject it into the grid and the other is to use it within the sewage plant. If the electricity is injected into the grid it would help in improving the quality of supply on the line that is connected to the plant. This is because distribution lines tend to have a sagging voltage towards their end and connecting a generating plant to them improves the voltage profile hence the quality of supply.

If the electricity is used within the sewage works it displaces grid electricity at the retail price hence increases the financial value of the generated electricity. Also, the generation plant will provide an alternative to grid electricity thereby increasing the security of supply for the sewage works. The sewage gas may not meet all the energy needs of the sewage works but it can supply the required minimum pumping load to reduce the chance of raw sewage overflow during grid outage. This in a way would reduce the chances of water pollution from sewage hence improve the quality of raw water downstream to the sewage works.

Waste heat from gas engines can be used for water heating or refrigeration. In the case under consideration hot water can be used for maintaining digester temperature at about 35 deg C. This is necessary for optimum activity of the micro-organisms that produce methane. The balance of the heat can be used for production of ice since there is no further use of hot water within or near the sewage works. Ice can be sent to nearby industries where it can be used for production of cooling water or cooling air. Food grade ice maybe restricted due to the proximity to the sewage works but a sealed system can be developed for production of food grade ice. Ice production would reduce the demand for electricity to produce ice or cooling in industry. The net effect of sewage gas in terms of electricity demand from the grid would therefore be much higher than the electricity produced. Additional equipment is required for ice production and this would have to be imported.

Water Heating
Technology Assessment

Zimbabwe lies in a high solar radiation belt with annual radiation averaging around 20 MJ per square metre per day. Solar water heating is a mature and tested technology. The Standards Association of Zimbabwe (SAZ) has developed performance standards for solar water heaters in Zimbabwe in collaboration with the solar industry and Government, although the adoption of these standards is as of now still voluntary. There are also Australian Standards, British Standards (BS) and South African Standards (SABS), which govern the performance of solar water heaters manufactured in these countries.

Market Assessment

It has been estimated that within the domestic sector, 45 – 50% of the electricity is used for water heating (S. Mackenzie 1998). In the medium to high-income households in Zimbabwe, domestic water heating consumes an average of 500 kWh per month (Nziramasanga 1992[2]). Other estimates by ZESA Consumer Services Department put this at 550 kWh. Although solar water heaters could provide adequate supply of hot water for a domestic consumer, a hybrid system in which solar energy is assumed to contribute 60 – 70% of the heating requirements, with electricity meeting the balance is usually considered. (Interview, B.Masola).

A survey by ZESA (ZESA Surveys 1996) showed that there were at least 100 000 electric water heaters in Harare and that new house units were going up at a rate of 44 000 per year. If it is assumed that 10% of these would have an electric geyser the total population of electric heaters could be close to 140 000.

Mackenzie estimated the market for domestic solar water heaters at 10 000 units per year. A business proposal prepared for the Government of Zimbabwe and the UNDP under the SADC project had a target of 4 000 units per year. We can assume a rate of 7 - 8 000 per year for the domestic market alone.

Another potential market for solar water heaters is at hospitals and hotels where there is need for large volumes of water at moderate temperatures. Just as for the domestic sub-sector, we can assume a hybrid configuration in which the solar heater meets only part of the water-heating load.

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[2] Project Sunswitch, Solar Energy Society of Zimbabwe, 1992

Market Assessment

The general term efficient lighting covers a wide range of products, which_include compact fluorescent tubes, the so-called efficient lights and high-pressure vapour lamps. There is no local facility for the manufacture of light bulbs in the country and all tubes and bulbs have to be imported. The most expensive component in the compact fluorescent light is the electronic ballast / capacitor. In older technology the fitting is separate from the lamp. However, newer technology has internal ballast. This is more convenient as the fitting is made to fit the ordinary screw or bayonet (BC) fitting so that one does not need to buy a special unit and can use the same fitting as for incandescent lights. The costs have also gone down considerably.

The market for efficient lighting is enormous if one considers the fact that every electrified home has an average of between 6 and 10 light bulbs. In addition, there are a number of industrial applications such as for security lighting where high-pressure sodium vapour lamps offer advantages over high wattage incandescent lamps.

Barrier Assessment

Capital Costs. The energy saving lights on the market cost five to ten times the cost of an incandescent light bulb. Although in the long term one saves money by buying the energy saving lights, the more immediate impulsive decision is to buy the cheaper incandescent bulb. In addition, some of the older technology efficient lights require special fittings, which cannot be used with the ordinary incandescent bulb. This imposes a further barrier as it removes flexibility from the consumer. He has to go one route or the other and cannot switch back from one to the other.

i) Little consideration for running costs at the Design Stage. Property developers who put up most of the large high rise office and residential blocks build these facilities for letting out and not for own use. As a result, the running costs of such facilities, including electricity, are not high on their list of priorities. They tend to fit the cheapest devices on the market in order to maximise their returns. It is a well-established fact that retrofitting is always more expensive than if the right decision had been made in the first place. To compound the problem tenants would not normally be inclined to or be allowed to fit energy saving devices unless, of course they have decided to buy the premises.

ii) Competition from cheap products

    At times cheap low quality bulbs e.g. of Chinese manufacture flood the market. The consumer, as always, has to make the choice between long term saving and immediate short-term savings and invariably the latter rules the day. Experience with these cheap products is that some of them will not last a few days.

iii) Lack of awareness.

Some of the middle to high consumers who might afford the prices of the efficient lights are not aware of or have not been made to appreciate the benefits that come with the energy efficient lights. This is particularly important for those who are building their own houses and could fit the energy efficient lights up front instead of retrofitting.

iv) Lack of an incentive scheme

Whereas Government sometimes makes available money on concessionary terms, such as for the productive sector, there is no corresponding facility for energy efficient equipment.

v) Irregular Supplies

The Zimbabwean market for efficient lights is still very small and so does not receive the best attention by international suppliers. Thus, even those consumers who have installed the efficient lights have sometimes to go for weeks without supply of replacements.

3.3.1 Technology Transfer Already in Place

Zimbabwe has had a few initiatives aimed at transferring clean technologies. Most of these were funded through bilateral or multilateral agencies. The table below summarises these initiatives.

Table 3.5 Zimbabwe Initiatives for Technology Transfer.

Year	Initiative	Funding	Objective
1994 – 2000	GEF PV Pilot Project	UNDP-GEF	To promote PV solar home systems and PV Power
	SADC-CTI Project	OECD-CTI	Promote investment in cleaner energy technologies in SADC
	National Climate Change Assistance Program	Dutch Government	To assess barriers to adoption of energy efficient technologies and to propose barrier removal options
1996 – 1997	Willowvale Industrial Park Project	UNDP – Public Private Partnership Program	To introduce an industrial park level energy and waste management scheme
	SADC Industrial Energy Management Program	CIDA	Promoting Industrial Energy Management and Capacity Building
	GEF – Small Grants	UNDP- GEF-SG	Promote adoption of climate friendly technologies

3.3.2 Current Limitations and Responses

Barriers to Electricity Production from Sewage Gas.

The opportunity for electricity production from sewage gas has been known for a long time. The Ministry of Energy and Power Development (predecessor) has tried to run a diesel engine from sewage gas being ejected along one of the sewer lines South of Harare without success. It appears the type of engine used and the quality of the gas did not match.

Several initiatives have analysed the potential for electricity production from the sewage gas at Crowborough Sewage Works but no investment has been carried out yet. Discussion with City of Harare highlight **lack of capital** as one major impediment. It is however not clear whether the City has **failed to secure donor or loan financing** for the project. The Zimbabwe Power Company, a subsidiary of ZESA, has previously indicated that they would want to buy the gas and produce electricity for the grid. In that respect they would not want to produce electricity for City of Harare. This precludes the possibility of an energy conversion contract where ZPC would convert the gas to electricity and be paid for the service. The City of Harare would then need to price the gas. Such **skills are not resident within the City** hence the arrangement proposed by ZPC is not feasible at this stage. It is also not clear whether ZPC has **fuel-pricing skills especially for sewage gas**. If the electricity produced does not yield immediate benefits for City of Harare it is unlikely that any fuel supply contracts can be signed.

The **technology required for the production of electricity from sewage gas is not common**. GE Jenbacher produces the engines in Austria and a few other manufacturers have converted diesel engines for this purpose. However any process to procure the engines would be between the purchaser and a few suppliers. Since these **suppliers do not have a history in Zimbabwe or the region** there is insufficient marketing information on their equipment. The **technology remains novel and not well understood in Zimbabwe**. The same applies to large-scale absorption refrigeration.

Since there **has not been a directive to investigate the adoption** of this technology it is difficult to explicitly identify the barriers that have prevented the successful implementation of this opportunity. Explicit barriers can only be identified when steps are taken to implement the project. The absence of a directive by senior authorities is also an indication that the **technology has not been presented in a way that it would claim sufficient attention within the planning framework of the local authority**.

Barrier Removal Options.

Addressing the barriers listed above implies addressing the information or policy gap that gives rise to the barrier. In other words the barrier should cease to claim a preferred position against the use of the sewage gas to generate electricity. The table below attempts to give the steps that are required to address each barrier. Also indicated in the table are the institutional roles that are needed to address the barriers.

Table 3.6: Barrier Removal Options for Biogas Electricity Production

Barrier	Impact	Steps for Removal	Primary Responsibility
Lack of capital Limited access to financing	• Local authority does not prioritise opportunity • Energy supply left to utility • Focus on other more "urgent" issues.	• Document opportunity and publicise benefits • Identify climate related or renewable energy funding sources	• Line Ministry • NGO's • Ministry of Environment and Tourism
Limited skills for energy pricing and energy analysis	• Weak policy dialogue • Adoption of indecisive policy positions • Over protection of policy position	• Present projects with various financing plans • Present alternative pricing structures • Solicit support from energy regulator's office	• Ministry of Energy and Power Development •
Limited technology awareness	• Inadequate appreciation of task. • Poor representation of benefits • Incomplete assessment of opportunity	• Obtain further technical information on technology. • Compile case studies • Compile benefits to user, local authority and to nation	• Govt Line Ministries • Industry bodies • NGOs • Pvt Companies
Lack of policy directive. Inadequate appreciation of technology at policy level.	• Inadequate allocation of time for analysis • Poor research effort and reporting of information • Limited attention by decision makers	• Prioritise technology transfer amongst officers duties • Upgrade officers' skills • Increase linkage between govt officers and technology users	• Ministries – Energy and Power Dev, Environment, Mining, Transport and communications, Industry and International trade • Industry bodies

Barriers to Application of Variable Speed Drives.

Variable speed drives often come as part of original equipment in which case the user is obliged to operate and maintain them. This is the case with building elevator systems and some conveyor belts. However variable speed drives can be retrofitted to other equipment for the purpose of conserving energy. Discussions with industry have shown that **retrofits are viewed as cosmetic** since the original plant would be operating to satisfy production needs. In that case the owner sees no need to expend large sums of money to reduce the electricity bill when the **business is viable anyway**. It is only in those cases where energy bills are threatening viability that the plant owner feels the pressure to modernise equipment and improve efficiency.

In an environment where the production **sector is facing various other constraints** they do not prioritise energy conservation. The company would rather spend available manpower and financial resources to secure production inputs rather than retrofit motor drives. **The initial investment for the variable speed drives tend to be high** in comparison to motor cost especially where the motor sizes are small i.e. 20kW and less. Estimates are that variable speed drives cost between 250USD and 320USD per kilowatt of motor size. In the case of Zimbabwe motor drives involved either **imported components when manufactured locally or are imported as complete units**. The **availability of foreign exchange is limited** and companies would rather find foreign currency for the purchase of inputs rather than for improving energy use performance.

There is also a general feeling that if electricity users **conserve energy and reduce their energy bill the utility would just increase tariffs so as to maintain the revenue flows**. It is not appreciated that a reduced demand implies deferred investment and a reasonable justification for tariff reduction or tariff freeze.

Levels of **awareness on the use and benefits of variable speed drives are low**. One supplier indicated having installed some speed controllers in a sugar mill as part of the plant-upgrading program, however other candidate facilities have not been forthcoming to the same extent.

The suppliers have also provided short-term finance by installing the equipment and being paid over six months or a year. This would be expected to mitigate against shortage of capital, however the scheme has not yielded much in terms of sales. Private sector financing options provided by the public sector have been too slow in paying such that the suppliers have been reluctant to supply equipment under these programs.

Barrier Assessment

Despite the high solar radiation in the region, the use of solar energy for water heating has not been widely adopted. Discussions with both the consumers and the suppliers of equipment have identified a number of barriers.

i) Lack of Clear Government Policy

While there have been general statements of intent and support for renewable energy by Government, these have not been translated into concrete actions, strategies and attendant incentive schemes.

Government has also not provided a leadership role in matters to do with the promotion of renewable energy in general and solar water heating in particular. In addition to its role in policy formulation and enforcement Government is also a player by virtue of its housing schemes and programmes for its servants. Thus, while there are admittedly some Government institutions and housing units with solar water heaters installed this has not been consistent.

Government has also not extended any incentives for solar water heating such as tax and duty exemptions for solar water heater components nor concessionary funding like what is currently being extended for the productive sector and for agricultural inputs.

In countries where solar water heating has been successfully adopted and implemented such as Israel and Cyprus, Government has made it mandatory for any new housing developments to have solar water heaters. While a blanket approach may not be practical in the Zimbabwean situation, selective application to medium and high income consumers who can afford an electric water heater and therefore end up using a lot of electrical energy for water heating could be considered.

ii) Costs

The cost of an average 100 – 200 litre solar water unit, which would be able to provide adequate water for a family of 5 – 7 people for about (USD2 500). This is more than a low-income consumer can afford. The market for solar water heater is therefore the middle to high-income bracket.

Even for this income group direct purchases would be difficult without a favourable financing scheme. There are no financing schemes for solar water heaters.

The market for solar water heaters is still small and weak and needs to be nurtured. This also means that there are no economies of scale and a catch-22 situation is created. There is need to break this vicious circle.

iii) Lack of awareness

Even those who can afford them do not always appreciate the benefits of solar water heaters. The recipients of one solar water heating system in Harare only became aware of the existence of such a technology and its benefits through an Australian volunteer working at the institution.

iv) Unrealistic electricity tariff

The current ZESA electricity tariffs are unrealistically low and do not send the right signals to the consumer about the real cost to ZESA of supplying energy to them. At the prevailing domestic tariff, there is no incentive for the consumer to even start thinking of installing a solar water heater as it would not immediate economic impact. The average metered domestic tariff is currently about 0.5 USc per kWh. Assuming the SWH would meet about 60% of the water heating requirements of the home this would give a simple payback period of 20 years! This is normally the assumed useful life f a solar water heater and thus there is no incentive from a financial point of view.

v) Equipment malfunction and poor back up service

Although the failure rates for solar water heaters have not been quantified, any equipment failure for a new technology is likely to receive more publicity than the successes. Most of the SWH equipment failures cannot be attributed directly to the solar panels but arise more from plumbing faults. The consumer would always interpret this as a failure of the solar equipment as all he wants is the final product – hot water.

This is made worse by the poor back up service from the equipment suppliers. At one installation visited by the project, two solar panels had not worked right from the day they were installed about two months earlier. The supplier had sent his team to rectify the problem but no feedback was given to the expectant and by then rather disappointed consumer who was still waiting for an answer to his problems. In another case, the equipment had worked very well for three to four years and had just suddenly stopped working. The supplier had not rectified the problem three months later. All these experiences send negative messages about the technology.

Some of the poor perceptions of SWH by consumers arise from lack of knowledge in terms of what the equipment can do and this results in unrealistic expectations. I n some cases the consumer is not told how to take best advantage of the equipment. For instance, it could be highlighted to the consumer that using the water from the SWH in the evening gives the best results instead of early in the morning.

Overcoming the Barriers (Alternative Actions)
Benefits of Solar Water Heaters

Solar water heaters displace the demand for electricity. It has been estimated that each solar water heater displaces about 3 kW of electrical demand and can double the energy demand of a household without adding to the demand on the grid (Climate Change Studies in Zimbabwe, 2004). At present Zimbabwe imports about 45% of its electricity requirements and is currently facing a looming power shortage as no definite date has been fixed for the construction and commissioning of the next power project. A prudent investment in solar water heaters would thus not only defer the immediate need for a power station but would also reduce the size (capacity) of the project. The wider use of solar water heaters would also reduce the use of coal for electricity production as about 60% of the country's power requirement are produced from coal based generation.

Policy and enabling environment

Government should develop and promote an appropriate policy with incentives for the suppliers as well as for the consumers. These should include tax and duty exemptions or reduction for solar water heating equipment, legislation on mandatory equipment standards and requirements for new medium to high income housing schemes to have solar water heaters of approved specifications. Government might also consider setting up, together with ZESA, a financing scheme for solar water heaters. The finance scheme should cover both the consumers as well as the companies in the solar industry. Experience from the GEF funded solar photovoltaics project proved that unless the solar companies are also supported there will be distortions in the market and the programme would not be sustainable.

As a player in the field, Government should also lead by example by ensuring that its own housing schemes include solar water heaters.

Costs

One factor contributing to the high cost of solar water heaters is the small volumes whereby imports and local manufacture cannot enjoy economies of scale. This creates a vicious circle, which can only be broken by an aggressive policy and programme by

Government. As stated elsewhere in this report, Government can lead the way by example. It could start by including solar water heaters at Government hospitals, hostels and housing schemes. In addition, Government can facilitate the setting up of a solar water heater finance scheme under which consumers could purchase solar water heating equipment and repay through their electricity bills. Government should also reduce duty on imported solar water heating equipment and other renewable energy equipment.

Awareness programmes

Awareness programmes should be intensified. However, these awareness programmes should be accompanied by concrete projects where people can see the benefits of the technology. Initially, the programmes should be targeted at the middle to high-income consumers who can not only afford the solar units but whose electricity and hot water consumption make it worthwhile. The recommended media would be television, trade and business expose and business magazines. Eventually, the technology will be more widely adopted and more affordable even for the low-income groups.

Electricity tariffs which reflect the Cost of Supply

The electricity tariffs should reflect the true cost of supply. While Government has a duty to protect the low-income citizens this can be done by imposing a tariff that subsidises the low energy consumer without at the same time subsidizing the high-income high-energy consumer. The tariff should encourage energy conservation at all levels of consumption.

Equipment Backup Service

Adoption of the Standards Seal should be mandatory for both local and imported solar water heaters and a consumer watchdog should be put in place to handle consumer complaints. Installers would also have to be registered and continued reports of unattended equipment malfunctions should be sufficient grounds for deregistration. This becomes necessary if Government makes it mandatory for medium to high-income housing projects to have solar water heaters. Solar water heater installers should also teach the consumers how to get the maximum from a solar water heater.

Energy Saving Lights

Technology Assessment

The incandescent light bulb is the most common and most easily available electric light in the country. The incandescent light bulb is very inefficient and produces a lot of heat.

A number of more efficient electric light sources have been designed and produced to replace the incandescent bulb and these offer a lot of advantages compared to the incandescent light bulb, such as

- 80% energy saving. For instance, a 7W compact fluorescent tube produces the same amount of light as a 40 W incandescent.
- Longer life. A compact fluorescent tube has an average life of 3 000 to 6000 hours compared to less than 1 000 hours from an incandescent bulb.
- better light quality (antiglare, daylight quality)
- Produce less heat. This is important in air conditioned office blocks where substantial energy could be spent on cooling the building.
- Adjustable light intensity. With electronic ballasts, some of the efficient lights come with brightness adjustments.

Electricity from Biogas

Biogas is a mixture of primarily carbon dioxide and methane which is generated through anaerobic digestion of biomass or other biological matter in an oxygen free environment. Biogas is generated when organic matter in sewage decomposes under water or when animal waste is stored in liquid waste ponds. Commercial systems for the production of biogas have been developed and several examples exist that generate electricity for sale to the grid.

Zimbabwe has several municipal sewage plants that produce biogas from anaerobic waste digesters. These plants are in Harare, Mutare, Bulawayo, Masvingo and Gweru. However only Harare collects the gas and flares it in open air.

CHAPTER 4: INDUSTRY/MINING SECTOR

4.10. Introduction

Zimbabwe has a diverse industrial sector dominated by manufacturing based on raw materials from agriculture and mining. The industry produces goods for both local and export consumption. Industry is the major user of commercial energy hence is indirectly responsible for greenhouse gas emissions from energy use. There are also industrial processes that result in greenhouse gas emissions. The major ones are:

- Cement manufacturing
- Iron and steel smelting
- Coal tar distillation and
- Solvent and paint production

These emissions are however dwarfed by the energy sector emissions and in most cases they are not considered except for cement and iron and steel production.

4.20. Climate adaptation and mitigation technologies.

Industry's vulnerability to climate change is based on the indirect impacts of climate on energy security and availability of raw materials. Another indirect impact of climate change is the reduction in market as the target sectors reduce production in case measures are not implemented to safeguard those sectors especially agriculture and energy. On the other hand industrial is the major supplier of adaptation technologies hence security against climate change in the industrial sector is influenced by the ability of industry to supply adaptation technologies. It is therefore apparent that industry is the key recipient of transferred technology before it is disseminated locally. This chapter deals specifically with technologies that secure the industrial sector under climate change and those technologies that assist industry in avoiding greenhouse gas emissions that may enhance the climate change effect.

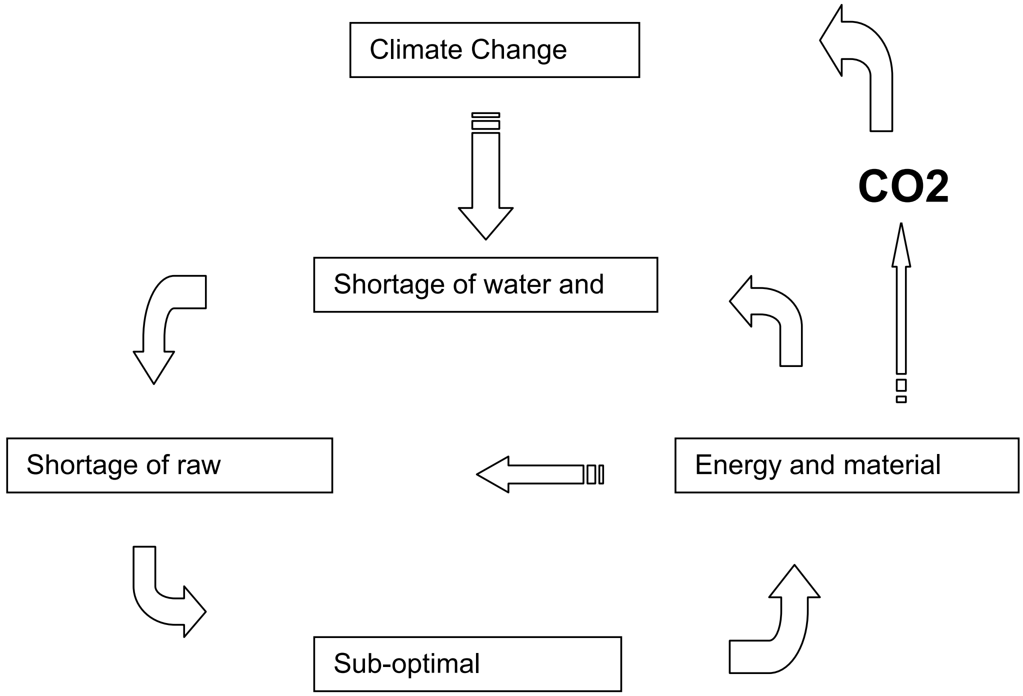
4.2.1 Adaptation Technologies

Zimbabwe has gone through recurrent severe droughts. Given that climate change will worsen the effects of drought in the region it is realist to assume the effects of droughts on the economy as an indication of how climate change will affect the economy. Water shortage is one major impact with industry having to implement water saving measures so as to survive droughts. An example is the beverage industry where water constitutes the bulk of their product. One brewery managed to cut water use per unit of beer by 50% as a survival strategy. Some companies drilled deep wells to augment municipal water supplies. All these measures meant the modification of processes so as to be able to handle the new water supply regime. Water treatment is important since changing from municipal water means the companies have to treat their own water to meet product specifications. A project carried out in the Willowvale Industrial Park demonstrated that water released by industry could be recycled provided the industries could set-up a joint water treatment facility to improve waste water quality to a level where it could be reused. Removal of sediment, removal of oil and grease and correction of pH were found as some of the treatment requirements if the water was to be used for non-critical processes. Another adaptation option is the use of wood waste as an alternative to fossil fuels. Timber companies produce high volumes of wood waste when they process timber. The waste is dumped or incinerated in open air. The effects of this mode of disposal is the pollution of surface water systems and the release of greenhouse gases and other air pollutants. If the waste is used for energy then the emissions of methane from dumps and the continued migration of the waste into surface water systems is avoided. Air pollution is also reduced since energy systems have controlled emissions.

The nature of agro-processing industry is that raw materials are dependant on agriculture which is vulnerable to climate change. When raw materials are in short supply industry operates at sub-optimal levels and therefore exhibit a much lower energy intensity. Sub-optimal performance increases water intensity and therefore raises the competition for water in an environment that would be low on water resources. The process therefore worsens its vulnerability to climate change. The energy sector in Zimbabwe is dependant on hydro-electricity hence it is also vulnerable to climate change which in turn affects industry. The figure below illustrates these interactions.

Technologies that intervene to break the cycle are therefore adaptation options. Very little has been done in terms of identification of adaptation technologies outside energy use efficiency. The agricultural sector is generally treated separate from industry. Interventions in the agriculture sector tend to focus on food security and exports.

Fig 6: Climate Interactions with Industry



4.2.2 Mitigation Technologies

For the purpose of this study water supply and waste treatment are included as part of industry. Industrial emissions of greenhouse gases are very low when compared to emissions from energy use. The major sources of emissions are cement production and waste treatment. Mitigation options in the industrial sector include;

- Use of blast furnace slag in cement production – slag is a by-product of steel production and has no additional emissions if used for cement production.
- Reduction of dust emissions in cement production – dust is wasted cement
- Optimisation of wood recovery in sawmills – inefficient recovery produces sawdust and other waste that has to be disposed off
- Water conservation in water treatment plants – backwash and decanting wastes pumped and sometimes treated water
- Effective sewage treatment – treated sewage can be recycled as raw water
- Methane recovery at sewage works – anaerobic digesters can be used as energy supply sources
- Methane recovery at landfills – methane emissions in landfills are a major cause of fires
- Waste paper recycling – hardboard and newsprint can easily be made from recycled paper thereby reducing the energy intensity of paper production. Also recycled paper helps avoid use of new timber which involves waste disposal
- Optimising blast furnace charge to reduce excess coke combustion – coke supplies carbon as well as energy for steel making.

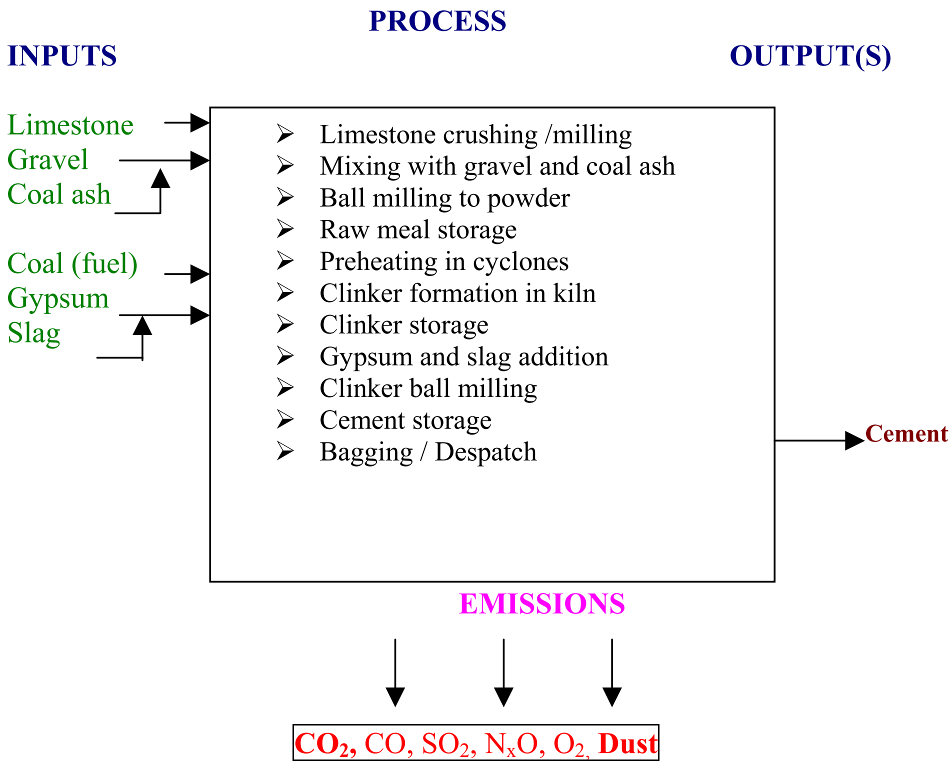
4.30 Market Assessment of Technologies

Table 4.1. Sub-sectors and Organizations Selected for Study in the Industry and Mining Sector

Co No	Name	Area	Type of Business
1	Circle Cement	Harare	Cement Manufacturing
2	Portland Cement (Unicem)	Bulawayo	Cement Manufacturing
3	Sino- Zimbabwe Cement	Midlands	Cement Manufacturing
4	Charter Saw Mills	Chimanimani	Timber processing
5	Erin Saw Mills	Nyanga	Timber processing
6	ZISCOSTEEL	Kwekwe	Iron and steel production and processing
7	Bulawayo Water Works	Bulawayo	Water treatment and delivery
8	Harare Water Works	Harare	Water treatment and delivery

I Cement Manufacturing

The processes employed by the three cement-manufacturing companies are generally the same. However, the composition of additives varies from company to company depending on availability and the desired cement quality. Below is the representative process.



a) Emissions and their sources

1. **Dust** from limestone crushing and milling of clinker
2. CO2
3. CO
4. SO2
5. N_xO

(2–5) From pyro-processing in the kiln and from boilers for slag drying

b) Emissions controlling measures

1. Use of waste sources of energy as substitutes for coal
2. Use of cementation materials as extenders
3. Energy efficiency improvement
4. Installation of dust traps at various points of the flow-line

II Iron and steel manufacturing (ZISCOSTEEL)

The Zisco iron and steel plant is a mixture of old and new plant and equipment and characterized by numerous broken and disused pieces of equipment and plants. It is a monumental challenge to restore most of this equipment to good working order. Dust and debri have accumulated liberally throughout the plant, which is currently operating at 30% capacity because of various challenges including coal unavailability.

Process

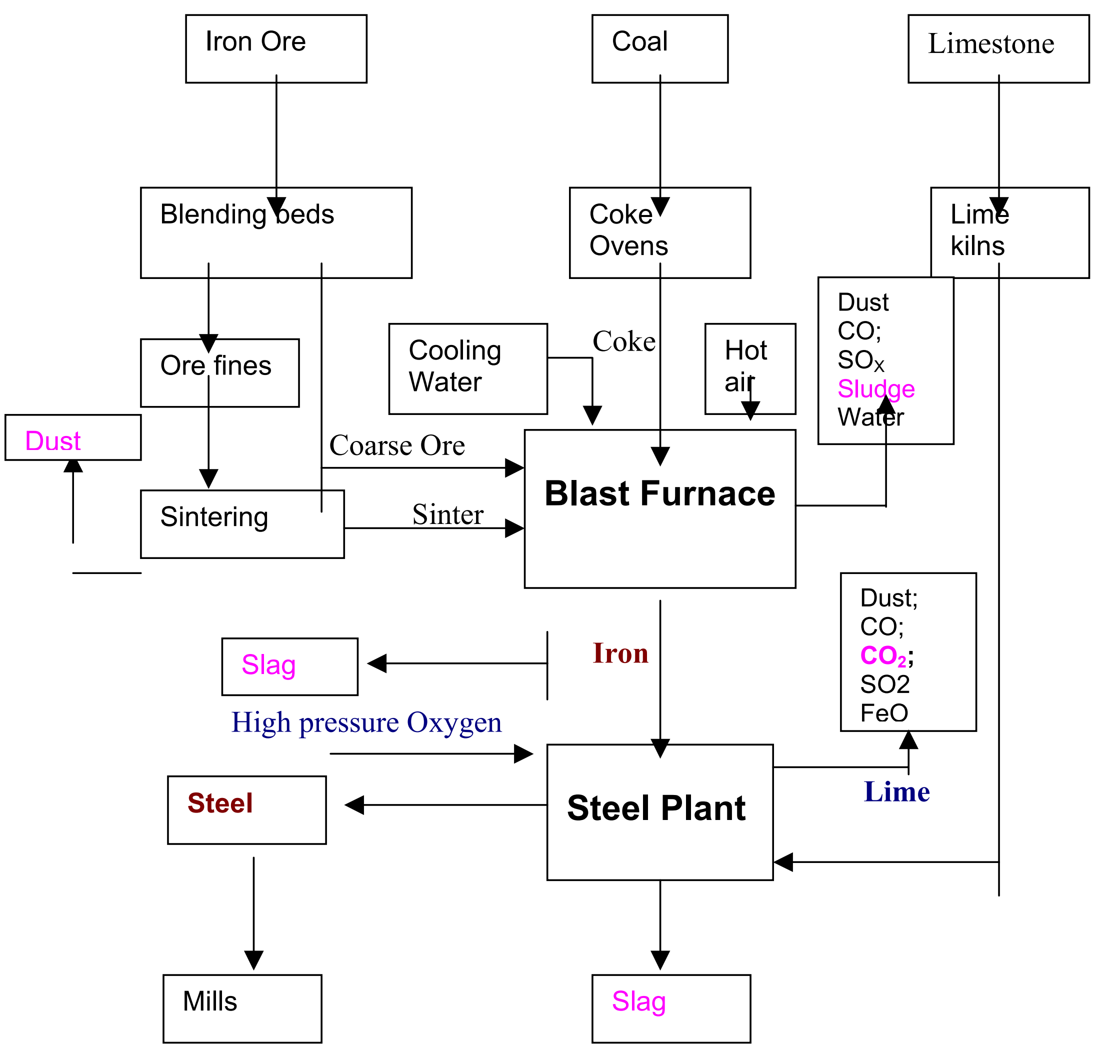
a) Inputs:

1. Iron ore- from Ripple creek (17km) by conveyor
2. Limestone - from local quarry
3. Coal- from Wankie Colliery by NRZ
4. 0xygen- pipeline from Sable chemicals
5. Water- Kwekwe river
6. Power- from ZESA

b) Output: Iron; Steel; Waste; Emissions

Iron ore is reduced to iron in a blast furnace using coke. Oxygen is then blown into the molten iron vessel where lime and other additives like silicon, ferromanganeses are added to get steel of the required specifications. The iron manufacturing process used by ZISCOSTEEL compares very well with the standard process.

Process Flow Diagram:



Coke Ovens- four batteries (with one out of commission)

1. Crushing and milling of coal to less than 6 mm
2. Carbonisation through controlled combustion without air
3. Emission of coal gas, methane, ammonia, hydrogen, benzol and. tar
4. Coke for the blast furnaces

Coke ovens waste

i) Coal gas; Stored in tanks (CH_4, CO and H_2)
ii) Tar and benzol; Electrostatic tar precipitators in detarrers
iii) Ammonia:

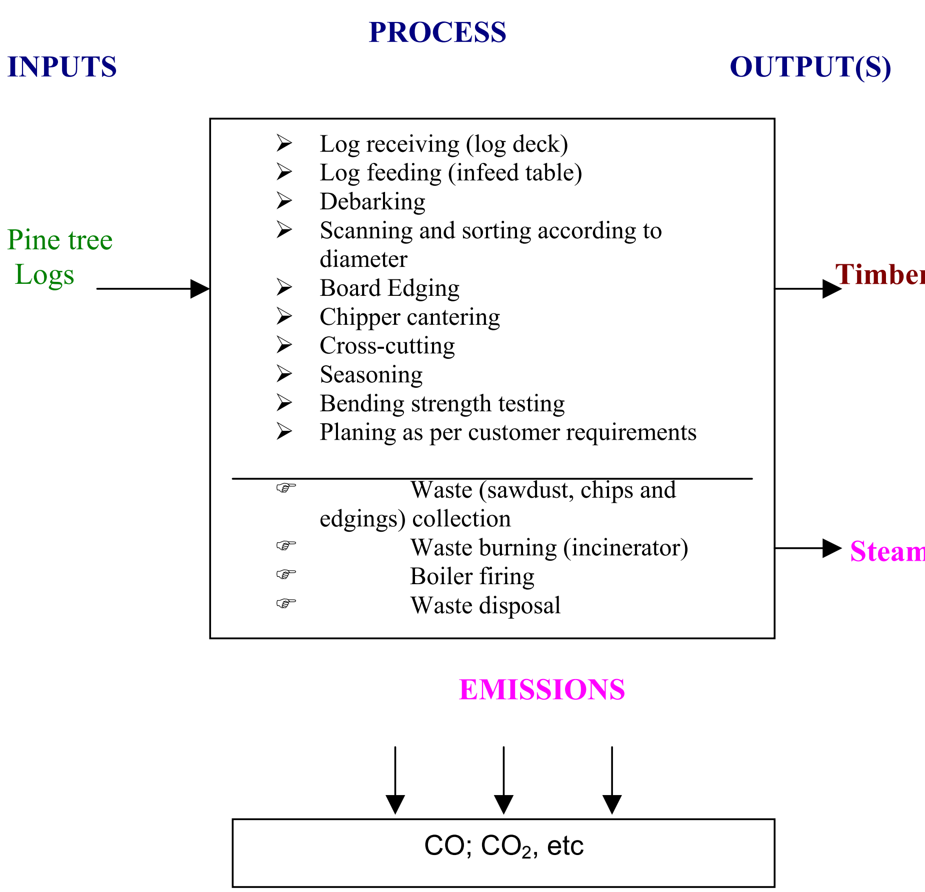
- Ammonia plant broken down i.e. distillation and incinerator
- Ammonia gas is being released into the atmosphere,
- The plant is heavily corroded

Sinter plant

1. Processing of iron ore fines, limestone and coke residue for input into blast furnaces
2. Dust is emitted from this process
3. The plant is relatively new

Saw Mills
Process Flow

Below is the general process used in timber production. However, there are slight differences in the two organizations ERIN Saw mills and Charter Saw Mills.



Production Waste

Timber processing generates a lot of waste that comprises:

1. edgings
2. bark
3. saw dust
4. chips (constitute 60% of the waste produced)

The table below gives the approximate quantities and uses of waste by the two companies studied.

Item	ERIN	Charter
Approx. % of input comes out as waste	45	44
% of the waste is used for firing the boiler	30	20
% of the waste is incinerated	50	60
% of the waste is disposed off at a cost	20	20
Waste disposal cost per month	Z$5 – 6m	Z$3-4m

Bulawayo Water Works

The water supply for the City of Bulawayo is different from the one in Harare as the city has its catchment area upstream and to the east of the railway line from Gweru. This guarantees a supply of relatively clean water to the treatment works at Ncema and Criterion. However the villagisation that is taking place in the catchment area threatens the supply with waste, siltation, cutting down of trees and cow dung that now finds its way into the rivers in the catchment area.

The major constraints facing the city's water supply are inadequate water for the city, old treatment plants characterised by frequent breakdown of equipment and an aged reticulation system dating back to the 1920s. The main waste treatment plant Aisleby 1 and 2 are very old and are in a state of collapse. The sewage is corrosive and has caused extensive damage to the infrastructure. Most of the treatment plants are in need of extensive rehabilitation as effluent is being insufficiently treated with occasional spillage of raw sewage into the Umguza River. Most of the equipment such as pumps, motors and drives are in a serious state of disrepair affecting the efficiency and effectiveness of effluent treatment.

Aisleby Effluent Treatment Plants 1 and 2

Processing

1. **Intake**: Industrial and domestic effluent from the Darlington industrial area, city centre and domestic effluent from Entumbane, Njube and Sauerstown
2. **Screening** - to remove rags and course debris
3. **Settlement** of small particles in the Tritor chamber

4. **Primary clarification** in settlement tanks for the removal of sludge through precipitation and floating material using a scrapper. Sludge is pumped to digesters and the resulting methane used to burn rags trapped at the screens
5. Primary bio filters for the **removal of colloidal material** through bacterial digestion. Fermentation gases are released to the atmosphere
6. **Humus removal** in the humus tank. Sludge is fed back upstream of the works as bacterial seed
7. Release of treated effluent for **irrigating pastures**
8. Disposal of sludge on beds

Problems

1. Extensive corrosion of plant and machinery components
2. Critical shortage of replacement spares for electrical and mechanical equipment; secondary bio filters were by-passed because the pumps broke down
3. Shortage of granite stones for the bio filter
4. Insufficient treatment of effluent with occasional discharge of raw sewage downstream with the attendant health hazards for humans, animals and aquatic life

Aisleby Works No 3

The works is primarily for the treatment of domestic effluent by the activated sludge method. This is a relatively modern plant set up in the 1960s and discharges relatively clean water into the river although some of it is used for irrigation.

Processing

1. Inflow
2. Screening
3. Load balancing
4. Fermentation zone recharged by sludge from the humus tank
5. Anoxic zone
6. Aeration zone
7. Re-aeration
8. Clarification in humus tank – sludge feedback to fermentation zone
9. Digestion of sludge
10. Release of effluent to night dams for irrigation

Recommendations

1. Effective process control of effluent parameters
2. Provision of spares for plant and equipment
3. Harnessing of methane gas from digester as a source of energy

Criterion Water Works

The Criterion water purification works was constructed in the 1950s with some upgrading in 1980. It provides 2/3 of the water while Ncema provides the rest.

Purification process

1. Catchments area : Upper Ncema, Lower Ncema, Umzingwane, Insiza and Shangani rivers
2. Raw water reservoir with a capacity of 1,5 million m^3
3. Inlet from reservoir to two purification plants
4. Solution tanks for pre- treatment chemicals:
   - Aluminium sulphate for co-agulaion,
   - Chem. Log 304 – poly electrolyte coagulation aid
   - Lime – pH adjustment- added dry
   - Activated carbon (dry) - adsorptive removal of odours
5. Dosing station:
   - gravity doser for pre-treatment chemicals
   - equipment not functional
   - mixing by turbulence
6. Clarification – flocculation and clarification
7. Filtration-by sand filter beds
8. Aeration
9. Chlorination and addition of ammonia
10. Stabilisation of clean water in contact tank- a clear water reservoir
11. Supply of clean water to the city

Harare Water Works

Unlike other cities, the city of Harare sits on its catchment area and upstream of its raw water reservoirs, which increases the treatment costs of the city's water. The cost of water purification was Z$400m in 1998 but has now ballooned to Z$8506b in 2004. The city water treatment woes are compounded by the prohibitive costs of biological nutrient removal using imported chemicals and poor maintenance and lack of replacement spares for the treatment plants, machinery and equipment.

The effluent treatment works have failed to cope with the rapid expansion of the city resulting in severe capacity constraints. The situation is further worsened by the indiscriminate cutting of trees upstream of the city, which has a severe impact on water flow into the river. Sewage is very corrosive and contributes to the rapid deterioration of plant and equipment. This results in inadequate treatment of effluent and occasional discharges of raw effluent into lake Chivero, which is the worst polluted lake in Zimbabwe. Occasional spillage from excessive rains comes as a welcome relief for the city's water purification woes.

The biggest contribution to the city's contaminants comes from the industries, particularly the food, fertilizers and chemical manufacturing industries. It would be desirable for industry to adopt cleaner production technologies that would see industries setting up their own pre-treatment facilities on site. To this end the city of Harare is supporting the establishment of environmental industrial clusters within the city to take charge of their biospheres. Currently most industries are discharging their impurities and waste water directly into the streams although there are notable exceptions like Cairns Foods in the Ardbennie industrial area.

Morton Jaffray Water Purification Works

(a) Intake:

Raw water is supplied from Lake Manyame and Lake Chivero and is blended before treatment. The raw water is fed into three plants for treatment.

(b) Pre-treatment:

Water from Lake Chivero is heavily contaminated on account of industrial pollutants hence the need for pre-blending with water from Lake Manyame. The resultant pH is very high hence the needs for pH adjustment using sulphuric acid to an acceptable pH of 8,4.or less.

(c) Mixing

The water is subjected to turbulence in the mixing chamber to facilitate aeration.
pH adjustment with sulphuric acid and removal of odours using activated carbon imported from Brazil.

(d) Chemical dosing

The dosing station caters for:

- Aluminium sulphate, coagulant -Zimphos ,S. Africa
- Sulphuric acid-from South Africa
- Sodium Sulphate –coagulant aid , and
- Lime – p H adjustment.

(e) Distribution

The water is distributed in the distribution chamber to the three treatment plants/works clarifiers

(f) Clarification – in clarifier beds /settling tanks

(g) Filtration

- In sand filter beds / filter gallery
- Algae growth that blocks filters is a nuisance which means more frequent filter backwashes

(h) Treated water pumping:

Morton Jaffray Water Works supplies most of Harare, Norton, Darwendale and Ruwa and, and in cases of emergency, also Chitungwiza and Hatfield (which are normally supplied by the Prince Edward Water Works)

Constraints

1. Most of the Works machinery and equipment is either broken down or malfunctioning resulting in reduced capacity
2. Most of the process control equipment in the Control room (e.g. flow meters and level indicators) is not functional rendering process control or timely corrective actions very difficult
3. There is little evidence of in-line control of water quality parameters to facilitate timely corrective action
4. Feedback from the central laboratories comes too late to facilitate process control
5. There is no evidence of planned maintenance at the works
6. Power consumption records were not readily available

Crowborough Sewage Treatment Works

- ☞ Established in 1958 with capacity of 54 mega litres
- ☞ Current throughput ranges from 120 to 160 mega litres far in excess of design capacity. The current congestion in the residential areas was not envisaged in the planning
- ☞ Sewage treatment is based on the biological filtration and biological nutrient removal
- ☞ Catchments area :

1. Willovale industrial area,
2. Part of Southerton,
3. Part of Harare CBD,
4. Workington ,
5. Mount Pleasant,
6. Marlborough,
7. Mabelreign,
8. Avonlea,
9. Dzivarasekwa,
10. Westgate

Conventional Biological Filter Plant

Processing

1. Intake from catchment area
2. Screening to remove coarse debris
3. Grit removal – grit tanks – it is essential to remove sand to facilitate biological treatment – use of air lift pumps to introduce air to facilitate sand removal
4. Fine screening – removal of rags and clothing material
5. Division box for distribution to 18 settling tanks
6. Splitter box for channelling to individual settlement tanks
7. Settlement tanks :
    - ☞ sedimentation of solids,
    - ☞ hydrostatic sludge draw off,
    - ☞ skimming off floating material,
    - ☞ overflow of effluent to launder
8. Primary anaerobic digestor– for sludge treatment,
9. Secondary digestion - for sludge stabilisation

10. Dosing Syphon – supply of effluent to biological filters based on hydrostatic pressure,
    - Overflow of effluent results in discharge of raw untreated effluent to ponds and subsequently into the river,
    - Approximately 30% of untreated effluent goes into the ponds for disposal
11. Bio filters:
    - – filled with granite stones,
    - rotary filter distributes effluent onto the surface of the bio filters,
    - biodegradation by a slimy coating of microbes on granite stones

12. Humus tank:
    - removal of humus,
    - recharge of bacterial sludge,
    - discharge of clear treated effluent

13. Maturation ponds- holding ponds for treated effluent for use on irrigating pastures
14. Sludge disposal – in drying beds

BNR- Biological Nutrient Removal Plant

- Plant was constructed in 1984
- Plant Capacity: 18mgl per day
- Current throughput: : 12ml a day an account the breakdown of one of the three clarifiers

a) Processing

1. Inlet from division box
2. Fermentation zone - release of phosphate
3. Anoxic 1- :Denitrification $2NO_3 \longrightarrow N_2 + 3O_2$
4. Aeration basin – uptake of phosphates and nitrification

$$2NH_3 \longrightarrow NO_2 \longrightarrow NO_3$$

5. Anoxic 2 – nitrate (NO_3^-) removal from aeration basin
6. Re - aeration basin - removal of residual nitrates and phosphates
7. Clarifiers: :for sludge removal and recycling
8. Treated effluent discharge

Firle Sewage Treatment Works

Firle works is the biggest sewage treatment plant in Harare with a total of 32 settlement tanks, six of which are for biological nutrient removal using activated sludge
Firle 1 and 2 were constructed in the 1960 while Firle 5 was constructed in 1996

- Design capacity:: 144 Mega litres /day
- Current throughout: 200-220 Mega litres /day

- ☞ Population explosion resulting from rural to urban migration accounts for increased through put. Coping with the throughput is hampered by frequent breakdowns resulting from inadequate maintenance and shortage of spares. Unit 3, for example, with a capacity 18-mega litres has been out of commission since 1997.

Catchment area:

1. Willovale,
2. Southern Surbubs,
3. Waterfalls,
4. part of Southerton,
5. Graniteside, and
6. Hatfield.

Conventional Plant

Processing;
1. Inlet
2. Screening of fine, medium and coarse debris
3. Grit tanks- for sand removal (one tank has been down for 2 years!)
4. Primary settlement tanks:-
   - ☞ five tanks not functional,
   - ☞ Compressors for unblocking settlement tanks are down
5. Distribution to 4 bio reactors in division box

Biological Nutrient Removal (BNR) Plant

1. Fermentation zone
2. Anoxic zone
3. Aeration zone
4. Clarifiers: there are 12, but 7 are down
5. Cascade for releasing treated effluent to Mukuvisi River
6. Ponds for receiving effluent in the event of a break down

a) Constraints

1. Equipment and machinery breakdown. Of the 10 pumps at the ponds 8 are down. Some gearboxes and motors for aerators have broken down. There are no spares for Grits tank equipment.

Barriers to adoption of appropriate technology

1. Low environmental awareness and short-term focus
2. Weak enforcement of stipulated environmental standards
3. Penal approach by water authorities rather than securing buy-in and voluntary compliance from stake holders
4. Unfavourable macro-economic environment that pushes environmental issues to the back burner and company survival to the fore.

5. Weak management system in the case of Harare City Council Water Works
6. Lack of supportive environment from government on sound environmental practices through incentives.
7. Absence of investment funds to support implementation of new technologies.

Technology Transfer Already in Place

Pilot Production of Sawdust Briquettes

Envirotech, a small private sector company with an environmental focus carried out a feasibility study on the production of binderless briquettes from sawdust waste at the Border Timbers Ltd furniture factory in Mutare. The project was partially supported by the UNDP's GEF Small grants Programe in association with Africa 2000+ who provided the briquettes machine. Border Timbers provided the site for the pilot plant, engineering support and the sawdust waste for the project.

The feasibility study was borne out of the concern at the incineration of 50% sawdust waste by sawmills as a means to dispose of the waste. Plumes of smoke clouds from the incinerators are a characteristic feature of sawmill areas. Though about 30% of the waste is used for firing boilers, the remainder of the sawdust waste is carted to rubbish dumps at considerable financial costs to the sawmills.

Envirotech was determined to harness the energy in the sawdust for productive use as a substitute for both fuel wood and coal in the domestic, agro-industrial and industrial sectors. The briquetting of sawdust would avoid the emission of greenhouse gases and the associated environmental impact on the one hand whilst providing an alternative renewable source of energy and reducing deforestation associated with fuel wood harvesting on the other.

The pilot production ran for five months producing over 100 tonnes of briquettes that were distributed to the industrial, agro-industrial and domestic sectors for field performance evaluation. Some samples were sent to the Mechanical Engineering Dept of the University of Zimbabwe for the comparative determination of calorific content.

The calorific analysis established that the calorific content of the briquettes was comparable to that of coal and that the briquettes left very little residue in the form of ash. The briquettes contained more volatiles than coal that boosted the calorific value. Positive feedback was received from the industrial, agro-industrial and domestic participants in the field trials who expressed satisfaction on the performance of briquettes as a substitute for both coal and fuel wood

Commercialisation of the production of sawdust briquettes would open up prospects for the environmentally friendly disposal of sawdust waste

4.3.1 Potential Technology Transfer

Sewage Works

Harare

1. Re-capitalization and expansion of treatment plant to boost capacity and avoid discharge of untreated effluent into the river
2. Institution of planned and total productive maintenance
3. Provision of spares for machinery and equipment
4. Harnessing of methane gas as a source of energy
5. Review of reporting and administrative structure to enhance accountability and responsiveness
6. Installation of additional BNR plants that are more environmentally friendly
7. Need for residential electrical and mechanical artisans and laboratory technicians on site
8. Intensification of trade effluent control from industries and setting up of pre-treatment facilities on factory site
9. Need for a stand- by generator
10. There is need to expand plant so that it copes with effluent throughput
11. Need for a standby generator in the event of power cuts or load shedding

Bulawayo

1. Capital outlay for plant refurbishment which is estimated at $5 billion
2. Provision of spares for plant and equipment
3. Harnessing of methane gas as a source of energy.
4. Institution of effective on-line control of effluent discharge parameters.

Water Treatment Plant

Harare

1. Institution of planned and total productive maintenance
2. Provision of replacement spares for critical machinery and equipment to ensure high plant availability.
3. Institution of energy audits to establish power consumption
4. Setting up a laboratory on site for oversight and in-line control of critical parameter such as pH, BOD, COD, TDS and residual mineral content
5. Revisiting the reporting and administrative structure of the Water Works to facilitate responsiveness and accountability
6. Need for standby generator for emergency cases
7. Need for a reservoir for treated water (a buffer)

Bulawayo

1. Provision of spares to revamp plant and boost supply capacity
2. Consideration to be given to the re-cycling of treated domestic effluent water and blending it with reservoir water to boost supply capacity
3. Conservation measures to be promoted in the catchment area to protect clean water sources that reduce the treatment burden of raw water.

General recommendations for the Cement Industry

i) use of ventilation systems in conjunction with hoods and enclosures covering transfer points and conveyors for the control of fugitive emissions
ii) use of adjustable conveyors to minimize drop distances
iii) designing stormwater drains to minimize solids wash off
iv) effective collection and recycling of dust
v) determination of the sulphur content of raw materials to facilitate the control of SO2 emissions
vi) instituting effective total productive maintenance schedules
vii) installation of continuous monitoring equipment for particulates in stack exhausts
viii) wetting of dusty areas and roads to reduce the generation of dust
ix) upgrading of plant and equipment to improve operational control and efficiency
x) exploration of the use of renewable sources of energy that are more environmentally friendly than coal

Steel Plant Problems

1. Excessive emissions of dust because of break down of gas plant and of the washing unit
2. Motor and drives for the clarifier broke down.
3. Damper door and induced draft fan also malfunctioning resulting in release of emissions to the atmosphere

Recommendations for ZISCO Iron and Steel Plant

1. Consideration should be given to alternative technologies such as the direct reduction of iron ore .
2. Improvement of blast furnace efficiency by using coal and other fuels as a source of energy instead of coke thereby minimizing emissions.
3. Measures should be implemented to control dust emission throughout the plant from blending beds, screening and conveyance, coke ovens, sinter to the steel plant and mills.
4. Urgent attention should be taken to repair broken down equipment and plants and gas washing and dust collection units.
5. The coke oven plant requires extensive refurbishment including the ammonia plant.
6. Steps should be taken to avoid the release of ammonia gas into the atmosphere and the overflow of ammonia ponds during the rainy season.
7. Effective containment measures for tar, oil and benzol should be implemented to avoid contamination of effluent water.
8. On no account should untreated effluent be discharged into Kwekwe river.
9. Steps should be taken to treat and stabilise sludge before disposal
10. Samples from the effluent treatment plant should be taken regularly and results fed back for process control.
11. The use of tar as fuel for mills section which produces toxic emission to the atmosphere should be reconsidered.
12. Re-use of waste water

Sawmills Environmental Problems

1. Accurate determination of waste generated at each process stage as a basis for process improvement
2. Determination of the quantity and types of gases produced through incineration
3. Consideration of waste recovery for either electricity generation or briquetting (see the pilot project in the insert below)
4. Use of more efficient saws like bend saws that produce less waste
5. Tarring log deck area to improve handling during the rainy season

4.3.2 Current Limitations and Responses

☞ - Coal availability
- Power cuts

☞ - Raw material handling and storage
- Power cuts
- Coal availability
- Excessive emission of particulate matter

☞ - Malfunctioning Conditioning tower
- Excessive emission of particulate matter

Common problems in the cement-manufacturing sub-sector

1. Dust

Dust, which poses health problems to workers in the vicinity and is actually cement loss, is emitted from various stages of the process. However, in some sections dust is trapped and sent back into the system. Electrostatic precipitators are used to trap dust on the ball mills and air bags are used in other cases. Advanced plants have their conveyors enclosed but those of the three companies visited were open.

The dust emissions levels acceptable to the World Bank Group are 0.2-kg/ t of clinker.

2. Gases

Many gases are emitted from the kiln with very few being measured and analysed. Carbon monoxide is measured more as process control parameter. The impact of carbon dioxide on climate is not appreciated by many, and not all of those who do, think that something can be done to reduce the CO_2 emissions. The use of additives with less carbon content than that of limestone is common practice in the industry. However, there is need to measure and analyse the amounts of CO_2 in relation to the quantities of inputs and outputs. The barrier to the measurement and monitoring is the lack of funds. The financial constraint is being blamed on the depressed activity in the construction industry.

3. Energy Efficiency

Energy (both electricity and coal) costs are on the upward trend so much that cost-competitiveness is being compromised. One of the three companies (Circle Cement) does an energy balance once in three years; while Sino–Zimbabwe monitors coal usage per tonne of production. However, it is believed that detailed energy audits are necessary.

4. Equipment Maintenance

Any piece of equipment needs to be well maintained for it to continuously give the required performance. Different types of machines require different types of maintenance depending on design and utlisation. However, proactive maintenance is advisable as it prevents premature failure which, in turn, reduces production and increases emissions per unit of production.

The World Bank Group stipulates a plant availability of at least 95% in its measurement of emissions. This level of plant availability requires adequate financial and skills.

CHAPTER 5:

PROGRAMMES, POLICIES AND OTHER INTERVENTIONS FOR TECHNOLOGY TRANSFER IN ZIMBABWE

5.10 Adoption barriers/constraints

For farm-level adoption, the barriers include small farm size, credit constraints, risk aversion, lack of access to information, lack of human capital, inappropriate transport infrastructure, inadequate incentives associated with tenurial arrangements, and unreliable supplies of complimentary inputs. To add to that, it has been observed that the population has a feeling that new technologies may be immature and pose poorly understood risks, as well as offering hard-to-quantify benefits. Local industry is not giving enough support to the technology options that are feasible.

In Zimbabwe, irrigation efficiency requires large investments and national commitment, technology transfer to the farm level, cooperative community action. Substitution of traditional crop varieties with improved varieties causes problems of dissatisfaction as the yield output is of less preferred grain quality. This also causes problems of new pest problems in some areas, and may require a changed management structure.

Modification of animal feed would play an important role in reducing GHG emissions, however, ammonium sulphate is more expensive than urea, which is currently being used.

More investment is required in the large-scale biogas digester, despite the fact that these are complex to operate and maintain.

It is now agreed that Information technology is the driving power for technology transfer. It has the potential to revolutionize the dissemination of knowledge about GHG emissions mitigation, climate change and adaptation strategies in the agriculture sector.

Poverty decreases the ability of a population to cope with climate variability and change. Zimbabwe is currently experiencing macroeconomic instability characterized with high inflation, lack of foreign currency, unstable exchange rate and high unemployment. Mitigating GHG emissions and adaptation to climate change requires action across society, professions, organizations, and countries. The country does not have the capacity to handle this issue.

There is a complex interaction in the country between the rights of an individual to good environment; his or her responsibilities to protect it; the rights of a community to protect itself against climate change threats; and its responsibility to provide for the food requirements of its members.

5.20 Programmes and policies to encourage technology transfer

The landscape in which agriculture works has been changing rapidly. The Political, Economic, Social and Technological factors conceptual framework is used to analyze the environment for technology transfer in the agriculture sector. The sections that follow examine the four factors in detail.

Zimbabwe is a signatory to the UNFCCC and other key environmental United Nations conventions, which provides ideal global context for progressive action on climate change. The Government of Zimbabwe (GOZ) has put various ministries under pressure to show they can protect the environment for their population. The Environmental Management Act (EMA) and Water Act recognize the importance of climate. A National Environmental Policy framework exists, and the country commits not less than 2% of GDP to support agriculture to develop and implement agricultural practices that are environmentally friendly and sustainable. The Government already collects revenue for environmental programmes through Carbon tax.

Zimbabwe has an established Climate Change Office, which is mandated to co-ordinate climate related projects. The Climate Change Office has conducted several studies on climate change and climate-related issues since its inception in 1996. Below is a summary of the technology transfer related projects that have been carried out since 1990.

Ross and Touche Greenhouse Gas Studies

Ross and Touche Consultants first conducted studies on climate change in 1991 under the sponsorship of the British Overseas Development Agency. These studies mainly concentrated on the inventory for greenhouse gases.

United Nations Institute for Training and Research (UNITAR) Project

In 1992 and 1993, UNEP through its RISO Centre conducted studies on various abatement options through a local non-governmental organisation, the Southern Centre for Energy and Environment. The objective of this project was basically raising climate change awareness in different segments of the society i.e. policy makers, industrialists, academics and the general public.

UNDP Capacity Building Project

In 1996, with the assistance of UNDP (GEF), Zimbabwe participated in a two-year regional four-country Capacity Building Project. The main objective of this project was to enable the four countries (Mali, Ghana, Kenya and Zimbabwe) to meet their obligations under the UNFCCC. In Zimbabwe, the newly formed Climate Change Office in the Ministry of Mines, Environment and Tourism executed this project. The methodology for project execution was through national and provincial workshops throughout the country as well as focused studies on mitigation options particularly in the energy sector. The greenhouse gas inventory was also revisited on the basis of 1994 as a baseline year. The project also attempted to examine climate change policies in the four participating countries. These studies were completed in 1998. These attempts were successful in the sense that the level of climate change awareness is now relatively high in Zimbabwe. Furthermore, the basis for future policies and measures was also laid through participation in this project.

Initial National Communication

In 1997, Zimbabwe started working on its Initial National Communication under the UNEP/GEF Enabling Activity Programme. The Climate Change Office also executed this project. Under the general framework of the Zimbabwe Initial National Communication Project, greenhouse gas inventories were further improved through expanded areas of sources of emissions as well as improved quality of data. This exercise was facilitated by the presence of a reasonable number of previous studies (particularly the greenhouse gas and impact studies generated under the United States Country Studies and the UNDP Capacity Building Project) as mentioned before in this section. The final product - the Initial National Communication was submitted to the UNFCCC Secretariat in May 1998.

World Bank National Strategy Study on Activities Implemented Jointly and Clean Development Mechanism

Zimbabwe also conducted a National Strategy Study for Activities Implemented Jointly (AIJ) and Clean Development Mechanism (CDM) to enable/prepare policy makers to make informed decisions with respect to AIJ and CDM. This was a short four-month World Bank programme financed through a trust fund arrangement - Switzerland being the Donor. This project started in December 1998. Only two African countries were involved in this study i.e. Zimbabwe and South Africa.

From the studies that were carried out, it became clear that there are some gaps in our climate change studies. These gaps were categorised into three groups: -

a) Identification of barriers for adoption of recommended technologies (mitigation options) by industry in Zimbabwe.
b) Assessment of these technologies.
c) Improving/strengthening the existing vulnerability and adaptation studies in the agriculture sector.

Netherlands Climate Change Studies Assistance Programme

These studies were carried out with the assistance of the Institute of Environmental Studies (University of Amsterdam). The rationale of the proposed studies in removal of barriers is premised on the fact that a lot of climate change studies have been carried out in Zimbabwe on mitigation options but, on the other hand, industry as a whole, have not incorporated these proven more efficient technologies into their operations. Given this situation, the focus of the proposed study on removal of barriers would emphasise on the demand-driven side from the industrialist' point of view. From the foregoing it was therefore necessary to conduct studies on the removal of barriers for adoption of recommended technologies (mitigation options) by industries in Zimbabwe. Assessment of these technologies would also be done. A second component of these studies was to deal with the improvement/strengthening of vulnerability and adaptation studies in the area of agriculture.

Programmes and Policies to Encourage Technology Transfer

5.21 Energy and Industry

Consideration should be given to the following recommendation that facilitate the mitigation of climate change:-

a) Cultivation of a sense of environmental responsibility on the part of all stakeholders including the general public to promote voluntary compliance
b) Collaborative problem solving by all stakeholders to mitigate climate change
c) Raising environmental awareness nationally
d) Implementation of total productive maintenance
e) Environmental assessment of industrial establishment as a reality check on greenhouse gas emissions
f) Regular energy audits to promote efficient use of energy
g) Instituting sound environmental management systems in the Industry and Mining sectors
h) Setting up a data base on environmentally friendly technologies
i) Making environmental education an integral part of school curricula

5.22 Industrial Energy Management Programs

Zimbabwe has had several industrial energy efficiency projects. Most of them were structured to build local capacity in implementing efficiency improvement measures as well as assessing the potential for various energy efficiency improvement measures. The table below lists the major initiatives.

Table 5.1 Sample Energy management Initiatives Carried Out in Zimbabwe

Project	**Principal Sponsor**	**Objectives**
ESMAP Energy Sector Review	World Bank and UNDP	Assess energy supply options and develop a development plan
Zimbabwe Energy Efficiency Project	International Energy Institute	Assess sectoral energy efficiency improvement options and build local capacity to realise the opportunities
SADC Industrial Energy Management Program	CIDA	Train technical people in industry and other sectors for assessing energy efficiency opportunities and help establish a skills base for continued training.
Barrier Removal to Energy Efficiency Improvement in Industry	UNDP-GEF	Assessment of barriers and identification of barrier removal options primarily through establishment of Energy services Companies in Zimbabwe.

The above projects identified technologies that could be adopted to improve energy use efficiency. In addition some of the projects identified barriers to energy efficiency improvement. The UNDP-GEF funded project drew a proposal for establishing an Energy services Company business in Zimbabwe. This proposal included an investment budget. The main limitation was the lack of co-funding, which is a condition for continued GEF funding for the implementation phase.

5.23 Previous Experience with Pilot and Demonstration Projects

i) The largest energy pilot project in Zimbabwe was the GEF PV Pilot project, which supplied lighting systems for household use in rural areas. The project involved setting up of an administration framework for GEF seed funds and establishment of a network of system installers as well as suppliers. The project had an initial target of 10000 units but delivered about 9000 units counted in terms of 45watts per unit. The actual number of units was less than 9000 since some installations were more than 45 watts in capacity. The seed funds from GEF were converted into a revolving fund with beneficiaries paying a subsidised price for systems they purchased. At the close of the project there were excess funds which could be used for further activities. The money was later earmarked for investigations into how a PV lighting program could be set up.

ii) UNDP-GEF also funded a briquetting project that was discussed earlier in this report. The project established the viability of sawdust briquetting ad it's potential for use as a fuel for households and industry. The project now awaits commercialisation.

iii) A wind powered electricity generation project was carried out by ZERO from a testing phase to a pilot phase. The project assessed wind potential for small-scale applications and installed a pilot project with 4 wind machines in Rusape. Local capacity was built for production of the wind machine. The collaborating partners included ZERO as the project managers and a British consultant as the supplier of technology. A local manufacturer, Powervision, built the machines and is now involved in export of wind machines to the region and to the USA.

Technology transfer in industry is fairly common. There are several private sector initiatives, which are based on franchising or contract manufacturing which involve transfer of technology and skills for production and marketing of goods and services. The issue in this study is the transfer of clean technologies in cases where private sector initiative is limited by barriers both known and unknown. A strategic approach would be to map out public sector initiatives to mimic private sector technology transfer initiatives. This would reduce cost and also avoid generating new barriers by introducing new concepts.

5.24 Policy Environment and Institutional Framework

Technology transfer is enabled by a combination of sectoral policies. The policy framework for each sector is driven by the responsible authority, which in most cases is the responsible Ministry. Policy implementation is spread across all sectors. In some cases the authority responsible for implementation becomes the authority for the policy segment that they are implementing. This leads to fragmentation with the result that policies with common objectives become detached and develop independently. An example is the environmental policy, which has had to be redrafted with a new ACT and clearer definition of the responsible authority. The Environmental ACT is a driver for technology transfer but little is mentioned in the ACT to link the responsibilities and actions of the institutions responsible for technology and industrialisation with regards to responding to the Environmental ACT. The Environmental ACT is presented more as a controlling tool to safeguard the Environment as opposed to being a tool for promoting technology upgrading as a way of optimising resource use and supporting a competitive manufacturing sector that in addition to producing quality goods also produces a quality environment.

There is need to facilitate policy integration that allows all responsible authorities to see their role in each others guiding policy instruments. This can be done through interpretation of the various policy statements to highlight the various responsibilities for successful implementation of the instruments. The following table gives an example of such an interpretation.

Table 5.2: Example Policy Cross Linkage Between Ministries.

Ministry of Energy and Power Development	Ministry of Finance and Economic Development	Ministry of Industry and international Trade
Policy Statement; Promote use of energy efficient devices	Interpretation; More efficient technologies should have duty and tax incentives	Interpretation: Trade agreements should include compliance with universal efficiency improvement guides such as climate change criteria.
Interpretation; Energy sector contracts should demonstrate local skills development	Policy statement; Increase local content in energy sector investment	Interpretation; Trade in energy equipment/technologies should be biased towards CKD and soft technology imports.
Interpretation; Define energy tariffs to suit the needs of small scale enterprises.	Interpretation; Make available micro-finance schemes	Policy Statement; Promote small scale enterprises

The above matrix can be expanded to cover all other sectors. The critical element is the matching of each policy statement to other sector policies as a way of bringing integration.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Zimbabwe's rainfall is characterized by high inter-annual variability with recurrent droughts and occasional floods being a permanent feature of the country's climate. Agricultural systems are vulnerable to climate extremes with effects varying from place to place in response to the modulating effect of soil type, production system, farmer skills and other factors. Change in frequency of drought, tropical storms, floods and other extreme climate events are likely to have significant consequences. A major source of climate variability in the country is El Nino – Southern Oscillation (ENSO).

Scientific evidence has shown that there is a decline in rainfall with time in Zimbabwe and the southern Africa sub-continent. This has resulted in a consequent decrease in runoff amounts in Zimbabwe. The country has a fairly established infrastructure to deal with the issues of hydrological and meteorological data. There is an elaborate legal and institutional framework for water resources development and management. The issue of climate change is not well dealt with in the water sector. However, research work and field trials of diverse water serving technologies are being carried out in the marginally drier regions of Zimbabwe.

Of all the sectors of Zimbabwe's economy, agriculture is perhaps most directly dependent on annual weather conditions and long-term climatic factors. Small annual fluctuations as well as extreme events impact crop and livestock production, and determine the economic success of farmers, agri-business and the country as a whole. Most climate change scenarios predict that a doubling of atmospheric carbon dioxide will lead to warmer conditions throughout the year. At the same time, the model predicts a decrease in precipitation over Zimbabwe.

Reduction of greenhouse gas emissions and adaptation in the agricultural sector would help offset these impacts. Nearly 25% of agricultural emissions in Zimbabwe are estimated to arise from nitrous oxides released from cropping and nutrient management practices while 66% per cent come from methane released through enteric fermentation and manure practices. The agricultural sector can work to reduce greenhouse gas emissions through methods such as zero tillage, shelterbelts, reduced fossil fuel use, best management practices in manure and fertilizer use, livestock feeding strategies, and other land management practices.

Recommendations

In order for comprehensive analysis of the climatic situation to be done, the meteorological and hydrological observing networks have to be upgraded. Donor funding, which currently constitute a large percentage of investment into equipment needs to include funds for training of staff as well as provision for spare parts.

It is recommended that technology transfer in the agriculture sector follow a phased approach. Phase 1 - enabling actions are presented.

PHASE 1 – Enabling activities

For technology transfer to take-off in the agriculture sector, it is critical to initially support actions that are most cost-effective while delivering in the shortest possible time (quick wins) important health, economic, environmental and social benefits. These initial actions lay the groundwork for future progressive action and could include activities such as:

- Water harvesting and conservation
- Expanding and conserving forest areas
- Provide improved forage/feeds for livestock
- Manure to methane energy projects

Other activities that may be long-term in nature could also be initiated in Phase 1 of the National Climate Change Strategy Implementation. These include:

- Improvement of crop and livestock genes

Phase 1 must seek to engage a broad section of agricultural sector and environment players to take action now to solve Zimbabwe's overall emissions and expand carbon sequestration potential to reduce future costs.

The roadmap for technology transfer in the agriculture sector for climate change mitigation and adaptation should be underpinned by the following enabling actions in the first phase:

i. **Institutional framework and stakeholder buy in**

It is critical to secure stakeholder buy in and ownership of the technology transfer process. It is therefore imperative to establish a clear institutional arrangement to support the Climate Change Office in the technology transfer implementation process. A typical institutional arrangement is presented in a later section.

ii. **Enhancing Awareness and Understanding**

Inform, educate and build awareness of the science and impacts of climate variability and change in agriculture, including the capacity to adapt. Develop broad support for making climate change a priority and encourage and motivate Zimbabweans to take personal actions to reduce GHGe and preserve and expand carbon sinks.

iii. **Promoting Technology development, innovation and transfer**

Increase the availability and promote the development and use of technology and farm management practices that help reduce GHGe and the vulnerability of agriculture to climate variability and change.

iv. Government lead by Example

Government should set a positive example and continue to send a signal to Zimbabweans that climate change is an issue that must be addressed. Government can provide leadership by disseminating information to communities and private sector about best practices.

v. Investing in knowledge and building the foundation

Equip decision makers with the knowledge, capacity and experience to make informed decisions and lay foundation for future actions. To this end, support work on:

1. Global environmental change modeling and diagnosis
2. Assessment of impacts and adaptive capacity to reduce scientific uncertainty,
3. Options for future policies.

vi. Encourage action

There should be immediate action to demonstrate and test effectiveness of available technology and management practices to reduce GHGe, increase carbon sequestration and adapt to the effects of climate change.

BUSINESS PLAN

A series of annually updated 3-5 year business plans could be adopted to assist the technology transfer process. The business plans should be presented to both the Minister of Environment and Agriculture for approval. The business plan will have:

- Clear objectives
- Identify specific, concrete actions that government and other partners have committed to undertake,
- Identify actions government is considering for implementation in the 3-5 year period as well as those that require further work and consultation for later decision and implementation.
- Monitor and report progress publicly.

Typically, the balanced score card will be used to formulate objectives. Typical objectives could be set as follows:

GOAL 1: FINANCE

Strategic objective 1: To lobby and mobilize sufficient resources to support technology transfer initiatives.

GOAL 2: CAPACITY BUILDING

Strategic Objective 2:
To build capacity among local institutions in terms of skills and competencies to develop and adapt climate change mitigation and adaptation technologies to local conditions.

GOAL 3: VULNERABILITY REDUCTION

Strategic Objective 3: To develop and implement programs to reduce by 60% the vulnerability of communities to climate change hazards by December 2008.

GOAL 4: AWARENESS

Strategic objective 4: To improve the agriculture community's awareness of climate change related risks and response.

GOAL 5: LIVELIHOODS

Strategic Objective 5: To improve the livelihoods of at least 20% of the rural poor, particularly women and children who are vulnerable to climate change by December 2008.

GOAL 6: GREENHOUSE GAS EMISSIONS

Strategic Objective 6:. To reduce the emissions of greenhouse gases from agriculture by at least 10% by 2008.

GOAL 7: CARBON SEQUESTRATION

Strategic Objective 7: To increase the carbon sequestration capacity of Zimbabwe by at least 5% per year.

INSTITUTIONAL ARRANGEMENTS

No initiative will be implemented without leadership or a champion. A number of institutions already exist in the country to spearhead technology transfer in agriculture. It is proposed that a virtual center coordinated by a Department in the Ministry of Agriculture be formulated to help coordinate technology transfer in the agriculture sector (Fig 6.1). The institution arrangement for technology transfer in agriculture is underpinned by the desire to rationalize the execution of responsibilities and is guided by the need for efficiency, effectiveness, accountability, resource sharing and cost effectiveness.

The consortium of experts or working group could comprise experts from:

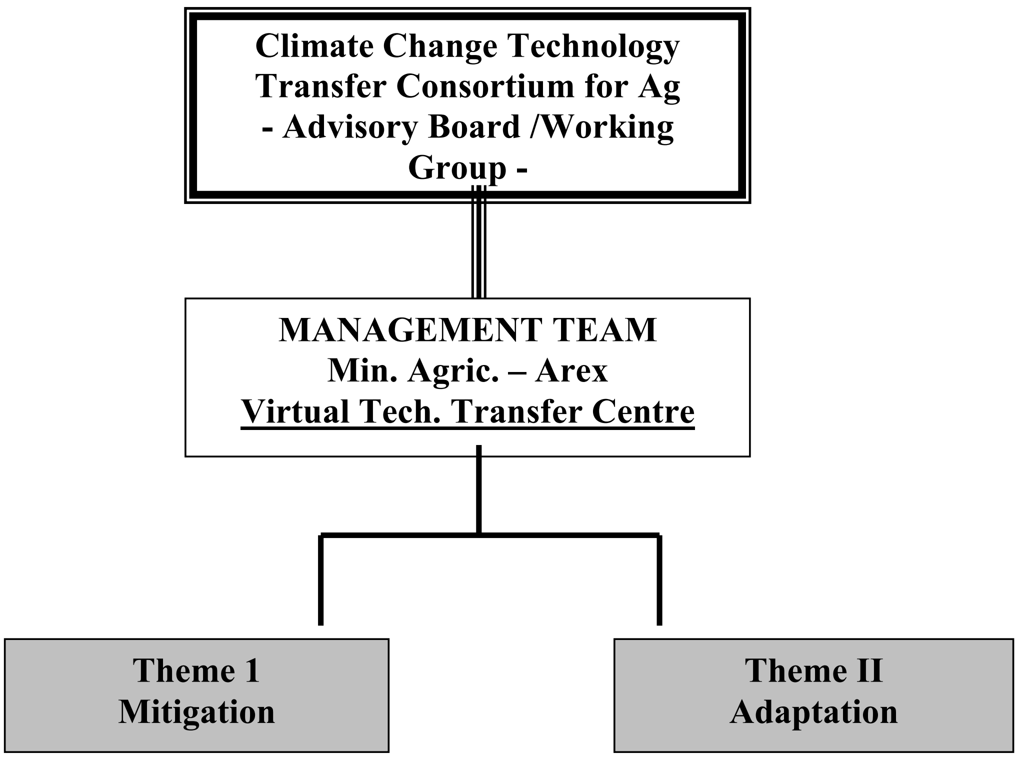
- Government Departments
- Ministry of Environment and Tourism

- Private Sector
- Non-Governmental Organizations
- National Research Centres
- International Research Centers in Zimbabwe
- Zimbabwe's Development Partners
- Ministry of Finance (Chair)

The terms of reference of the virtual center are as follows:

- Work with stakeholders
- Priority setting
- Develop baseline /benchmark information to monitor progress and impact
- Field testing and recommend technologies for adoption
- Information, Awareness and Advocacy
- Training

Figure 3 Proposed institutional arrangements for climate change technology transfer in agriculture



Monitoring and evaluation

The general objectives of monitoring and evaluation of the technology transfer process are:

1. To ensure that technology transfer proceeds as planned in pursuit of the defined objectives i.e. to ensure that resources are properly used.
2. To monitor the outcomes of technology transfer in reduction of community vulnerability to Climate Variability and Change

3. To detect changes in the situation that might call for an adjustment of objectives, plans or procedures during the implementation process

It is suggested that the logical framework be used for effective monitoring and evaluation of the technology transfer process. The logical Framework describes the desired impacts, outputs and activities with clear performance and verification indicators. A matrix clearly identifies what data is needed, the source of data, how often it will be collected, by whom it will be collected, what methods will be used in the collection and finally in which reports and forums the data will be presented. A matrix is critical for establishing clear roles and responsibilities of partners. It is builds upon information already discussed in the logical framework and developing assumptions by identifying relevant indicators and ensuring that the related data is collected, analysed and used.

6.2 Energy and Industry Sectors

Technology adoption decisions in the energy and industry sectors are based on individual priorities. Energy production and supply maybe in the national realm in terms of investment and regulation but energy end-use is centred on individual decisions. It is therefore apparent that programs to promote technology upgrading in the energy sector have to be structured so as to influence individual decisions. This implies a wide range of high cost activities which need careful consideration to promote success. Integration of technology transfer objectives into current policy objectives can help in minimising cost. The Environmental ACT is one policy vehicle that can be used to promote technology upgrading. It is however important that the ACT is analysed for opportunities where technology transfer can support the objectives of the legislation whilst instruments available to the ACT can be used to promote technology transfer. The types of technology that can be transferred range from local soft technologies that can be transferred between local organisations, local hardware, to imported hardware and soft technologies. In all cases the benefits of the technology need to be measured in terms local economic priorities, local environmental priorities as well as global environmental benefits.

The national energy mix is critical to energy security. Given the potential impacts of climate change on the energy sector it is important to build an energy supply system that has sufficient diversity to safeguard the economy against climate induced energy shortages. Out of the 1800MW of installed capacity in Zimbabwe, 750MW is hydro supplied by the Kariba Power Station. Electricity is also imported from Mozambique and Zambia both of which are hydro dependent. Efficiency improvement through technology upgrading would reduce the potential impact of failure of the regional hydro resources. If the potential impact of the hydro resources is estimated to within reasonable limits the required level of technology upgrading to minimize the impact of climate change on the economy can be defined. This would lead to the development of appropriate policy to guide the expansion of the energy supply system.

The productive sector is continuously being driven to produce for the export market. Issues of quality, quantity and environment are key to local industry meeting demands for export goods. In the centre of this criteria is the availability of appropriate technologies. The market for export goods and the local capacity to produce such goods are usually analysed separately. If the two parameters are analysed together there would be a clearer guide for industrial policy that would link up with other technology related policies as well as energy supply policies. A program to define the local technology market in relation to requirements for production could be established with the key Ministries being Ministry of Industry and International Trade, Ministry of Energy and Power Development and Ministry of Environment and Tourism. Such a program would link up with any climate related policies and benefit from UNFCCC mechanisms.

REFERENCES

1. **IPCC. 2001. – "Climate Change 2001: Impacts, Adaptation and Vulnerability", Cambridge University Press, UK.**

2. **Ndammba J., Sakupwanya J.S., Makadho J. and Mamike P. – "A Study to Determine Water Demand Management in Southern Africa – The Zimbabwe Experience", IWSD, IUCN, SIDA.**

3. **Nisson A., Hammer A. – "Study of Water Resources in Zimbabwe", SIDA, 1996.**

4. **Zimbabwe National Communication under the UNFCCC, 1998. Min. of Mines, Environment and Tourism.**

5. **Greenhouse Gas Abatement Costing Studies, Zimbabwe Country Study, Phase Two, Southern Centre and Riso.**

6. **Project Sunswitch, Solar Energy Society of Zimbabwe, 1992.**

7. **Donald R Wulfinghoff, 1999, Energy Efficiency Manual.**

Annex 1

CLIMATE CHANGE INCEPTION WORKSHOP FOR TECHNOLOGY TRANSFER NEEDS ASSESSMENT, NEW AMBASSADOR HOTEL, 23 APRIL 2004,

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TITLE	NAME	INSTITUTION
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Annex 2

CLIMATE CHANGE TECHNOLOGY TRANSFER NEEDS ASSESSMENT REPORT BACK WORKSHOP (4 – 5 August 2004, Caribbea Bay Hotel, Kariba)

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33**	Mr. M. Mangwende	Min of Finance
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