The Republic of Uganda

# MINISTRY OF WATER, LANDS AND ENVIRONMENT

## DEPARTMENT OF METEOROLOGY

# CONSULTANCY SERVICES FOR TECHNOLOGY NEEDS ASSESSMENT FOR MITIGATION OF GHG EMISSIONS IN UGANDA

## FINAL REPORT

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# PREFACE

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This document was produced as a result of collaborative effort from many stakeholders drawn from government ministries, Non- Government Organisations (NGO) and the private sector. Technology Consults Limited thanks the many stakeholders who have participated through workshops.

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| | |
|---|---|
| AHP | Analytic Hierarchy Process |
| BOOT | Build Own Operate and Transfer |
| CBA | Cost Benefit Analysis |
| CBD | Convention on Biodiversity |
| CCD | Convention on Control of Desertification |
| CDM | Clean Development Mechanism |
| CEA | Cost Effective Analysis |
| CHP | Combined Heat and Power |
| $CH_4$ | Methane |
| $CO_2$ | Carbon Dioxide |
| DA | Decision Analysis |
| EIA | Environmental Impact Assessment |
| GEF | Global Environment Facility |
| Gg | Giga grams |
| GDP | Gross Domestic Product |
| GHG | Greenhouse Gas |
| GWH | Giga watt Hour |
| HRSG | Heat Recovery Steam Generation |
| IPCC | Inter-governmental Panel on Climate Change |
| JEEP | Joint Energy and Environment Projects |
| MCA | Multi-Criteria Analysis |
| MDG | Millennium Development Goals |
| MEMD | Ministry of Energy and Mineral Development |
| MLA | Multilateral Agreements |
| MOWHC | Ministry of Works, Housing and Communications |
| MSW | Municipal Solid Waste |
| MWL&E | Ministry of Water, Lands and Environment |
| $N_2O$ | Nitrogen Oxide |
| NAADS | National Agricultural Advisory Services |
| NARO | National Agricultural Research Organisation |
| NDG | National Development Goals |
| NGO | Non-Governmental Organisation |
| NMVOC | Non-Methane Volatile Organic Compounds |
| $NO_X$ | Nitrous Oxides |
| OECD | Organisation of Economic Co-operation and Development |
| PEAP | Poverty Eradication Action Plan |
| PV C | Photovoltaic |
| R&D | Research and Development |
| RBA | Risk Benefits Analysis |
| SAR | Second Assessment Report |
| SHP | Small Hydro Power |
| $SO_2$ | Sulphur Dioxide |
| SWM | Solid Waste Management |
| TAR | Third Assessment Report |
| TNA | Technology Needs Assessment |
| UCODEA | Urban Community Development Association |
| UNDP | United Nations Development Programme |
| UNFCCC | United Nations Framework Convention on Climate Change |

# EXECUTIVE SUMMARY

## ES-1 Climate Change and its Impacts

It is widely accepted that the global climate system is changing as evidenced by the average rise in surface temperature, sea levels and ocean heat content. The Intergovernmental Panel on Climate Change has concluded that it is a result of greenhouse gases (GHG) which are emitted into the atmosphere due to various human activities. Global warming poses serious environmental problems with far reaching social and economic consequences.

Although all countries are vulnerable to many adverse effects of climate change, developing countries are more vulnerable to such impacts because of their low adaptive capacity. The least developing countries in general and Uganda in particular faces the following major adverse impacts of climate change:-

- Food insecurity arising from occurrences of floods and droughts
- Land degradation caused by heavy rainfalls
- Damage to communication infrastructure due to floods
- Damage to roads due to heavy rains
- Outbreak of respiratory diseases associated with droughts
- Outbreak of diseases such as malaria, dengue fever and water borne diseases (cholera and dysentery) due to floods.
- Low water levels affecting power generation and docking of boats at landing sites

Indeed, the last few decades have seen an increase in the frequency and intensity of extreme weather events like droughts and floods in Uganda. The El Niño of 1997/1998 is one such event (MWL&E, 2002) which inflicted heavy losses; bridges were swept, crops were destroyed and there was an outbreak of water borne diseases such as cholera and other flood related diseases.

## ES-2 International and Local Reaction to Climate Change

The international community decided that the risks of the adverse impacts of climate change were too big to be ignored. Hence the Second World Climate Conference requested the United Nations to take immediate action to protect the global climate system. In response to this request, the United Nations Framework Convention on Climate Change (UNFCCC) was set up in 1992. The ultimate objective of UNFCCC is to achieve stabilisation of greenhouse gases. Uganda signed the convention in 1992 and ratified it in 1993. The UNFCCC entails both obligations and privileges.

Uganda's commitment to UNFCCC is to assist in mitigating adverse effects of global warming. Towards this goal, Uganda has taken various steps. The country has highlighted a number of relevant policy guidelines and objectives related to climate and climate change in various policy documents which include: Population Policy, Health Policy, Disaster Management and Preparedness Policy, Forestry Policy, Environment Policy, National Water Policy, Energy Policy, Waste Management Policy and National Wetlands Policy.

In addition, climate change studies have been conducted including:

- Inventory of GHGs
- Vulnerability and Adaptation studies
- Policy implications of implementing the UNFCCC
- Clean Development Mechanism (CDM) studies

In 2002, Uganda prepared the country's Initial Communication to the UNFCCC. This document covered areas such as National Circumstances, National Inventory of Greenhouse Gases, Vulnerability and Adaptation, National Policies and Measures and Education, Training and Public Awareness.

## ES-3 Need for Technology Needs Assessment

The various measures identified by Uganda Government to mitigate climate change include technological measures, information provision, financing, conducive regulatory measures and culturally acceptable measures. It is noted that application of technology plays a major role in climate change mitigation. But the capacity of developing countries to adapt to these technologies is limited. Developing countries have expressed the wish to be helped by developed nations. The international bodies have responded by requesting developing countries to present their precise technology needs. Uganda has responded by contracting a consulting firm to carry out the technology needs assessment.
The assessment is essential because technology has many features which include:

- Broad based (therefore, it has to be selected, classified, elaborated and sourced)
- Mostly foreign based (hence, shall need to be transferred, sourced)
- Advanced/new (shall need training and adaptation
- Sector dependent barriers (needs focussing).
- High initial capital costs

These many attributes dictate that technology has to be assessed if it is to be used effectively. Technology Needs Assessment is defined as a process of identifying and evaluating technology options according to set criteria. Hence the need to conduct a Technology Needs Assessment (TNA ) study was justified.

## ES-4 Methodology of the Technology Needs Assessment

The methodology used in the TNA was generally guided by the UNDP/GEF Handbook *"Conducting Technology Needs Assessments for Climate Change"* by Gross, R., Dougherty, W., and Kumarsingh, K. (2004). The Ministry of Water, Lands and Environment delegated the Department of Meteorology to contract a consulting firm to carry out the technology needs assessment. The Department together with the consultants identified experts from selected sectors to form a group of stakeholders. The consultants drafted documents which were discussed by the Stakeholders either as a panel or in groups.

The Terms of Reference for the consultancy can be summarised into three major objectives:

(i) To identify and evaluate mitigation technologies that Uganda should implement

(ii) To identify barriers and corresponding steps to overcome them.
(iii) To develop actions plans for implementation of selected technologies.

Preliminary data and information was obtained from various documents in the literature on global warming. Data was compiled and collated into working papers. The consulting team discussed the papers and modified them. The documents were then passed through three consultative workshops where stakeholders from each sector discussed them and made pertinent proposals. A final report was then prepared. The findings are reported in this document.

The scope of the work covered six sectors recognized as contributing most to Uganda's GHG emissions. These are: Energy, Industry, Transport, Agriculture and Forestry, Housing and Solid Waste. These were also considered critical for the economy of Uganda. For each sector, the technology needs assessment was considered at two levels, i.e. at the institutional and at the macro levels.

## ES-5 Selection Criteria for Sectors and Technologies

Because of limited financial resources and data, it is difficult to mitigate climate change effects in all sectors at the same time. It is essential that some prioritisation be done. The assessment tool chosen was the Analytical Hierarchy Process (AHP). The ranking of sectors was based on their contribution to four factors: National Development Goals (as given in the Uganda's Poverty Eradication Action Plan), the United Nations' Millennium Development Goals, Commitments to Multilateral Agreements and consideration of Equity Issues.

The consultative process discussed various combinations of weights and developed the following weighting system, basing on 100%:-

- National development goals : 60%
- Commitment to multilateral agreements : 25%
- Millennium Development Goals : 10%
- Equity aspects : 5%

Based on this weighting set up, the sectors were ranked in the following decreasing order:-

1. Energy
2. Agriculture and Forestry
3. Industry
4. Transport
5. Solid Waste
6. Housing

The next step was the selection of the technologies in each sector. The criteria for selecting technologies were based on five factors: namely, economic development, contribution to climate change, social benefits, market potential and technological aspects. Under each factor, a number of indicators were proposed. For each indicator, a value between 0 and 5 was allocated; with the highest rank of 5 indicating positive effect on mitigation and the lowest rank of 0 representing detrimental effects.

## ES-6 Selected Mitigation Technologies

Using the selection criteria, the following mitigation technologies were identified and prioritised in decreasing order of priority for each sector.

### Table 1: Priority Technologies per Sector

| Sector | Mitigation Technologies |
|---|---|
| Energy Sector | Improved combustion technologies<br>Small scale hydropower<br>Solar thermal technologies<br>Solar PV system<br>Gasification<br>Cogeneration<br>Large hydropower<br>Geothermal power |
| Agriculture Subsector | Organic farming<br>Upland rice cultivation<br>Cogeneration<br>Biomass |
| Forestry Subsector | Afforestatioin<br>Forest Conservation |
| Industry Sector | Improved combustion technologies<br>Improved efficiency of machines<br>Eco-design<br>Energy conservation technologies<br>Waste heat technologies<br>Alternative fuel use<br>Material recycling technologies |
| Transport Sector | Improved infrastructure development<br>Alternative fuels<br>Improved vehicle efficiency |
| Solid Waste Sector | Composting<br>Recycling<br>Anaerobic landfill<br>Aerobic landfill<br>Minimising of waste production<br>Sanitary landfill<br>Sorting |
| Housing Sector | Unfired brick and tile technologies<br>Biogas technology<br>Improved combustion efficiency of household appliances<br>Solar energy<br>Efficient lighting improvements<br>Proper building design |

## ES-7 Barriers and Steps to Overcome Them

The application of the selected technologies is subject to various barriers. These barriers have been identified for the following technologies: Improved efficiency technology, Small scale hydropower, Solar thermal, Solar Photovoltaic ( PVC), Cogeneration, Large hydropower, Improved cement production, Organic farming, Improved Road infrastructure, Ethanol Production, Waste composting, Waste recycling, Stabilised blocks and improved cooking stoves.

The common and general barriers and the steps to address them include:

**Table 2: Common Barriers and Steps to overcome them**

| **Barriers** | **Action to overcome barriers** |
|---|---|
| Limited capacity | Train people locally and abroad |
| High investment | Secure grants or loans |
| Lack of incentives | Put in place fiscal incentives |
| Limited standardisation | Review standardisation |
| Lack of information | Inform. Educate and demonstrate |
| Inadequate policies, regulations | Review policies and regulations |

The technology specific barriers include the following:

**Table 3: Technology Based Specific Barriers and Steps to overcome them**

| | Technology | Barrier | Action to overcome barriers |
|---|---|---|---|
| 1 | Efficient Energy Technology | Inadequate National quality standards | Enact standards |
| | | Lack of Installation capacity | Train local personnel |
| | | Lack of credit/loans | Institute loans |
| | | High import prices | Wave taxes |
| | | | |
| 2 | Small Hydropower | Slow implementation of developments | Mount vigorous planning and implementation |
| | | | |
| 3 | Solar Water Heating | No data on solar heating requirements | Collect data under special study |
| | | Limited design expertise | Train locals |
| | | Fear of previous failure | Demonstrate some systems |
| | | | |
| 4 | Solar PVC | Lack of standards for practice | Institute standards |
| | | Inadequate local skills | Train locals |
| | | | |
| | | | |
| 5 | Large Hydropower | Institutional deficiencies | Assist institutions in planning |
| | | Pricing distortions | Normalise prices of power |
| | | | |
| 6 | Improved Cement Production | Slow penetration of technology transfer | Sensitise concerned factories |
| | | | |
| 7 | Organic Farming | Adoption constraints | Investigate and solve them |
| | | No enabling policies | Review policies |
| | | Limited capacity to reach rural areas | Mount seminars in various places |

| | | | |
|---|---|---|---|
| | | | |
| 8 | Biofuel Technology | Competition with other uses | Close other uses |
| | | No capacity to adopt present designs | Train people abroad |
| | | | |
| 9 | Waste Composting | Un-segregated waste at local levels | Sensitise people to sort out wastes |
| | | No comprehensive policy | Institute favourable policy |
| | | Low institutional co-ordination | Train the people |
| | | Inadequate private sector participation | Encourage them through fiscal incentives |
| | | Poor social acceptance | Sensitise the public |
| | | | |
| 10 | Waste Recycling | Bad social norms and aspirations | Sensitisation of public |
| | | Imperfect markets | Create favourable markets |
| | | | |
| 11 | Stabilised Blocks | Inadequate codes/standards | Enact appropriate codes and Standards |
| | | | |
| 12 | Improved Wood Stoves | Inadequate program implementation | Set up strong monitoring mechanisms |
| | | High costs for local people | Subsidise efficient stoves |
| | | | |
| 13 | Agroforestry | Inadequate enabling policies | Review policies |
| | | Poor domestic law prohibiting women to own land | Change this law |
| | | Inadequate group co-ordination | Provide incentives to co-ordinators |

## ES-8 Key Technologies

From the 35 identified technologies, 12 key technologies were selected as key technologies for Uganda. This was because of their immediate contribution to the economic development of the nation and resulting reductions in emissions. These technologies have to be productive, profitable, efficient and essential if they are to attract investment. They were selected to address problems of: power shortage, poor agricultural methods, limited building materials, high fuel imports, high wood consumption and high garbage accumulation.

The technologies to address the above specific national problems include:

| | | |
|---|---|---|
| Power shortage | - | Biogas, Solar energy and Small Hydropower |
| High Fuel Imports | - | Ethanol Production |
| Poor Agricultural Practices | - | Organic and Upland Rice Cultivation |
| Limited Building Materials | - | Stabilised Soil Blocks and Improved Cement production |
| High Wood Consumption | - | Improved Cook stoves |
| High Garbage Accumulation | - | Waste Composting and Waste Recycling |
| Deforestation | - | Afforestation technology |

## ES-9 Major Characteristics of the Key Technologies

There are a number of desirable characteristics which a mitigating technology should e xhibit and these include: accessibility, local sourcing, low cost, suitable capacity, possess detailed specifications, require minimal adoption, require minimal expert installation, possess operating and maintenance manuals and be insurable. But in practice it is difficult to find a single mitigation technology with all these attributes.

An outline of the major characteristics of the key technologies includes the following:

**Table 4: Major Characteristics of Key Technologies**

| No | Technology | Benefits | Investment | Source | Emission Reductions |
|---|---|---|---|---|---|
| | | | | | |
| 1 | Small Scale Hydropower | New supply<br>Serve rural areas | US $ 2000 per kW | Imported | Capacity of 70 Megawatt (MW) saves 391 Gigagrams (Gg) of Carbon dioxide ($CO_2$) |
| 2 | Biogas Technology | Alternate fuel<br>Double use | US $ 50 -500 | Local | Doubling present production to 176GHW saves 149 Gg $CO_2$ |
| 3 | Solar Energy | alternate fuel<br>better light | US$<br>200- 1000 | Imported | Displace 25,000 litres of kerosene saves 76 Gg of $CO_2$ |
| 4 | Improved Cement Production Technology | less fuel<br>less pollution<br>less power | US $ 10,000–50,000 | Imported | Biomass substituted for 25% fuel saves 295 Gg of $CO_2$ |
| 5 | Improved Road Infrastructure | less fuel<br>less pollution<br>easier access | US $ 10,000 per km | Local | Road rehabilitation saves 5 % of total emissions, 64 Gg of $CO_2$ |
| 6 | Ethanol Production | Less fuel imports<br>Creates Jobs<br>Less pollution | US $ 25m<br>For whole plant | Imported | Blend present petrol by 20% ethanol saves 22Gg of $CO_2$ |
| 7 | Stabilized Building Blocks | No wood used<br>Strong houses<br>Less skills | Low | Local | Remove fired kilns saves 22Gg of $CO_2$ |
| 8 | Improved Cook Stoves | Less fuel<br>Higher efficiency 25 to 35 % | US $ 6 -50 | Local | If 50% Households used improved stoves, saving is 32 Gg of $CO_2$ |
| 9 | Organic Farming | Soil conservation<br>Better yields | Low | Local | Displacement 20 % of fertilizes saves 165 tons of Nitrogen oxide ($N_2O$) |
| 10 | Upland Rice Cultivation | Water conservation<br>Less imports | Low | Local | If 50 % paddy rice land is removed, saving is 15 Gg of methane |

| | | | | | |
|---|---|---|---|---|---|
| | | Affordable by poor | | | |
| 11 | Waste Composting | less skills<br>creates manure | US $ 50 | Local | If 50% of present waste is composted. Saving is 22000 tons of methane |
| 12 | Waste Recycling | Lower costs<br>Decreases deforestation | US $50,000 to 1m | Local/Imported | If 10% wastes are recycled, saving is 44 tons of methane. |

## ES-10 Recommendations

The TNA carried out under this study has confirmed and identified specific barriers to deployment of technologies that will help mitigate GHG emissions in Uganda. Recommendations on policies, strategies and interventions to overcome or minimize these barriers include:-

i. Strengthening the relevant sector institutions. Within the Ministry of Water, Lands and Environment, the recently established National Steering Committee on Climate Change which is meant to handle matters on the Clean Development Mechanism needs to be strengthened to include issues of climate change.

ii. Formulating and harmonise the legal and regulatory framework to handle climate change and global warming issues needs and other related legislation and regulations.

iii. Providing financial and regulatory incentives so that investors, both individuals and the private sector, whose limited resources cannot meet the relatively high costs of technology transfer.

iv. Developing capacity building programs for: sensitisation of the public on many issues of climate change and technologies, development of local expertise in developing local mitigation technologies and training private sector institutions on the process of identification, sourcing and deployment of mitigation technologies.

v. Developing and enforce relevant standards and codes of the various technologies.

vi. Grouping the six national sectors that have been identified as: Group I: Energy, Industry, Transport and Agriculture and Group II: Solid Waste and Housing and initially treat Group I with a higher level of a priority as far as investments are concerned since this group has higher GHG emissions.

vii. Carrying out a detailed study of the costs/risks through Cost Benefits Analysis and Risk Based Analysis tools on the selected technologies identified in this study.

viii. Immediately implementing those mitigation technologies that can be sourced locally and do not need elaborate technology transfer mechanisms. Where additional development is essential, various sectors should take up the required development.

Making specific recommendations to the International Community, based on Article 4.5 of the UNFCCC which mandates Annex 1 parties and developed parties included in Annex II to take steps to assist parties, in particular developing countries, in the process of technology transfer include the following:

i. Creating or facilitating an enabling environment for favourable monetary transactions in forms such as bilateral and multilateral guarantees to overcome the major difficulties regarding financial transactions involved in the transfer of technology.

ii. Supporting continuously research, development and dissemination of technologies and the efforts towards the building of the local capacity to handle mitigation technologies.

To address the various gaps that are specific to the identified technologies, the recommendations include the following.

**Table 5: Technology Based Recommendations**

| Technology | Recommendations |
|---|---|
| Small and Mini Hydropower Technology | • Identify and attract private foreign direct investment<br>• Provide expertise for appropriate training leading to capacity building and development of pilot sites; |
| Solar Water Heating | • Help in exposing local engineering enterprise to modern production techniques and adopting backward integration of the technology for long-term sustenance of the local industry.<br>• Help in identifying international funding sources for production and use of solar energy. |
| Solar Photovoltaic Technologies | • Set up joint-venture initiatives to fabricate subsystems and components such as regulators and assemble PV modules.<br>• Promote cooperative programs between researchers in local universities, research institutions, public and private sector institutions.<br>• Provide access to facilities in advanced countries in order to help update and improve skills and consequently strengthen the local capacity.<br>• Assist Uganda to develop code of installation and practice as well as regulations for the local PV industry. |
| Improved Cook Stoves and kilns | • Provide funding to support construction and demonstration of the Retort stove for the public.<br>• Provide funding for the construction and demonstration of efficient kilns in rural areas. |
| Biofuel Production | • Provide support for public awareness in the production, use and the potential of biofuels.<br>• Provide funding for setting up initial infrastructure for ethanol production either through loan guarantees or insurance. |
| Waste Composting Technology | • Provide technology transfer in compost production (e.g. magnetic waste separators and short duration composting technology).<br>• Assist in capacity building in operation, management and maintenance of composting equipment. |
| Afforestation Technology | • Assist in promoting growth of trees in public areas such as along roads. |

# 1.0 INTRODUCTION

## *1.1 BACKGROUND INFORMATION*

### 1.1.1 Concept of Climate Change

That our atmosphere is changing is evidenced in one or more of the following ways:

- During the last century, the atmospheric concentration of greenhouse gases and their radioactive forcing have continued to rise as a result of human activities.
- Global average surface temperatures have increased by about 0.6°C.
- Global average sea level has risen and ocean heat content has increased.

It is also known that "the balance of evidence suggests a discernable human influence on global climate" (IPCC, SAR, 1995), and that "there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities" (IPCC, TAR, 2001). Hence, there is no doubt that $CO_2$ concentrations and global average temperatures will continue to rise.

It should be noted that developing countries are the most vulnerable to climate change. This is due to the following:

- **Impacts are worse** - already more flood and drought prone and a large share of the economy is in climate sensitive sectors.
- **Lower capacity to adapt** because of a lack of financial, institutional and technological capacity and access to knowledge.
- **Impacts disproportionately upon the poorest countries and the poorest people**, exacerbating inequities in health status and access to adequate food, clean water and other resources.

There is  need therefore to adapt to the climate change. Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation. Adaptation has the potential to reduce adverse effects of climate change and can produce ancillary benefits, but cannot prevent all damages. Greater and more rapid climate change would pose greater challenges for adaptation, but lower levels of future GHG concentrations will make the adaptation challenge easier.

### 1.1.2 Adverse Impacts of Climate Change

According to Bert *et al.* (2001), the climate change problem is global, long-term and involves complex interactions between climatic, environmental, economic, political, institutional, social and technological processes. Adverse effects of climate change are threatening to undo decades of development efforts. Least developed countries like Uganda are particularly vulnerable to climate change because of their low adaptive capacity. Impacts of adverse effects of climate change include:

- Food insecurity from frequent and intense occurrences of droughts and floods.
- Outbreak of diseases such as malaria, dengue fever, water borne diseases (e.g. cholera, dysentery) associated with floods and respiratory diseases associated with droughts.
- Reduction in agricultural production as a result of floods and droughts.
- Heavy rainfalls which can accelerate land degradation.
- Damage to communication infrastructure by floods.
- Heat waves in hot climates.
- Scarcity of water for both human consumption and production, particularly in drought prone areas.
- Increased ethnic conflicts due to scarcity of resources.

The last few decades have seen an increase in the frequency and intensity of extreme weather events like droughts and floods in Uganda. For example, the El Niño of 1997/1998 is one such event (MWL&E, 2002) which inflicted heavy losses; bridges were swept, crops were destroyed and there was an outbreak of water borne diseases such as cholera and other flood related diseases.

### 1.1.3 Mitigation Measures

The measures to reduce the sources of greenhouse gases or enhance their sink include:

(a) Advances in technologies:

- Minimisation of industrial by-product gases (e.g. $N_2O$ from adipic acid production and per-fluorocarbons from aluminium production).
- Efficient hybrid engine cars.
- Improved efficiencies of end use devices and energy conversion technologies.
- Shift to low-carbon and renewable biomass fuels (biomass from forestry and agricultural by-products, municipal and industrial waste to energy, dedicated biomass plantations, landfill methane, wind energy and hydropower).
- Zero-emission technologies.
- Improved energy management.
- Reduction of industrial by-product and process gas emissions.
- Pre- or post-combustion carbon removal and storage.

(b) In agriculture, methane ($CH_4$) and $N_2O$ emissions can be reduced, such as those from livestock enteric fermentation, rice paddies, nitrogen fertiliser use and animal wastes.

(c) Depending on application, emissions of fluorinated gases can be minimised through process changes, improved recovery, recycling and containment, or avoided through the use of alternative compounds and technologies.

(d) Changes in the market structure:

- Innovative financing and institutional reform and removing barriers to trade.
- Price rationalisation.
- Increased access to data and information.
- Availability of advanced technologies and financial resources.
- Training and capacity building.

(e) Changes in policy instruments:

- Emissions/carbon/energy taxes.
- Tradable or non-tradable permits.
- Provisions and/ or removal of subsidies.
- Deposit/refund systems.
- Technology or performance standards (e.g. energy efficiency standards).
- Energy mix requirements.
- Product bans.
- Voluntary agreements with industries.
- Government spending and investment.
- Support for research and development.
- Information campaigns.
- Environmental labelling.

### 1.1.4 Previous Work and Gaps

The United Nations Framework Convention on Climate Change (UNFCCC) was formulated in recognition of the adverse effects of global warming as a result of greenhouse gas (GHG) emissions. Uganda, having ratified the Convention, is obliged to fulfil her commitments under the Convention and also enjoy the privileges therein.

The country has already compiled its Initial National Communications under the Enabling Activities Phase I Project, as part of her commitments. Under the Enabling Activities Phase II Project being executed by the Ministry of Finance, Planning and Economic Development and implemented by the Department of Meteorology, Ministry of Water, Lands and Environment, Uganda wishes to assess its mitigation technology needs and also identify barriers to the transfer of such environmentally-friendly technologies into the country.

The existing gaps in knowledge include:

- Potential costs of both $CO_2$ non-energy mitigation options.
- Improved data resources for climate mitigation and capacity building in the area of integrated assessment.
- Characterising and measuring barriers that inhibit greenhouse gas reducing action.
- Improving analytical tools for evaluating ancillary benefits.
- Exploration of alternative development paths.

## 1.2 OBJECTIVES OF TECHNOLOGY NEEDS ASSESSMENT

The main objective of the consultancy in Technology Needs Assessment (TNA) was to review country-wide activities in all sectors in the economy and identify those activities whose implementation has an impact on climate change (through greenhouse gas emissions) leading to climate vulnerability. Line sectors under which these activities fall were identified and their status in the climate and developmental perspective assessed.

Current strategies, institutional arrangements and activities in place for addressing climate change were reviewed with a view to identifying gaps in development and climate response needs and technology requirements for mitigating the adverse effects of climate change.

Mechanisms and arrangements for addressing the gaps identified in terms of technology needs, technology information (appropriate mitigation technology and sources), enabling environment, mechanisms of selection and transfer of mitigation technologies and capacity building were proposed as key outputs from the assignment.

Challenges of implementation of up-date or adoption of mitigation technologies for example technology transfer barriers (financial, legal and capacity) were also addressed by the consultancy.

## 1.3 SCOPE

The study covered six sectors: Energy, Industry, Transport, Agriculture and Forestry, Housing and Solid Waste. These were selected after applying selection criteria for sectors. The level of analysis was limited to institutional and macro-economic aspects.

## 1.4 METHODOLOGY

The methodology used in the TNA was generally guided by the UNDP/GEF Handbook *"Conducting Technology Needs Assessments for Climate Change"* by Gross, R., Dougherty, W., and Kumarsingh, K. (2004). It involved:

(a) Identification of the Criteria for Technology Assessment:

- The objectives of the evaluation criteria were clearly stated in order to provide a means by which technologies and sectors may be evaluated.
- The process by which evaluation criteria were to be decided was elaborated.
- The steps were agreed with core stakeholders.

(b) Preparation of a Preliminary Overview of Options and Resources:

- Carrying out a review of mitigation studies from the Initial National Communication and national/sectoral development plans.

- Compiling of an overview of existing information and data sources.
- Identification of information and data gaps, the main sectors, the leading technology options and policies for each sector.
- Preparation of preliminary assessment report.

(c) Identification of Priority Sectors and Selection of Technologies:

- Identification of the sectors with potential to benefit from technology development and transfer and/or the need for further information and data.
- Identification of technology options and resources available and/or the need for further data.
- Evaluation needs to consider a broad range of options, but identify a smaller number of priority areas of implementation actions.
- A ranking matrix was used to ensure each technology was assessed against each criterion in a transparent way.
- Further ranking was used to identify two key technologies in each sector
- A preliminary report was produced that stated all of the technologies and sectors assessed, the criteria used for evaluation, the stakeholders involved and the priority sectors and technologies.

(d) Identification of Mitigation of Financing Implications and Opportunities:

- Identification of financing implications for each sector.
- Identification of financing opportunities for each sector.

(e) Identification of Barriers and Policy Needs:

- Identifying generic barriers to increased deployment of new technologies by sector, and included categories, e.g. policy, market structure and market.
- Identification of specific barriers to priority sectors.
- Identification of ‘barrier busting’ policy measures.
- Revisiting priority sectors in light of the barrier assessment.

(f) Definition and Selection of Actions:

- Producing an action plan that takes account of the following;
- Objectives of technology needs assessment in the context of national development priorities.
- Identification of priority sectors, technologies for initial action and leading technology options.
- Capacity building measures.
- Barrier busting measures.
- Direct interventions.
- Securing funding.

(g) Preparation of a Synthesis Report

The report included:

- A preliminary summary of climate change technologies, broken down by sector where appropriate.
- An evaluation of sectoral needs and opportunities.
- A statement of information and data gaps.
- Statement of criteria and process for technology evaluation.
- An overview of the assessment of technologies according to the agreed priorities.
- List of priority sectors and key technologies for preliminary action.
- A review of key barriers and steps to overcome them, with reference to existing plans and programmes.
- A technology transfer action plan with activities, actors and milestones.
- A list of stakeholders and programme for continued engagement.

## *1.5 STATUS OF THE SECTORS*

This section examines the present status of the selected sectors as they relate to the national development goals and the concept of climate change. Technologies which cause greenhouse gas emissions are highlighted. Six sectors are presented below, namely:–

1. Energy
2. Agriculture and forestry
3. Housing
4. Industry
5. Transport
6. Solid waste.

### 1.5.1 Energy Sector

**Background**

The Energy Supply Sector includes industries involved in the extraction of primary energy, those that transform energy supplies from primary fuels into secondary fuels, and those that are involved in transporting energy.

Uganda's economy depends mainly on two traditional sources of energy: hydropower and woodfuel and imported petroleum products. There is neither indigenous nor imported coal used in the country. There are substantial quantities of peat in the central areas of Uganda, especially around Lake Kyoga. Future exploitation of this energy resource may be limited by the need to preserve the diminishing wetlands (Turyahikayo *et al*, 1996). The Energy Sector falls under the Ministry of Energy and Mineral Development (MEMD) and comprises of the following supply sub-sectors:

(i) Power
(ii) Petroleum
(iii) New and Renewable Sources of Energy; and
(iv) Atomic Energy.

Uganda's economy is based mainly on agriculture. At just about 4%, the level of electrification is extremely low, providing approximately 2% of the total energy. The major part of the country's energy consumption is the household sector. About 94% of the household energy consumption is derived from firewood with the rest of the household energy being from agricultural residues and kerosene (MEMD, 2002; Gombert, 2003). Energy consumption based mainly on biomass is responsible for the current high level of deforestation and greenhouse gases (GHGs). Over the last four decades the potential fuel wood resources in Uganda have significantly reduced. Heavy reliance on fuel wood and the attendant deforestation have been linked to the global increase in atmospheric carbon dioxide as well as the increased respiratory health complications observed in the country today. The increasing human demand for land and forest resources make the regeneration of biomass almost impossible and any afforestation effort very difficult.

There are now serious questions as to how long dependence on biomass energy sources can continue as the population grows, deforestation continues, GHGs increase and development remains the national goal. Uganda, however, is endowed with some other alternative sources of energy, mainly hydro, solar, wind, biogas and geothermal power, whose use would lower deforestation rate and emission of carbon dioxide into the atmosphere.

Uganda has achieved strong economic growth averaging about 6% per annum as well as macro-economic stability over the last decade, owing largely to the implementation of an ambitious programme of macro-economic adjustment and structural reforms. However, this performance can only be sustained by increased investments and creation of employment opportunities which, in turn, can only be realised with adequate supplies of energy.

Meeting the energy demands of a growing economy on a sustainable and efficient basis and improving the living standards of the population is a major concern to policy makers and researchers. The electrification of rural areas remote from the grid, where most of the population lives, should be the priority. A major problem, therefore, is to screen, select, adapt and manage emerging energy technologies for the country. Scenarios for future energy development should include, supply, demand, resources, cost-efficiency, capital constraints and environmental aspects on equal footing.

**Emission Sources**

These include the following:

- $CO_2$ from combustion processes for power and heat generation, *e.g.* burning of furnace oil and other fossil fuels, burning of firewood and other biomass and operating diesel engines.
- $N_2O$ from combustion and power generation processes.

- $CH_4$ from landfills and biogas plants.

### 1.5.2 Industry Sector

**Background**

The Uganda Industrial sector Sector (UIS) is composed of both large and small scale industries. The goal of every industry is to continually improve business and realise growth. Industries are struggling to increase their efficiencies, improve on the quality of their products, and to properly manage their production processes.

UIS grew from 8.1% in 2003/2004 to 9.1% in 2004/2005. The main types of industries processes/activities found in Uganda are:

- Iron and steel production.
- Chemicals manufacture.
- Food (e.g., fish, sugar, edible oil, coffee, tea) processing.
- Pulp and paper manufacture.
- Cement and lime production.
- Ferrous metal processing.
- Non-ferrous metal processing.
- Tanning of hides and skins.
- Textile processing (e.g., cotton ginning).
- Tobacco processing.
- Beverages (e.g., soft drinks, beer) production.
- Grain milling processes.
- Construction materials (*e.g.*, sheets, tiles, bricks) production.

**Emission Sources**

- $CO_2$ from combustion processes, *e.g.*, burning firewood and furnace oil (for heat and steam production) and operating diesel engines.
- $N_2O$ from combustion and industrial processes.
- $CH_4$ from industrial processes.

Although there is limited data available about emissions from individual industries, there seems to be a lot of potential for emission reduction, particularly as a result of fuel switching (low or no carbon energy sources) and efficiency improvements.

### 1.5.3 Transport Sector

**Background**

Transport plays a major role in economic activities. This sector aids and facilitates growth and development in all other sectors of the economy. Effective transport provides support to increased agricultural, industrial, trade and tourism, social and administrative services and ultimately promotes growth and economic integration of the country.

The availability of an adequate transport infrastructure is a prerequisite for poverty alleviation, attraction of private investors and facilitation of regional economic integration and international trade.

In Uganda, rural feeder roads are the principal means of vehicular access to rural areas where the majority of the country's poorer population live. Urban roads are very necessary for a drive to industrialisation. They promote industrial development, trade and commerce. It is important that access to rural areas and economically-productive areas be improved.

Transport sector issues in Uganda span a number of ministries and institutions. The Ministry of Works, Housing and Communication (MOWHC) is the key Ministry responsible for the general policy framework for the transport sector in Uganda. The Ministry of Energy and Mineral Development is responsible for energy provision and utilisation policy, while the Ministry of Finance, Planning and Economic Development is responsible for the taxation policy aspects of the sector.

Road, rail, marine and air constitute the principal modes of transport in Uganda. The railway network is very poor and inadequate. Uganda therefore relies on road transport for both goods and people. Mini-buses and taxicabs dominate passenger transport while pick-ups and lorries dominate freight transport. Buses are more prominent on long distance routes for upcountry destinations. The transport sector is the leading consumer of petroleum products.

The transport sector is one of the leading contributors to the tax revenue in Uganda. Freight and insurance costs amount to about 40 percent of CIF (cost, insurance and freight) landed cost thereby highlighting the need for cheaper transportation modes such as pipelines and rail ferry wagons.

Most of the imported vehicles are used or reconditioned. The main source of the vehicles is Japan and via the Middle East. There has been a remarkable increase in the number of vehicles over the last decade.

**Energy Use in Transport Sector**

Road transport will continue to be the dominant mode of the transport for both passenger and freight. The minibus is the main means of transport in urban areas and towns, which are less than 200 km from the capital city (Kampala). It is estimated that 60% of all the vehicle fleet operates within Kampala.

Buses are the most popular means of transport for long distance travel. The numbers of buses have been increasing at a rate of 10 per cent per annum over the last decade. There are no buses used in town services. The town services are monopolised by minibuses. Buses contribute less than 15 % of total number of passengers. The competition for passengers is too stiff for the would-be bus operators. Heavy commercial vehicles and pick-ups are the categories of vehicle used in freight transport. The use of locomotives is very limited.

The Uganda Railways Corporation, a Government parastatal body under the Ministry of Works, Transport and Housing, is responsible for operating and managing of railway and marine services in Uganda. It has a railway line system of 1300 km, out of which only 290 km are operational.

There are 997 km of railway lines that were suspended either for being uneconomical or insecure. The Ugandan Railways comprises of 1,250 km of track. Less than 10 per cent of the domestic and less than 30 per cent of external trade freight is carried by rail. The rail services largely depend on the capacity and volume of imports and exports. The active marine service covers 1673 km, linking the ports in Kenya and Tanzania

Air transport and support services have not expanded significantly. The growth rate is about 1% per annum. Currently, over 14 scheduled and unscheduled international airlines operate in Uganda. The only state-owned commercial air transport company, the Uganda Airlines Corporation, was liquidated.

**Ethanol**

Ethanol is produced from sugarcane. Uganda has three major sugar estates and a number of sugarcane out-grower plantations located across the country. With a total planted area estimated at over 27,000 hectares, and a total crushing capacity of the three factories estimated at over 7,000 tons of cane per day, over 133,000 tons of molasses can be produced annually. There is considerable potential therefore for producing ethanol, which can be blended with petrol to produce gasohol. A considerable investment is however required to develop this source of energy.

**Emission Sources**

Combustion of fuel in reciprocating internal combustion engines, which comprise of spark-ignition (petrol/gasoline) and compression-ignition (diesel) engines. These emit greenhouse gases, mainly $CO_2$.

### 1.5.4 Agriculture and Forestry Sector

**Background**

Uganda is one of the poorest countries in the world, with a per capita income of about US$ 250 per year. Its economy is largely natural resource based, with over 80% of the population living in rural areas and engaged on agro-pastoralism for food and income. With a gross Domestic Product (GDP) growth rate of about 6% and a population growth rate of 3.2%, natural resource exploitation will continue to form the basis for livelihoods of the majority people in the foreseeable future. The land under crops in Uganda is being cultivated primarily by small-scale farmers with an average farm size of 2.5 ha. For the pastoral communities, the main natural resources are grasslands and drylands.

Lying astride the Equator and at an average height of more than 1000 metres above sea level, Uganda enjoys a comparatively rich endowment of natural resources in the form of soils, water resources, and biodiversity. These form the basis of the national economy. Thus the national economy relies on agriculture, which contributes about 42% of GDP, over 90% of export earnings and employs about 81% of the labour force. Agricultural performance, however, fluctuates widely due to changes in weather conditions. In addition, it is adversely affected by the rudimentary means of production and poor market and storage infrastructure.

Uganda's agriculture is characterised by low rate of land use and poor crop husbandry, very low yields and high crop losses. There is also high dependence on rudimentary technology, particularly the hand hoe. Other key inputs such as improved seed varieties, pesticides and fertilisers are rarely used.

Land use in Uganda can be characterised as dependent heavily on traditional practices and the dictates of poverty. Such practices have over the years given rise to soil degradation in many parts of the country, particularly the highland areas. In areas where cattle keeping is common, overgrazing is leaving the soil bare. Yet, among most people in these areas, the number of cattle or the size of the herd continues to symbolise economic wealth and social status. Thus overstocking has caused a decline in the quality of rangelands.

**Forestry Sector**

Forests, trees and woodlands are important resources and play multiple ecological, economic, social and cultural roles. Uganda's forests are classified as savannah woodland (80%), tropical high/mountain forest (19%) and plantation forest (1%).

Regarding forests, uncontrolled harvesting of timber negatively impacted on the natural forest. The deforestation problem has been accentuated by overwhelming dependence of the population on fuelwood as the source of energy for cooking.

The importance of forestry in Uganda is wide. At both household and industrial level products and services in form of firewood (for domestic use, lime and brick making, tea and tobacco curing, fish smoking, brewing), timber and poles (creating employment in pit sawing and income from sales, construction, carpentry, boat-building), and non-timber products (charcoal, honey, craft materials, fruit, mushrooms, bark cloth) are common. Environmental benefits of forests are strongly felt (soil fertility, shade, windbreaks, micro-climate and rain). Forest reserves are also seen to be the source of other products.

**Agricultural Sector**

Crop production dominates Uganda's agricultural activities. Almost 70% of farm holdings are engaged in crop production as a principal activity and about 25% are in mixed farming. Ugandan farmers grow both food and what are considered traditional cash crops. The main food crops include: cereals (maize, millet and sorghum); legumes (beans, field peas, cow peas and pigeon peas); oilseeds (simsim, groundnuts and soya); and root crops (sweet and Irish potatoes, cassava and yams).

As stated earlier, a sizeable proportion of the population of Uganda derives their livelihood from pastoral agriculture. Uganda's rangelands are principally characterised as dryland, which are generally defined in climatic terms as lands with limited rainfall. They are characterised by low (100 – 600 mm annually), erratic and highly inconsistent rainfall levels (IFAD 2000), or simply, "anywhere that rainfall is a problem because of amount, distribution and unreliability".

**Drylands**

Uganda's drylands occupy what is commonly referred to as the "cattle corridor", an area stretching from the north-east, through central to south-east of the country. It covers many districts stretching from Kotido, Moroto and Katakwi in the northeast through Nakasongola and parts of Luwero in the central to Rakai, Mbarara and Ntungamo. These areas are mainly rangelands and they cover approximately 84,000 sq. km. (about 40%) of the total land area. In these areas, semi-arid and dry sub-humid conditions prevail. They receive low and unreliable rainfall (450 - 800 mm) and drought is a common recurrent phenomenon, thus the vegetation is sparse. The drylands are considered to be the second most fragile ecosystem in Uganda, after the highlands.

The land tenure of most of the drylands or rangelands is communal, with grazing mainly on natural pasture. However, major socio-economic changes are occurring in the drylands and these have affected this ecosystem, for instance, increasing human population density and immigration by agricultural settlers. The increase in both human and livestock populations in Uganda's drylands over the years is placing pressure on the land with intensive degradation occurring, especially at watering points, along livestock paths and on hilltops. Most of the drylands in Uganda face a lot of environmental problems.

**GHG Emissions from Agriculture**

Agriculture is the biggest contributor to all GHG emissions other than $CO_2$. In the Initial Communications, Uganda used Organisation of Economic Co-operation and Development (OECD) emission coefficients and a large variation was reported in the agricultural sector. Emissions were linked to agricultural cultivation and livestock grazing. Some of the gases and activities that contribute to GHGs from the agricultural sector include - $CH_4$ from Enteric Fermentation (digestive) of livestock; manure; agrochemicals; $CH_4$ from rice cultivation and $N_2O$ from disturbance of agricultural soils.

**Enteric Fermentation of Livestock**

Emissions are in the form of $CH_4$ emitted from normal digestive processes, mostly, of ruminant animals such as cattle and sheep, and some non-ruminants such as pigs. The main factors influencing emissions are; type of digestive system, age, weight, quality and quantity of feed intake.

**Manure from livestock**

Emissions are in form of $CH_4$ from anaerobic decomposition of organic matter, mostly slurry/liquid manure which depends on the manure management system, the temperature and quality of manure produced. It should be noted that there is limited organised use of manure in Uganda.

**Agrochemicals**

Another source of GHG emissions is agrochemicals. To date, Uganda's agriculture is generally low-input low-yield technology. Nonetheless, as Ugandans move towards modern agriculture and the growing of high value crops, the use of agrochemicals is expected to increase. According to Facron (1990), during the period 1971 to 1975, on average, Ugandans used about 1,600 metric tonnes of fungicides, herbicides and insecticides per year. Also, close to 12,000 metric tonnes per year of fertilisers (ammonium sulphate, urea, nitrogenous fertilisers and potassium fertilisers) were also used over the same period. As agriculture modernises, these quantities of agrochemical inputs are likely to be exceeded as has been illustrated in floriculture.

**Flooded Rice Fields**

Decomposition of organic material in flooded fields produces $CH_4$ which escapes to the atmosphere primarily by diffusive transport through the plants. The rates of emissions are highly variable, both spatially and temporally-depending on water management, soil temperature, soil type and cultivation practices. Cultivation of flooded rice is limited in Uganda. Current efforts are targeting cultivation of dry (upland) rice in which the fields are seldom flooded.

**Emissions from Agricultural Soils**

Agricultural soils may emit or sequester $N_2O$, $CO_2$ and $CH_4$ in varying amounts depending on natural and management processes. Currently the IPCC methodology currently includes only $N_2O$. Very small amounts were reported in the First National Communication.

### 1.5.5 Housing Sector

**Background**

Housing plays a vital role in the development of a country and is one of the important sectors driving the development of Uganda**.** The housing problem in Uganda is both in quality and quantity but varies from location to location depending on the social, economic and geographical situation. The problem in urban areas is one of quantity while in rural areas it is that of quality. The government has responded by putting in the place a housing policy and a shelter strategy. The overall effect was to provide an enabling environment for various participants.

Shelters contribute the major part of the built environments well as a source of domestic effluence and wastes which are discharged into the atmosphere. Some appliances also induce pollutants into the house. There are regulations to protect the lives of people from such pollutants. As of GHG emissions, there has been no policy in the housing sector.

The bulk of the growth in the past two decades was in developing countries. Buildings account for 29% of global $CO_2$ emissions. Space heating is the dominant energy end-use. While developed countries account for the vast majority of building-related emissions, the bulk of the growth in the past two decades was in developing countries.

In Uganda, building related emissions account for 10% of the total emission and assess mitigation technologies in this sector.

**Emission Sources/Activities**

The Building Sector contributes to GHG emissions in two ways. The first way is through building equipment: heat pumps, air conditioners, refrigerators, lights, cook stoves and other household appliances. This equipment uses energy, which is produced by emitting GHG gases. The second method is through processing of building materials, such as: bricks, cement and tiles. The production of each of these materials requires energy production.

The activities in the Housing Sector which contribute to climate change are:

- Burning bricks (firewood)
- Drying tiles (firewood, fuel)
- Space heating/cooling
- Home appliances

### 1.5.6 Solid Waste Sector

**Background**

Solid Waste is one of the sectors that contribute to climate change through burning of organic solid wastes, which produces carbon dioxide, anaerobic decomposition in a landfill, which produces methane, and incineration, which produces carbon dioxide.

Solid Waste Management (SWM) is a challenge to municipalities in developing countries, which spend close to 20-50 percent of their recurrent budget on solid waste management. Yet, it is also common that 30-60 percent of all the urban solid waste in developing countries is uncollected and less than 50 percent of the population is served. In some cases, as much as 80 percent of the collection and transport equipment is out of service, in need of repair or maintenance. This results into open dumping and burning which is a common practice in most developing countries.

Organic waste is a major component of municipal solid waste. Organic waste is biodegradable and can be processed in the presence of oxygen by composting or in the absence of oxygen using anaerobic digestion. Both methods produce a soil conditioner, which when prepared correctly can also be used as a valuable source of nutrients in urban agriculture. Anaerobic digestion also produces methane gas an important source of bio-energy, which should be collected and used to minimise its impact as a greenhouse gas.

**Emission Sources**

Solid waste emission sources include – open burning of organic solid wastes, which produces carbon dioxide; anaerobic decomposition in a landfill, which produces methane; and incineration, which produces carbon dioxide.

In order to minimise the impact of solid waste on climate change, solid waste mitigation technologies should address among others, the following:

- Collection and Transportation
- Recycling and Composting
- Treatment and Disposal

The main objective of solid waste technologies should be to oversee solid waste management in a corporate framework to achieve synergy, low unit costs, optimal utilisation of resources and environmental protection.

Critical performance areas in solid waste management include:

- Establishing solid waste profiles to consolidate data on waste types, quantities, handling costs and revenue
- Evaluating alternative solid waste technologies for least unit cost operation and high resource conversion
- Separation of solid waste at the point of generation
- Recycling of solid waste
- Disposal using appropriate technologies

## 1.6 GREENHOUSE GASES

### 1.6.1 Types of Greenhouse gases

Global warming is a result of greenhouse gases (GHG) which are emitted into the atmosphere due to various human activities. The GHG database contains estimates for:-

Main greenhouse gases,

- Carbon dioxide ($CO_2$),
- methane ($CH_4$),
- nitrous oxide ($N_2O$),
- perfluorocarbons (PFCs),
- hydrofluorocarbons (HFCs)
- Sulphur hexafluoride ($SF_6$) and;

Indirect greenhouse gases and other pollutants are:

- Carbon monoxide (CO),
- Nitrogen oxides ($NO_X$),
- Non-methane volatile organic compounds (NMVOCs)
- Sulphur oxides ($SO_X$).

### 1.6.2 GHG Inventory for Uganda

Uganda conducted GHG inventory in 1996 for various sectors such as: Energy, Industry, Agriculture, Transport, Solid Wastes and Housing sectors. The total emissions from each sector were estimated are given in Table 6 below.

**Table 6: Inventory of Greenhouse Gases in Uganda (1996)**

| | SECTOR | CARBONDIOXIDE Gg | METHANE Gg |
|---|---|---|---|
| | | | |
| 1 | Transport | 507 | - |
| 2 | Energy | 197 | 74 |
| 3 | Industry | 43.5 | - |
| 4 | Forestry | 9.4 | 5.67 |
| 5 | Agriculture | - | 227 |
| 6 | Waste | - | 2.92 |
| | | | |
| | TOTAL | 756.9 | 309.59 |

# 2.0 SELECTION OF PRIORITY SECTORS AND TECHNOLOGIES

## 2.1 INTRODUCTION

There are many mitigation technologies on the market; some are advanced while others are undeveloped. Furthermore, Uganda is handling its sustainable development goals under many sectors. With limited resources, it is important that mitigation measures start with priority sectors and priority technologies. This shall be possible if the priority items are selected from the broad range. Hence the objective of selection criteria is to develop guidelines which shall enable ranking of both sectors and technologies.

A number of assessment tools/techniques that can be used in TNA include:

1. Analytic Hierarchy Process (AHP)
2. Cost Benefit Analysis (CBA)
3. Cost Effective Analysis (CEA)
4. Decision Analysis (DA)
5. Risk Benefits Analysis (RBA)

The characteristics of each technique are given below:

AHP - This tool sets up criteria, puts weights on indicators of each criteria and values technology based on a single rule.

CBA - Estimates costs and benefits of each technology. The best is the technology with the highest net benefits. But quantifying all applicable costs and benefits is difficult.

CEA - Minimises cost to achieve desired performances under specific performance goals. This technique requires specification of performance goals for each technology.

DA - It identifies best choice from a range of alternatives. The tool involves development of explicit influence structures, possible outcomes and outcome values. But it has two major limitations: the difficult in determining all possible outcomes and bias due to assigning probabilities to individual outcomes.

RBA - This tool regards outcome values derived from identified risks as uncertain variables. Probabilities are needed to assign different scenarios of technology transfer. But estimation of these probabilities is difficult.

The above limitations of other techniques were used to select the AHP technique. Sometimes this technique is called Multi Criteria Analysis (MCA). It is suitable for preliminary assessments for it can be used by many stakeholders and experts.

The criteria were developed at three levels: factor level, sub-factor (indicators) level and weighting of each indicator level. Points between 0 and 5 were awarded and a total obtained. Sectors and technologies which have high values are put on the priority list.

## *2.2 SELECTION CRITERIA FOR SECTORS*

### 2.2.1 Background

To effectively implement its development objectives, Uganda Government has separated its activities into various sectors – such as Energy, Industry, Transport, Agriculture and Forestry, Housing, Tourism, Water, Solid Waste, etc. Each of these sectors contributes to the global warming but in different degrees. Because of limited financial resources and data, it is difficult to mitigate climate change effects in all sectors at the same time. It is essential that some selection be done. This section develops guidelines in form of sector selection criteria.

### 2.2.2 Selection Factors and Indicators

The selection of sectors was mainly based on their contribution to national development goals as given in the Poverty Eradication Action Plan (PEAP) document. However, there are three other considerations which are important. These are; Millennium Development Goals, Multilateral Agreements and Equity issues. The indicators for each factor are stated below:

**National Development Goals (PEAP):**

The elements under this category are:

1. Economic management
2. Enhanced production, competitiveness and incomes
3. Security, conflict resolution, and disaster management
4. Good governance
5. Human development

These five elements are taken from the PEAP document. Most of the sectors are covered under Enhanced Production, Competitiveness and Incomes.

**Commitment to Multilateral Agreements:**

There are many indicators in this category but three indicators, which contribute to environmental sustainability, are stated below:

1. Convention on Control of Desertification (CCD)
2. United Nations Framework Convention on Climate Change (UNFCCC)
3. Convention on Biodivesity (CBD)

**Millennium Development Goals:**

Indicators in this category include:

1. Eradication of extreme poverty and hunger
2. Achievement of universal primary education

3. Promotion of gender equality and empowerment of women
4. Reduced child mortality
5. Improved maternal health
6. Combating HIV/AIDS, malaria and other diseases
7. Ensuring environmental sustainability
8. Development of a global partnership for development.

**Equity Aspects**

The indicators under this group are:

1. Concern for Vulnerable persons
2. Concern for gender related issues
3. Equal access for both rural and urban people.

### 2.2.3 Ranking of Sectors

The AHP technique requires that weights be assigned to each indicator mentioned above. But this was found difficult because it was not possible to fix proper contribution of sectors to the specific indicator. Hence, ranking of sectors was based on the aggregates of the major factors.

The consultative process discussed various combinations of weights but it was decided that National Development Goals should take up more than 50%. The following weighting was therefore developed, based on a total of 100%:

| | | |
|---|---|---|
| National Development Goals (NDG) | : | 60% |
| Commitment to Multilateral Agreements (MLA) | : | 25% |
| Millennium Development Goals (MDG) | : | 10% |
| Equity Aspects | : | 5% |

These values are averages of individual proposals after screening out those values which were far out of the range.

### 2.2.4 Sector Ranking Matrix

The consideration here was based on comparing the contribution of each sector to each of the four main factors (NDG, MLA, MDG and Equity). That contribution was assigned bearing in mind the maximum points of that factor. For example, while considering NDG, the maximum points any sector would be awarded was 60. This evaluation exercise resulted in Table 2.

**Table 7: Ranking Matrix for Sectors**

| SECTOR | NDG | MLA | MDG | EQUITY | TOTAL |
|---|---|---|---|---|---|
| | 60 | 25 | 10 | 5 | 100 |
| Energy | 50 | 20 | 8 | 2 | 80 |
| Industry | 50 | 10 | 8 | 2 | 70 |
| Transport | 40 | 5 | 5 | 1 | 51 |
| Agriculture | 50 | 10 | 9 | 4 | 73 |
| Housing | 20 | 5 | 3 | 2 | 30 |
| Solid Waste | 30 | 15 | 3 | 1 | 49 |

The above matrix was used to rank the six sectors by considering each column. The averages of participants were recorded as follows:

1. Energy : 80%
2. Agriculture : 73%
3. Industry : 70%
4. Transport : 51%
5. Solid Waste : 49%
6. Housing : 30%

Subsequent work reflected this scenario.

## 2.3 SELECTION CRITERIA FOR TECHNOLOGIES

### 2.3.1 Background

Uganda like most of the least developed countries is characterised by low level of technology development. However there are various technologies available in the developed and some developing countries which can be transferred to Uganda that can facilitate mitigation options for greenhouse gases. The priority sectors have been identified. These technologies need to be evaluated based on national criteria. Furthermore, the technology transferred needs to be well managed for national benefit.

The process of transfer and adaptation of these technologies must be cost effective at the same time it should address Uganda sustainable development needs. According to Bruntland (1997), sustainable development is defined as “development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs”. Uganda’s sustainable development criterion is based on environmental, social, economic and technology transfer issues. The Poverty Eradication Action Plan forms the basis of sustainable development criteria. Any form of technology transfer should not only address the GHGs mitigation but should also contribute to the sustainable development criteria.

### 2.3.2 The Objective of Selection Criteria

Mitigation technologies have many features such as:

- Broad based (need classification, elaboration, selection and sourcing)
- New and/or advanced (require training and adoption)
- Majority foreign based (need technology transfer, financing and sourcing)
- Subject to implementation barriers.

These many features make it necessary that guidelines for selecting technologies be developed. The main objective of developing selection criteria is to establish the most appropriate method which can be used as a tool for choosing and prioritising mitigation technologies.

### 2.3.3 Selection Factors and Indicators for Technologies

There are various new technologies that can be sourced and applied in each of the six priority sectors under study. Generally, the criteria for selection of mitigation technologies and priority sectors for Technology Needs Assessment will be based on six main factors according to their contribution to mitigation of emissions. These are: economic development, climate change mitigation, environmental sustainability, social benefit, technological benefits and marketability.

**Economic Development:**

Technology transfer should be in line with the national development goals. It will be in national interest if the technology will improve on the economic development of the country. The indicators are:

- Job creation
- Improved livelihood of the poor (increased income)
- Sustainable use of natural resources.
- Increased production of marketable goods and services
- Improved infrastructure development
- Improvement in land usage (agriculture and forestry technology)

**Climate Change Mitigation:**

The technologies under consideration should not have adverse effects on the climate. The indicators are:

- Enhancement of $CO_2$ sink (Afforestation and reforestation technologies)
- Reduction in GHG emissions
- No GHG emissions

- No leakage
- Improvement of waste management practice

**Environmental Sustainability:**

The indicators for this factor are:

- use of minimum resources
- less air pollution
- less water contamination
- less land degradation

**Social Benefits:**

The indicators are:

- Social acceptability to the local community.
- Improvement/attraction of social services to community
- Improvement of food security.
- Development of social infrastructure (health centres, schools)
- Promotion of Gender equity

**Technological Benefits:**

The indicators are:

- Capacity of the local community to absorb and manage the technology.
- Replicability
- Possibility of expansion
- Human and Institutional capacity development (skills, regulations. Laws. policy)
- Promotion of cleaner production practice, e.g., waste recovery.
- Reliability
- Promotion of energy efficiency
- Potential for innovation
- Occupational health and safety to users

**Marketability:**

The indicators are:

- Cost effectiveness relative to other technologies
- Commercial availability
- Accessibility
- Demand
- Durability
- Low operations and maintenance costs

### 2.3.4 Weighting of Indicators

The indicators were ranked on a scale of 0 to 5 points. The value of zero represents zero contribution to the goal in the indicator while a point of five represents the highest contribution to the goals. The total points indicate the overall contribution to various specified goals. All points are weighed equally.

### 2.3.5 Process of Evaluation

**Opinion Sourcing:**

Opinion can be sourced from the following categories of people who will be assigning weights to criteria under consideration.

- Independent experts who may come from academic institutions, consultants or on individual merit
- Wider stakeholder such as industries, Uganda Manufactures Association, Uganda Small Scale Industries Association and NGOs
- The Government assessment/judgement, in this case the line ministries, will be considered depending on the nature of project and the implementing firm or agency

Generally it is the effective participation of the wider stakeholders which is crucial for the successful implementation of the weighing system.

**Methodology:**

The following weighing procedure is proposed:

- Initial ranking (transparent and defendable) by a panel of experts
- The key stakeholder (implementing firm) should also be able to rank the technology (if the firm does not agree with the ranking, it should be explained).

### 2.3.6 Ranking Matrix for Selection of Technologies

Once technologies for evaluation have been identified, a matrix as shown in Table 3 was prepared and indicators are ranked. The total score represents the ranking potential for mitigating emissions.

### 2.3.7 Selected Ranking Sector Matrices

Sector matrices were developed from the general ranking matrix template (Table 3). Beginning from this template matrix, indicators, which were not applicable to the sector being considered, were removed. The balance of indicators formed the sector matrix, which was then used to rank technologies in sectors. The consultative process resulted into sector matrices shown as Table 4 to Table 11 as indicated in Annex II.

## *2.4 PRIORITY SECTOR TECHNOLOGIES*

Using the above selection criteria for sectors, priority sector technologies were identified as follows.

### 2.4.1 Priority Technologies for the Energy Sector

The Working Group on the Energy Sector started with 15 technologies. Using the criteria of Contribution to Economic Development and Climate Change Mitigation, the Group short-listed 8 major technologies. The sector technologies were then prioritised and are indicated below in the order of decreasing priority.

1. Improved combustion technologies
2. Small scale hydropower
3. Solar thermal technologies
4. Solar photovoltaic (PV)
5. Gasification
6. Cogeneration
7. Large hydropower
8. Geothermal.

**Improved combustion technologies:**

Improved Combustion efficiency involves use of more efficient but low-cost biomass combustion technologies, e.g. improved cook stoves, efficient charcoal kilns, brick making kilns, fish dryers and smokers, tea and wood dryers. Improved cook stoves could ensure efficient utilisation of biomass and could significantly reduce indoor air pollution thus mitigating respiratory health and GHG problems associated with particulate emissions from traditional biomass cook stoves. The efficiency of improved stoves is 10 - 15% higher.

Charcoal burning is widespread in Uganda and uses a lot of wood. There is need to develop and demonstrate charcoal kilns of higher efficiency about 35%.

The majority of Ugandans use fired bricks for constructing houses. The bricks are produced using local kilns which are inefficient. Kilns developed in India are 40% efficient. There is need to adopt and demonstrate Indian kilns to the general public in Uganda.

**Small hydropower:**

Small hydro power (SHP) units have the potential for being used in agricultural sector for irrigation, milling and providing shaft power for crop processing in addition to electricity generation. SHP development mainly targets rural areas without grid connections, thus promoting rural economic development and improvement in the general welfare of the

people. The decentralised nature of SHP sources suits the dispersed nature of rural settlement pattern in Uganda. There is a very good hydropower potential in the Rift Valley region.
There are many potentially feasible sites for hydropower generation in the Rift Valley region and developing them would affect the environment in various ways. In order to minimise the negative effects of such schemes, there is need for carrying out an environment impact assessment before any decisions are made.
The low cost of some mini hydro schemes may prove more economic than extension of the existing UEDCL system in isolated areas. Investors may develop them privately using BOOT (Build Own Operate and Transfer) contract. BOOT provides that investors shall recover their investment over a fixed period after which the project is transferred to the government.

**Solar thermal technologies:**

Solar energy is abundant in Uganda, with insolation capable of providing very good low temperature application at a reasonable cost. High-temperature options are technically feasible in the country, but economic viability is severely constrained by inadequate access to finance capital and lower-cost energy generation options. Two applications of solar energy that is beginning to demonstrate signs of success in the country are solar water heating and photovoltaic. Solar water heaters are used in urban households and some institutions, but their performances and quality vary within and among districts.
Solar dryers can be used to reduce post-harvest losses and allow the farmers to secure off-season high returns. Production in the country often falls short of self-sufficient level due to post harvest losses, insect infestation and spoilage. Furthermore the use of solar dryers could reduce deforestation rate around fishing areas and thus contribute to GHG reduction.
There is also a potential for using solar energy for preheating purposes in industry.

**Solar PV system:**

The transmission and distribution costs of extending grid electricity is high, thus creating an ideal market for decentralised energy technologies that better match the dispersed nature of the country. As a result, the country is perceived to be an ideal place for deployment of PV electrification that will not only be cost effective but also environmentally sound.
Despite these interesting features, solar PV technologies do not yet have broad market acceptance and face significant barriers to widespread use in the country. The main obstacle is their initial purchase price (which can be partly attributed to excessively high import duties and dealer mark-up), which puts them out of the reach of most but upper-income households. Opportunities exist to reduce the cost of PV systems significantly in the near future. These include the outlook for ready decline in PV module prices on the international market, the savings possible from judicious use of locally-made and or locally- assembled components as well as the economies of scale in procurement, sales and servicing that an enlarged customer base can provide. However, even with these cost reductions, PV technology is not likely to have big contribution to economic development of the country.

**Biomass gasification:**

Biomass fuels such as firewood and agriculture-generated residues and wastes are generally organic. They contain carbon, hydrogen, and oxygen along with some moisture. Under controlled conditions, characterised by low oxygen supply and high temperatures, most biomass materials can be converted into a gaseous fuel (producer gas), which consists of carbon monoxide, hydrogen, carbon dioxide, methane and nitrogen.

Conversion of solid biomass into combustible gas has all the advantages associated with using gaseous and liquid fuels such as clean combustion, compact burning equipment, high thermal efficiency and a good degree of control. In locations, where biomass is already available at reasonable low prices (e.g. rice mills, sugar factory) or in industries using fuel wood, gasifier systems offer definite economic advantages. Biomass gasification technology is also environment-friendly, because of the firewood savings and reduction in $CO_2$ emissions.

Biomass gasification technology has the potential to replace diesel and other petroleum products in several applications, and thus save foreign exchange. It can be used in thermal applications, such as cooking, water boiling, steam generation, drying etc., and in power applications, e.g. using producer gas as a fuel in internal combustion engines for applications such as water pumping and electricity generation; and also using producer gas in dual-fuel mode in diesel engines, or as the only fuel in spark ignition engines e.g. gas turbines).

**Cogeneration:**

Due to competitive pressures to cut costs and reduce emissions of air pollutants and greenhouse gasses, Uganda is actively looking for ways to use energy more efficiently. One option is cogeneration, also known as combined heat and power (CHP). Cogeneration is the simultaneous production of electricity and useful heat from the same fuel or energy. Facilities with cogeneration systems use them to produce their own electricity, and use the unused excess (waste) heat for process steam, hot water heating, space heating, and other thermal needs. They may also use excess process heat to produce steam for electricity production.

Cogeneration systems could be designed and built for many different applications. Large-scale systems can be built on-site at a plant, or off-site. Off-site plants need to be close enough to a steam customer (or municipal steam loop) to cover the cost of a steam pipeline. Some industries and waste incinerator operators who own their own equipment will realise sizable profits with cogeneration.

While cogeneration provides several environmental benefits by making use of waste heat and waste products, air pollution is a concern any time fossil fuels or biomass are burned. The major regulated pollutants include particulates, sulphur dioxide ($SO_2$), and nitrous oxides (NOx).

Some cogeneration systems, such as diesel engines, do not capture as much waste heat as other systems. Others may not be able to use all the thermal energy that they produce because of their location. They are therefore less efficient, and the corresponding environmental benefits are less than they could be. The environmental impacts of air and water pollution and waste disposal are very site-specific for cogeneration. This is a problem for some cogeneration plants because the special equipment (water treatment, air scrubbers, etc.) required to meet environmental regulations adds to the cost of the project.

**Large hydropower:**

There are many potentially feasible sites for hydropower generation along River Nile with a potential of over 2000 MW. The Cost of this hydropower is estimated at US$ 1000/KW.
Liberalisation policies should be encouraged so that the private sector is more involved in energy production and delivery. These hydro resources are relatively cheap to develop in international terms.

**Geothermal:**

This energy resource could be tapped from the Rift valley region of Uganda, but so far, it has not been exploited. The estimated potential is 450 MW. There are three potential geothermal fields: the Katwe volcanic field to the south; the Buranga field at the foot hills of Rwenzori Mountains and; the Kibira field in the northern part of the Rift valley near Lake Albert. Of the three sites, the Katwe field is the most promising as well as famous for its explosive craters and saline lakes.

The hot water comes from sub-surface steam with a temperature of 230°C. In addition the Katwe field is well located that is only 35 km from the terminus of 132 kV transmission line at Kasese. The other two fields are located in sparsely populated and remote areas, with some potential for local consumption.

**Measures**

Two measures considered effective in the energy sector are:

- Institution of high tariffs to punish owners of plats with low power factors.
- Regulate code of practice for industries to carry out energy audits on regular basis.

### 2.4.2 Priority Technologies for the Agriculture and Forestry Sector

**Agriculture Subsector**

The Group working on technologies from Agriculture started from a broad list of 15 technologies. By combining some technologies or removing minor technologies. The balance of four technologies was left for prioritisation. The result in order of decreasing priority is stated below.

1. Organic Farming
2. Upland rice
3. Cogeneration
4. Biogas

**Organic Farming**:

This is an area in which Uganda has a comparative advantage. The approach is to utilise aerobic digestion of vegetation matter into organic manure to restore and improve soil resources as against use of inorganic fertilisers.

**Upland Rice Cultivation:**

This is the promotion of a variety of rice that does not need flooded fields. In the case of Uganda, flooded rice fields are mainly utilising wetlands. Current efforts are already being put in the upland rice promotion activities.

**Forestry Subsector**

The group started with four technologies and prioritised them as follows:
1. Afforestation
2. Forestry Conservation

**Afforestation:**

The turning of degraded lands such as hilly areas and destroyed forests into forests by Uganda's definition is having at least one hectare and trees of at least five metres.

**Forestry Conservation:**

This involves forest conservation and protection especially prevention of forest fires and wanton destruction by hunters and clear-and-burn agricultural practices.

### 2.4.3 Priority Technologies for the Industry Sector

The working group on the Industrial Sector started with 12 technologies. Using the selection criteria Developed in earlier, the group short-listed 7 technologies. These were then prioritised and are stated below in order of decreasing priority.

1. Improved combustion technology
2. Improved efficiency of machines
3. Eco-design
4. Energy conservation technology
5. Waste heat technology
6. Alternate fuel use
7. Materials recycling technology

**Improved combustion technology:**

Carbon dioxide emission results from the oxidation of carbon in the fuels during combustion. It is only in theoretically perfect combustion conditions can occur, where total carbon content of the fuel would be converted to $CO_2$. But in reality, combustion process is not perfect and consequently a small amount of partially oxidised but the unoxidised carbon are released in atmosphere.

There are several cases of close interaction between fuel used as energy and fuel used in various industrial processes. In this case we consider fuel as energy and not as a feed stock to industrial process. In a typical case where there is use of boilers, furnaces and dryers, in most cases they are the largest consumers of energy. A typical example is thermal energy use in cement industry, sugar industries and breweries. There is a need to improve their efficiency. That can be attained by application of: improved boiler technologies. improved furnaces and improved dryers.

**Improved efficiency of machines:**

About 70% of industrial electricity is used for electric motor driven equipment. Major industrial motor loads are pumps, compressor, fans and blowers. Energy efficient motors are about 30% more expensive than ordinary motor. Based on the energy cost, it can be determined if added investment is justified. Most efficient use of motors requires that attention is given to the following: optimum power; good motor maintenance; equipment scheduling; sizing of proper equipment. Evaluation of continuous verses batch processes and power factor.

One of the advances in energy saving is use of electronic adjustable speed drive (ASD). There is opportunity of energy saving up to 25% in ventilating, 15% in air-conditioning and about 10% in cooling of the total peak power. In refrigeration between 25 -10% of the energy can be saved.

**Eco design:**

There is a growing concern of energy and material use in production processes that have created a negative impact on the environment. The process should be designed in such a manner that it will cause minimum effect on environment. The process design should address issues like air and water pollution, low energy demand and use of environmentally benign sources of energy in the production process. Other steps include: production process modifications, process integration and efficient and improved material use.

**Energy conservation technology:**

Energy conservation is a term mostly used at national level, but at the individual level energy management is preferred. Energy conservation technology is the utilisation of energy by consumers in a manner best suited for realisation of economic objective, taking into account social, political and financial and environmental and other constraints. There are various approaches that can be implemented to achieve any energy conservation such as: energy auditing, equipment maintenance and reduction of energy losses.

**Waste heat technology:**

In most industrial processes, waste heat generated at times is not utilised. Such heat could be a useful in other thermal applications. The use of recuperator, economiser, shell and tube heat exchanger can be used in order to re-use waste heat. In a typical cement industry, opportunities for recovering heat from kiln exhaust gases exist.

**Alternate fuel use:**

There is growing demand for fossil fuel world wide. The growth rate is even higher in the developing countries like Uganda than in industrialised countries. The fossil fuel will be depleted in the longer term. Consequently its price will be rising annually. The fossil fuel emits GHGs, and this calls for alternative sources of energy in the industrial sector, preferable renewable energy. There are several alternatives to fossil fuel such as: fuel switching from furnace oil to biomass for calcinations process and use of solar energy for drying and water heating.

**Material recycling:**

The economic developments in the industrial sector are increasing pressure on the natural resources and increasing demand in energy. A typical application is the production of aluminium; one of the most commonly used material in many areas due to its unique characteristics and plastic material due to its low cost. These materials and other similar materials should be recycled.

### 2.4.4 Priority Technologies for the Transport Sector

The Group working on the transport sector short listed three technologies from a list of seven technologies which were then prioritised. The result in order of decreasing priority ids stated below

1. Improved infrastructure development
2. Alternative fuels
3. Improved vehicle efficiency

**Infrastructure and system changes:**

The Ministry of Works, Housing and Communication (MOWHC) is the key Ministry responsible for the general policy framework for the transport sector in Uganda. The MOWHC managed 9,700 km of the roads and 24,000 km is managed by the Ministry of Local Government.

In general, the roads in Uganda are narrow and in a poor state. They need a lot of reconstruction which demand a lot of money. Fortunately the technology is available locally
In most urban areas, there are several options of transport system. Mass transportation systems should be introduced but should be done in an orderly manner.

**Alternative fuel sources:**

There are two alternative fuels which can be used in Uganda: natural gas and ethanol. There is a chance of reconsidering the ethanol as an option for blending. That will reduce both the emission of GHGs and imports of fuel.

Technology of use of up to 100% ethanol in vehicles or blending with petrol up to 20% ethanol without any change in engine design, as has been practised in Brazil.

**Energy efficiency improvements for vehicles:**

Changes in vehicle and engine design are not possible in Uganda. It could be possible to change the petrol to diesel engines but most of the vehicles are second hand and have short lifetime. Maintenance should be given higher priority.

**Mitigation Measures**

There are four mitigation measures which are suggested for the transport sector:

1. Restriction of import of aged vehicles( may be maximum age of 15 years)
2. Regular check of vehicles on emissions which is linked to road licences.
3. Improve filling station conditions to avoid evaporation during filling.
4. Revival of train transport.

### 2.4.5 Priority Technologies for the Solid Wastes Sector

The Group working on the solid wastes sector started from a broad list of 12 technologies. By combining some technologies or removing minor technologies six technologies were left and were prioritised using the selection criteria. The result in order of decreasing priority is stated below.

1. Composting
2. Recycle
3. Anaerobic landfill
4. Aerobic landfill
5. Minimising waste generation
6. Sorting

**Composting:**

Composting can be used for reduction of solid waste organic matter. Aerobic biodegradation processes, such as composting, have demonstrated that many of the organic compounds found in MSW can be degraded in significantly short time frames by the introduction of air and moisture in the proper proportions. Home composting avoids related transport emissions and provides a useful material for soil improvement.

**Recycling:**

Recycling plays a critical role in reducing waste quantities, returning resources back to use and minimising the financial and environmental burden of managing solid waste. The crucial factor that puts recycling ahead of other technologies like incineration or landfill is that recycling a material uses far less energy than the extraction and processing of virgin materials. Incinerating waste results in more greenhouse gas emissions than does recycling, even taking into account generation of energy from waste.

Recycling, composting, resource recovery and resale of reusable solid waste can be an effective way of minimising waste and contributing to the economic welfare of those living within the urban community. By assisting informal scavengers, who may collect 10-15% of urban solid waste using recycling, reuse and "landfill mining" techniques, become more efficient and established business, cities can reduce their overall urban solid waste production by up to 30% and the landfill gas (LFG) that would be produced.

According to the United States Environmental Protection Agency (USEPA), recycling and composting household waste can save up to 4.5 million tonnes of carbon emissions (as the greenhouse gas carbon dioxide) per year as compared with an alternative scenario of incineration with energy recovery. Recycling has an extra advantage especially if it comes to wastes like paper. Recycling of paper is another strategy with the potential to reduce harvest levels [of timber] and promote greater carbon conservation.

**Anaerobic landfill:**

An anaerobic landfill is where organic wastes are broken down by the action of micro organisms in the absence of oxygen and methane is produced in the process. Methane gas is a greenhouse gas which is 21 times more effective than carbon dioxide in absorbing infrared radiation. Methane gas can be used as a fuel for domestic or industrial use. Methane can also be burnt to convert it into carbon dioxide (called flaring) hence reducing its potency. The heat from flaring can be used to generate electricity or supply heating needs. There are investigations in countries like Australia on ways to better capture and store methane in landfill by sealing the landfills using airtight materials. To maximise methane generation there is need to better control what material enters landfill and reducing contamination is also a priority. The residue remaining after digestion can be used as a soil conditioner.

**Aerobic landfill:**

In order to minimise the anaerobic conditions of a landfill and subsequent release of methane gas, air is injected into the landfill. For each aerobic landfill, the air injection mechanism comprises of electric blowers or an air compressor and piping, all connected to vertical air injection wells that are installed directly into the waste. Leachate, collected in holding tanks at each site, is pumped into each aerobic system through a leachate recirculation system installed on top of the intermediate cap. The leachate is then percolated downward through the waste mass and mixed with the air that was forced into the waste. Leachate that is not utilised during aerobic decomposition migrates downward to the leachate collection system where it is pumped back to the tank, to be recirculated again.

Aerobic degradation of waste within a landfill can rapidly increase the rate of waste decomposition and settlement, decrease the production of methane gas, improve leachate quality, and decrease the quantity of leachate that needs treatment. As a result of this increased "stabilisation", not only can environment risks be reduced, but more waste can be placed in the airspace gained, thus extending the life of the landfill.

**Sorting:**

Sorting involves separating solid wastes into different categories in view of reusing part of the waste. Setting aside of compostable and recyclable materials from the waste stream before they are collected with other solid waste can facilitate reuse, recycling, and composting. Also by using small, specialised industries to sort and process the reclaimable waste and waste-to-energy incinerators for the residue, raw materials and energy can be produced. Source sorting of waste from production (e.g. cardboard, paper and woodwork) can reduce the waste streams significantly. This eventually leads to the reduction of the solid waste that is eventually dumped on to the landfill.

### 2.4.6 Priority Technologies for the Housing Sector

The Group working on technologies for the housing sector started from a broad list of 15 technologies. By combining some technologies or removing minor technologies six technologies were left for prioritisation using the selection criteria. The result in order of decreasing priority is stated below.

1. Stabilised Soil blocks technology
2. Biogas technology
3. Improved efficiency of combustion equipment (e.g. stoves)
4. Solar energy for lighting and heating
5. Efficiency improvements of household equipment
6. Proper housing design

**Stabilised soil blocks technology**

Many buildings in Uganda are constructed using fired bricks. The brick kilns used consume a lot of wood and result in depletion of forests. The situation can be improved by increasing efficiency of kilns. However, a better solution can be obtained if unfired bricks are used. Such bricks are called stabilised bricks. Stabilised bricks are finding increased use in Uganda. This trend should be encouraged because it reduces on the amount of wood that would be used to burn bricks.

**Biogas technology:**

Biogas technology was introduced to Uganda and has potential use in hospitals, schools and universities. The raw material is human and animal dung, which is plentiful in many rural areas of Uganda. Biogas technology designs are also available in the country. There are key barriers to dissemination of biogas technology which include inadequate information directed to potential users, unavailability of sufficient feedstock, and limited technical expertise in the design and construction of biogas plants. Running a biogas plant is labour intensive as it requires collection of cow dung or other suitable feedstock and regular manual feeding. Government needs to devise measures to address these barriers.

**Improved cookstoves:**

Technology for improved efficiency exists in Uganda but there is still need for dissemination of information about them. The country can also mount demonstration programmes. Emphasis can be put on three stone and charcoal stoves.

**Solar power:**

The Housing Sector can benefit from solar lighting and heating (thermal). The technologies are available, and given the impressive solar insolation available in the country, there is enormous potential for growth.

**Efficient equipment:**

A lot of household equipment is inefficient. This equipment includes light bulbs, radios, televisions and refrigerators. There are efficient equipment on the market but they are expensive. Government should encourage use of these efficient equipment especially light bulbs to save on energy consumption

**Proper housing designs:**

The thermal integrity of any building affects the amount of energy consumed by that building. A building with poor thermal integrity consumes more power than one well designed. The thermal integrity can be improved by: improved insulation, installation of energy efficient windows and use of proper building orientation.

# 3.0 BARRIERS AND STEPS TO OVERCOME THEM

## *3.1 INTRODUCTION*

There was need to analyse the prioritised technologies listed in section 2.4 in terms of barriers and action plans. These were found to be too many and 16 of them were selected for further analysis. All technologies from the Energy Sector were selected because energy related technologies contribute a lot to emission mitigation. And the energy sector was ranked first. Additional technologies were the top two from other sectors. The technologies to be considered here are:

1. Improved Efficiency technologies
2. Small scale hydropower
3. Solar thermal technologies
4. Solar PVC
5. Cogeneration
6. Large hydropower
7. Improved Cement Production
8. Organic farming
9. Improved Road infrastructure
10. Ethanol production
11. Waste composting technology
12. Waste recycling technology
13. Stabilised Soil Blocks
14. Improved Cooking stoves

## *3.2 ENERGY EFFICIENT TECHNOLOGIES*

### 3.2.1 Background

The Energy Policy lists energy conservation as one of the objectives for energy demand management. There are a number of programs already in place for the promotion of Energy Efficiency Technologies. The Ministry of Energy and Mineral Development has been the liaising organization for the sector among government institutions, regulatory bodies and donor agencies to implement specific programs and projects such as: Compact fluorescent lights in residential and commercial applications, improved stoves and Energy efficient motors in industrial applications and power factor improvement.

This technology still faces a number of barriers.

### 3.2.2 Barriers

The barriers identified in this technology are:

- Lack of national energy efficiency quality standards.
- Lack of awareness on energy efficient technologies at the national level.

- Lack of credit and loans for investments in the energy efficient technologies.
- Inadequate local capacity for the installation, operation and maintenance of some energy-efficient technologies.
- Lack of a national policy on energy efficient technologies.
- High import costs on energy efficient devices

### 3.2.3 Actions to Overcome Barriers

The following actions can be taken to overcome the barriers:

- Encourage the public to introduce compact fluorescent lamps to replace mainly incandescent bulbs,
- Institute Industrial Energy Conservation Programmes (Motor replacements, Variable speed drives, Capacitor bank installation for power correction and industrial load management.)
- Develop Energy Demand side management in industrial, commercial and public buildings.
- Demonstrate projects for cottage industries to show the benefits of productive uses of electricity and training for beneficiary communities.
- Develop and introduce energy efficiency labels and standards for selected range of appliances.
- Ensure that the public has full knowledge of the energy efficiency ratings of appliances on the market.
- Facilitate financing schemes by development of partnership between Government and donor agencies
- Institute and enforce policies that will gradually eliminate interest in inefficient technologies.
- Encourage International financial institutions to facilitate financial assistance in the form of guarantees (both bilateral and multilateral).
- Invite Donor/funding agencies to help with the development of local capacity to handle energy efficient technologies.

## *3.3 SMALL HYDROPOWER TECHNOLOGY*

### 3.3.1 Background

Uganda's gross potential for exploitable hydropower resource has been estimated at about 2000MW. In 1999, the government issued new policy guidelines for the Energy Sector. One of the areas highlighted for rural energy development was micro/mini-hydro schemes up to 500kW capacity to provide, decentralised electric power to isolated rural communities.

### 3.3.2 Barriers

The following barriers have been identified regarding the small hydropower technolog:

- Limited capacity and know –how.
- Lack of policy to implement the development of mini hydropower.
- High investment costs and long pay-back period.
- Lack of sufficient incentives to attract private capital for renewable energy projects.

### 3.3.3 Actions to Overcome Barriers

Steps to remove the barriers are stated as follows:

- Studies have been done in the country in the identification of potential sites.
- Encouraging appropriate training and development of pilot projects that would provide hands-on experience for personnel.
- Liberalising the utility market
- Identifying and attracting private capital from abroad for investment
- Providing expertise for appropriate training leading to capacity building and development of pilot sites;

## *3.4 SOLAR WATER HEATING TECHNOLOGY*

### 3.4.1 Background

Most solar water heaters identified in the country are in the rural health posts and installed by local producers. There has been some penetration in the high-income residential areas by dealers in foreign brands. The Ministry of Energy has taken inventory of local installations.

### 3.4.2 Barriers

The barriers for implementing solar water heating are:

- No data on hot water consumption in hotels, restaurants and industries.
- Limited expertise in design of industrial solar water heaters.
- Relatively high initial capital cost as compared to conventional heating methods
- Lack of standardization on solar water heaters
- No regulations and code of installation and practice.
- Perceptions of poor performance from initial unsuccessful trials.

### 3.4.3 Actions to Overcome Barriers

The following steps are recommended to overcome barriers:

- Government has sponsored a number of workshops on the benefits of the technology
- Funding must be sought and made available to entrepreneurs through partnerships with solar water heaters manufacturers in other countries.

- Regulations and code of installation and recommended practices should be developed.
- Local production of solar water heaters be in standard sizes.
- Educating the public and informing them about the benefits and potential of solar water heaters particularly for the purposes of preheating.
- Applying International Community to help in exposing local engineering enterprise to modern production techniques and adopting backward integration of the technology for long-term sustenance of the local industry.
- Applying International Community to help in identifying international funding sources for solar water heaters production and use.

## *3.5 SOLAR PHOTOVOLTAIC TECHNOLOGIES*

### 3.5.1 Background

Solar photovoltaic (PV) Technologies include-the off-grid solar home system, PV for grid integration, public/street lighting, vaccine refrigeration, irrigation and water pumping. The average solar radiation across the nation ranges 4.0-6.0 sun hours per day.

Solar PV technology can utilize Uganda's abundant sunshine to meet basic electricity needs of off-grid rural communities.

### 3.5.2 Barriers

For Solar PV technology, the following barriers have been identified.

- Lack of favourable credit facilities for interested users.
- Inadequate standards and recommended practices.
- Low level of information about PV systems in general.
- Inadequate skilled labour.
- High initial cost
- No credit and financing.
- Mismatch between demand and resource availability.

### 3.5.3 Actions to Overcome Barriers

To remove barriers, the following actions are suggested:

- Mount public education at targeted beneficiaries.
- Requiring grant financing for implementation.
- Producing most of the system components locally.
- Seeking International Community to help update and improve skills and consequently strengthen the local capacity.
- Asking International Community to assist Uganda to develop code of installation and practice as well as regulations for the local PV industry.

## *3.6 COMBINED CYCLE TECHNOLOGY*

### 3.6.1 Background

Combined cycle technology provides the highest thermal efficiency of any large thermal power plant and is rapidly becoming the power generation technology of choice around the world where natural gas is available as a fuel. Whilst efficiency of combustion and steam turbines hover around 20-30%, combined cycles have efficiencies of up to about 45%. A combined cycle plant can be built faster and at a lower cost than a stream turbine plant of equivalent capacity. It is also more compact and can be installed at a smaller site than a steam plant.

Combine cycle is flexible in the sense that combustion turbine plant can be upgraded into combined cycle configuration by the addition of waste Heat Recovery Steam Generators (HRSG) and conventional steam turbine. Plant output is increased by some 50% with no necessity for additional fuel.

The normal arrangement for the combined cycle is to have each combustion turbine generator exhausting into its own heat recovery steam generator . It is important to note that when specifying a turbine, the power output diminishes as ambient temperature increases.

### 3.6.2 Barriers

The critical barriers identified for combined cycle technology are:

- High initial cost compared to combustion turbine.
- Inadequate skilled manpower

### 3.6.3 Action to Overcome barriers

The steps to overcome barriers are suggested below.

- Developing a viable financial mechanism to raise funds.
- Developing capacity and training programmes.
- Seeking the International Community to help build capacity in design, financial analysis and operation and maintenance through external training/ exchange programmes
- Requesting the International Community to help source funding to support investment.

## *3.7 LARGE HYDROPOWER TECHNOLOGY*

### 3.7.1 Background

There are many potential feasible sites for hydropower generation. Along the River Nile, there is potential of 2000 MW. Liberalisation policies should be encouraged so that private sector is more involved in energy production/generation and delivery

Development of these sites will affect the environment in various ways. Hence, there is need for an Environment Impact Assessment (EIA) before any decision is made.

### 3.7.2 Barriers

For large hydropower technology, the following barriers have been found:

- Institutional deficiencies
- Pricing distortions
- Lack of funds
- Limited information on renewable energy resource base
- Inefficient use of energy

### 3.7.3 Actions to Overcome Barriers

To overcome above barriers, the following steps are proposed:

- Encourage independent power producers to overcome institutional deficiencies.
- Introduce incentives and subsidies.
- Sensitisation of the public sector.
- Encourage efficient energy use.

## *3.8 IMPROVED CEMENT PRODUCTION TECHNOLOGY*

### 3.8.1 Background

Uganda has two old cement industries in Tororo and Kasese .The machinery in these two factories are old and inefficient. There is need to modernise them through four ways:

- Improve on machine efficiency
- Improve on heating equipment efficiency
- Institute waste heat utilisation
- Institute fuel substitution

### 3.8.2 Barriers

The barriers faced by cement production technology are:

- Lack of awareness about technologies
- Lack of capacity to handle new technologies
- Slow penetration of technology transfer
- Lack of capital
- Inadequate skilled personnel

### 3.8.3 Actions to Overcome Barriers

The following actions can alleviate barriers cited above.

- Purchase of more efficient boilers and motors.
- Sensitise people on efficient operations.
- Introduce tax incentives foe better efficiency and fuel switching mechanisms.
- Train people in new technologies

## *3.9 ORGANIC FARMING TECHNOLOGY*

### 3.9.1 Background

Uganda is an agricultural country and has plenty of vegetation matter. It is possible to utilise anaerobic digestion to produce organic manure to restore and improve soil resources against use of inorganic fertilisers.

### 3.9.2 Barriers

Organic farming technology is faced with the following barriers:

- Farm-level adoption constraints
- Lack of Government subsidies
- Inadequate capacity and skills
- Inadequate information
- Inadequate capacity for monitoring carbon stocks
- Lack of enabling policies initiatives, institutional mechanism, information and opportunities
- Limited capacity and reach of service providers - especially in remote areas
- Lack of awareness.

### 3.9. 3 Actions to Overcome Barriers

In order to overcome barriers, the following steps are proposed.

- Market based instruments (taxes, tradable permits, subsidies, refund systems)
- Standards, product bans, energy mix requirements

- Encourage voluntary agreements
- Set up information, and labelling programmes
- Government investment/ R&D spending
- Reform of the legal system
- Creation of open and competitive markets
- Enhancing physical and communications infrastructure
- Improve land tenure
- Improve macro-economic stability

## *3.10 IMPROVED ROAD INFRASTRUCTURE TECHNOLOGY*

### 3.10.1 Background

The roads in Uganda in general are in a poor state and are very narrow. Their use requires higher consumption of fuel and takes longer time to travel.

### 3.10.2 Barriers

The improved road infrastructure technology is facing the following barrier:

- Limited financing to improve on the infrastructure (road and road maintenance)

### 3.10.3 Actions to Overcome Barriers

The following steps are suggested to remove barriers:

- Government should contact donors for assistance.
- Government should increase its budgets on roads

## *3.11 BIOFUEL PRODUCTION TECHNOLOGIES*

### 3.11.1 Background

Uganda has crops which can be used to produce biofuels. Uganda has two sugar factories which can be used to produce ethanol as a substitute for fossil fuel (petrol and diesel) in combustion engines.

This has become necessary due to the increasing dependence on imported petroleum and its associated problems. Extraction of liquid biofuel as a substitute for petrol is obtained through fermentation of sugar bearing crops such as sugarcane. This fuel could be used to blend petrol for use in engine.

### 3.11.2 Barriers

Production of biofuel is hindered by the following barriers

- Inadequate awareness of the potential of bio-diesel or uncertainty about the economics of the bio-fuels production cycle, particularly in the Ghanaian environment.
- Potential land competition with food crop and energy crop plantation unless marginal land are used.
- Competition for use of energy crop such as sugarcane, oil palm etc. other uses such as food, soap preparations etc.
- Lack of local capacity for adoption of combustion engines to run on liquid biofuels.
- Lack of know-how for efficient and cost effective extraction of liquid biofuels.
- Lack of capacity in purification and blending of biofuels with corresponding fossil fuel

### 3.11.3 Actions to Overcome Barriers

The following steps are suggested to remove above barriers:

- Technology for efficient extraction and purification of bio-diesel
- Funding for setting up initial infrastructure either through loan guarantees or insurance.
- Technical assistance in quantifying and certifying carbon reductions from biofuels.

## *3.12 WASTE COMPOSTING TECHNOLOGIES*

### 3.12.1 Background

Urban areas in Uganda generate a lot of municipal solid waste in form of organic matter and sand. It has been observed that degradable organic material makes up the bulk of the solid wastes. This high percentage of organic material has often led to the suggestion that composting can be an appropriate and viable disposal municipal solid wastes technique for the country.

### 3.12.2 Barriers

Handling of compost waste technology faces the following barriers:

- Unsegregated domestic waste at communal level.
- Lack of comprehensive waste management policy and legislative framework.
- Inadequate institutional capacities.
- Inefficient institutional coordination

- Unwillingness of the public to pay for waste management services.
- Inadequate private sector participation.
- Poor social acceptance of compost use.
- Poor monitoring mechanism and enforcement of standards and guidelines.
- Land acquisition problems for compositing.

#### 3.12.3 Actions to Overcome Barriers

To remove above barriers, the following actions are proposed:

- Promoting source separation of domestic waste at communal level.
- Developing innovative financing mechanisms that are a combination of governmental infrastructure development and management.
- Undertaking education and public awareness.
- Promoting private sector participation in waste management.
- Encouraging research and development into compost technology.
- Promoting community involvement and partnerships in the production and usage of compost.
- Requesting International Community to assist technology transfer in compost production (e.g. magnetic waste separators and short duration composting technology).
- Capacity building in operation, management and maintenance of composting equipment.

### *3.13 WASTE RECYCLING TECHNOLOGY*

#### 3.13 .1 Background

There is a lot of waste which is dumped as garbage yet it would still be used as raw materials. This would reduce on material costs and eliminate excessive garbage collection costs.

#### 3.13.2 Barriers

Waste Recycling technology is faced with following barriers:

- High investment costs.
- Inadequate institutional and regulatory frameworks.
- Lack of information provision.
- Specific Social, cultural and behavioural norms and aspirations.
- Failures or imperfections in markets, policies or other institutions that lie between the market potential and the possible achievement of the economic potential.
- Aspects of institutions or social and cultural systems that separate the economic and socio-economic potentials.
- Lack of enabling policy initiatives, institutional mechanisms, information and opportunities and organisational problems in collection and transport.
- Inadequate co-ordination among different sectors of government

### 3.13.3 Action to Overcome Barriers

Suggested actions to remove barriers in waste recycling are:

- Deploying national responses to climate change as a portfolio of policy instruments to limit or reduce greenhouse gas emissions.
- Setting up information programmes designed to assist municipalities in understanding that employing technologies and practices will improve their competitiveness and reduce costs and at the same time safeguard the environment.
- Improving environmental legislation can be a driving force in the adoption of new technologies.
- Allowing regulatory environmental bodies to come in and enforce environmental standards related to GHGs.
- Instituting an integrated policy accounting for the characteristics of technologies, stakeholders, and countries addressed would be helpful.
- Introducing direct subsidies and tax credits or other favourable tax treatments.
- Introducing market based instruments (taxes, tradable permits, subsidies, deposit/refund systems)

## *3.14 STABILISED SOIL BLOCKS TECHNOLOGY*

### 3.14.1 Background

Medium scale houses are built using fired bricks which consume a lot of wood fuel. There are two options to this problem: either improve on brick kiln efficiencies or use unfired bricks/blocks. There are people in Uganda who have pioneered use of unfired bricks. To ensure that the bricks/blocks are strong enough, some cement is added. This technology has been called Stabilised soil blocks technology

### 3.14.2 Barriers

Implementation of stabilised blocks technology is hampered by the following barriers:

- Inadequate awareness of the technologies
- Lack of finance
- Inadequate skills
- Lack of codes and standards

### 3.14.3 Actions to Overcome Barriers

Barriers hindering production of stabilised blocks can be removed by following actions:

- Sensitising public on advantages of stabilised soil blocks.
- Instituting training on making stabilised soil blocks
- Formulating and enforce standards where they do not exist.

## *3.15 IMPROVED COOK STOVES TECHNOLOGY*

### 3.15.1 Background

Cooking is undertaken predominantly using firewood, crop residues or charcoal as fuel on a traditional three-some fireplace or on a simple charcoal stove. The use of these types of cooking methods has the following disadvantages:

- They are very inefficient and therefore consume more fuel.
- Cooking is very slow as most heat is lost to the surrounding.
- Smoke from the fuel cannot be controlled or channelled out of the cooking environment.
- Women and their children therefore inhale smoke and this has serious health consequences on the lifestyle of women, children and the environment.
- Babies and children are at serious risk from the exposed flame from the stove.

Current traditional stoves (three stone and coal pot) have efficiencies ranging from 10-20%, which are considered inefficient. Meanwhile, there exist improved stoves with efficiencies between 25-35% which when promoted could reduce total woodfuel consumption by about 40%

### 3.15.2 Barriers

Improved stove technology is facing the following barriers:

- Inadequate programme formulation and implementation strategy.
- Local tradition and practices not taken into consideration during the design of improved cook stoves
- Inadequate wood fuel conservation policy.
- Low cost of woodfuels (firewood/charcoal) offers little or no incentive for investment efficient stoves.
- High cost of improved woodfuel stoves production and marketing resulting in low patronage.

### 3.15.3 Actions to Overcome Barriers

To overcome the above barriers, the following actions are suggested:

- The Ministry of Energy and Mineral Development needs to develop and promote the rocket type wood stove which is 10 % more efficient.
- Local artisans be trained in all the regional capitals to produce and fabricate these stoves.

- The Ministry of Energy and Mineral Development is encouraging research and production of low cost cook stoves.
- Development of a national woodfuel conservation policy
- Implementation of a national action programme to combat drought and desertification
- Supporting public awareness programme to demonstrate environmental and social benefits
- Undertaking public education and awareness for efficient improvement of stoves and related health implications.
- Introducing tax on woodfuels supplied to urban centers to support a forestation
- Implementing programmes and strategies for improve cook stoves
- Involving end-users in the research and development of improved cook stoves.
- Providing funding to support development of policy, public awareness programmes and to develop affordable improved stoves.
- Providing technical support in selling carbon credits attributable to reduced wood fuel use.

## *3.16 AGRO FORESTRY AND FORESTRY CONSERVATION TECHNOLOGY*

### 3.16.1 Background

There are many degraded lands such as hilly areas and destroyed/degraded forests which can be turned into proper forests using afforestation technology. For the existing forests, there is need to preserve and protect them from fires and hunters as well as from clear and burn practices; hence the need to develop afforestation and forestation conservation technologies.

### 3.16.2 Barriers

The Forestry Sector is facing the following barriers:
- Inadequate technical capability
- Low capacity for monitoring carbon stocks
- Lack of enabling policies and institutional mechanisms
- Inadequate co-ordination among different groups

### 3.16.3 Actions to Overcome Barriers

Barriers in the Forestry sector can be overcome by following actions:
- Training forestry personnel in monitoring carbon stocks
- Reviewing the land laws which prohibit women to own land and have the urge to plant trees
- Improving co-ordination among various groups in the forestry subsector

# 4.0 KEY TECHNOLOGIES FOR UGANDA

## 4.1 INTRODUCTION

From the 35 technologies short listed in Chapter Three, twelve key technologies were selected for further elaboration. For each sector, the two top most technologies were selected.

1. Small Scale Hydropower Technology
2. Biogas technology
3. Solar Energy technology
4. Improved Cement Making technology
5. Road Infrastructure Development
6. Ethanol Production and Use technology
7. Stabilised blocks technology
8. Improved Cook stove technology
9. Organic Farming
10. Upland Rice Commercial Cultivation
11. Composting technology
12. Recycling technology

## 4.2 SELECTION CRITERIA

Uganda has problems whose solutions require application of these key technologies as indicated in Table 8. In order to attract investors/donors these technologies have to be productive, profitable, efficient and essential for the national economy.

**Table 8: Technologies Addressing National Problems**

| PROBLEM | TECHNOLOGY |
|---|---|
| Power Shortage | Biogas, Solar Energy and Small Scale Hydropower |
| High Fuel Imports | Ethanol Production |
| Poor Agricultural Practices | Organic and Upland Rice Cultivation |
| Limited Building Materials | Cement production technology and Stabilised Blocks |
| High Wood Consumption | Improved Cook stoves |
| High Garbage accumulation | Composting and Waste Recycling |
| Deforestation | Afforestation technology |

## *4.3 MAJOR CHARACTERISTICS OF KEY TECHNOLOGIES*

For each technology, some major characteristics have been identified which include: benefits, availability, investment costs and emission reduction due to the application of the technology. These characteristics are given below.

### 4.3.1 Small Scale Hydropower Technology

**Technical Aspects**

There is need to select suitable sites and develop power there. The small hydropower plants shall enable rural communities to access power**.** The capital cost per kW of a small hydropower plant is about US$ 2,000. The efficiencies of the turbines vary greatly; cross-flow – from 65 to 85%, Pelton – from 65 to 91%, Turgo – from 75 to 85. The small hydropower technology is available in Europe and North America. Companies like VA Tech – Austria, Alstom – Sweden, GE Hydro, and SKAT – Germany have well developed hydro technologies.

**Potential Emission Reductions**

Records from the Ministry of Energy and Mineral Development give the potential for small scale hydropower stations at 70 MW. The energy generation from the sites is estimated at MWh 459,900. The emission from hydropower stations is negligible. The use of the turbines depends largely on the site and cost of turbines. In case where there is no hydropower plant, the most favourable substitute is diesel generator and low power PV system. The emission avoided by use of hydropower plant is 390,915 tonnes of GHG annually.

### 4.3.2 Biogas Technology

**Technical Aspects**

There is need to construct and demonstrate typical biogas plants. The benefits of biogas are that it provides an alternative fuel and can be used for both lighting and cooking. There are three common types of digesters which are locally available namely: tubular type (cost US$ 30-40), floating drum type (cost US$ 100 – 130) and fixed dome (cost US$300-450). Only a few rural households can afford the biogas technology.

The unit cost of production can be reduced if the production units are produced in larger scale. If the unit cost can be reduced by 20% for example; tubular type will cost US$ 25 to 35, floating drum type will cost between US$ 80 to 120 and the fixed dome digester will cost between US$ 270 and 390. The cost can be shared if the biogas is community based. The improved biogas technology is well documented and is locally available at the Ministry of Energy and Mineral Development.

**Potential Emission Reduction**

In 2004 Uganda had installed 20 digesters with capacities between 0.17 and 0.23 $m^3/m^3$ Vol./day. The average volume of each digester was $10m^3$ and calorific value was 22 $MJ/m^{3.}$ The energy obtained from these digesters per year was 316800 MJ. Assume that development of biogas doubles digesters to 40, the energy produced would be 633600 MJ (176,000MWH). If this energy was supplied from diesel supplied electricity, it would result into an emission of 149Gg of $CO_{2.}$ Hence application of such biogas would reduce emissions by 149Gg of $CO_{2.}$

### 4.3.3 Solar Energy Technology

**Technical Aspects**

Two applications of solar energy that have potential for this country are solar water heating and photovoltaic electrification. The PV is better suited for dispersed areas. There is need to construct and demonstrate solar PV and solar water heating systems especially for institutions like schools and hospitals. The benefits include alternative supply of power and reliable power. The cost of PV systems is high (A typical system of 40-50 Wp costs about US$ 800) and subsidies shall be required. The technology is locally available but systems can be imported.

**Potential Emission Reduction**

Consider solar energy lighting displaces 25,000 litres of kerosene in a year. The emission factor for kerosene is 3.1 kg of CO2 per liters of kerosene. This would save 76 ktonnes of carbon dioxide per annum

### 4.3.4 Improved Cement Production Technology

**Technical Aspects**

There is need to improve on production of cement by increasing efficiencies of boilers, kilns, dryers and electric motors for the cement industry. The benefits include reduced air pollution, increased fuel efficiency, reduced capital costs, lower operating temperatures, lower noise levels, greater ability to accelerate at high initial loads and less affected by fluctuating loads.

The improved boiler burner technologies includes air heater design for increased performance and reduced corrosion, advanced secondary air injection system for increased boiler steam output and efficiency and advanced fuel spreader design for increased boiler efficiency and reduced capital cost. Modern burners include Sake burners (US$ 50,000), Nu-way burners (US$ 7,000).

The improved motor technology includes higher speed motors, squirrel cage motors and totally enclosed, fan cooled motors. The improvements include use of lower loss silicon steel, longer core to increase active material, thicker wires to reduce resistance, thinner laminations, smaller air gap between stator and rotor, use of copper instead of aluminium bars in the rotor, use of superior bearings and smaller fans. The improved motors efficiencies are from 84% to 93% between 2 and 20 kW. The drives include helical reduction gearboxes (97 to 98% efficient), wedge belts (2% more efficient) and flat/ribbed belts (up to 6% more efficient).
The technologies are imported.

**Potential Emission Reduction**

In Uganda, specific fuel consumption for cement is 40.2 MJ/ton and emission factor for furnace oil is 77.3 kg $CO_2$/ MJ. At present Uganda produces about 38, 0000 tons of cement and consumes 15276000 MJ of fuel. The emission from furnace oil would be 1,186 Gg of carbon dioxide. Assuming 25 % of furnace oil is replaced by agricultural wastes, this would save 295 Gg of $CO_2$.

### 4.3.5 Road Infrastructure Technology

**Technical Aspects**

There is need to improve on most roads in Uganda to make them more useful. The benefits are reduced amount of fuel imported, improved air quality and enhanced access to rural areas. The improved infrastructure system will cover the cost of improving the roads (main road and city roads), the road furniture and general maintenance. The World Bank and Japanese Government have shown interest in improving the infrastructure both in Kampala and the highways. The estimated costs of these improvements in Kampala alone is about US$ 60 million for the 619 km. Road maintenance cost US$ 587 million, while upgrading air transport infrastructure will cost US$ 152.4 million.

These technologies are available at the Ministry of Works, Transport and Communication.

**Potential Emission Reduction**

The infrastructure often lack proper maintenance. The GHG emissions in 2004 were estimated to be 1,289 million kg of $CO_2$ for roads only. Assuming rehabilitation and maintenance of road transport infrastructure would reduce emissions by 5%, this would reduce emissions by 64 kilo tonnes of C02 equivalent.

### 4.3.6 Ethanol Production Technology

**Technical Aspects**

There is need to produce ethanol and blend it with petroleum to run engines**.** The benefits are reduced amount of fuel imports, better air quality, less transport costs and job creation. The improved technology will involve blending ethanol up to 20% without change in engine design.. There are three sugar factories in Uganda, each producing molasses. And ethanol requirement for Uganda is about 30- 50 million litres per year.

The investment cost for blending is estimated to be US$ 25 million. Brazil is the leading country with this technology and with sources of vehicles that can run on up to 100% ethanol. Some of the Brazilian firms include; Desilaria Americana S.A., Agro Industrial Pass Tempo S.A., Usina Maracai S.A., Distilaria Gaisa S.A. and Usina Estava S.A.

**Potential Emission Reduction**

Ethanol can be used as a blending fuel for petrol. Since a blending up to 20% can be made without any modification of petrol engine, it will result in reduction in fuel import and greenhouse gases. In 2004, the GHG emission from gasoline was 580.6 million kilograms. If ethanol is used to substitute petrol; the avoided emission will be 0.56 kg of CO2 per litre (44.8 MJ). The GHG will be reduced by 21.75 Gg to 558 Gg.

### 4.3.7 Stabilised Soil Blocks Technology

**Technical Aspects**

There is need to document and demonstrate the technology of stabilized blocks in rural areas. The benefit of the stabilised soil blocks is that it does not need wood saving more biomass to act as carbon sinks. This technology would enable rural people to have long lasting houses. Houses from unfired bricks are also cheaper.

The technology involves addition of little cement to the traditional making of bricks. The technology is locally available.

**Potential Emission Reduction**

It is noted that one kilogram of biomass used in a brick kiln emits 1.03 kg of $CO_2$ .A typical kiln consumes one tonne of biomass. Assuming 4,000 kiln mountings per year, the emission saved would be 4 Gg of $CO_2$ per year.

### 4.3.8 Improved Cookstoves Technology

**Technical Aspects**

There is need to adopt, construct and demonstrate the rocket stove for cooking. The benefits of the improved stoves are savings in the fuel used consequently saving on money spent and forests for carbon sequestration. It is estimated that about 20% of the urban households use improved stoves. The stoves cost between US$ 5 to 6 and have efficiencies of about 25%, depending on the design.

The improved stoves technology is well documented at the Ministry of Energy and Mineral Development and by several NGOs like JEEP and UCODEA.

**Potential emission Reductions**

Use of metallic stoves is less efficient than improved stove. Metallic stoves efficiency is about 20 % while improved stoves vary between 24% and 35 %. The estimated emission from metallic stove is 2.96 kg of GHG per kilogramme of charcoal while the use of improved stoves the emission factor reduces to 2.73 kg of GHG per kg of charcoal. If 50 % of the households in the urban areas could use improved stoves the emission will be reduced from 1,350 Gg to 1,318 Gg, thus, a reduction of 32 Gg.

### 4.3.9 Organic Farming Technology

**Technical Aspects**

There is need to disseminate this technology to a wider public. The benefits include improved yields, soil conservation, saving in importation, biodiversity conservation, better quality crops and premium exports.

An improved organic farming technology is to use organic fertilisers like animal manure. It does not cost much since most of the inputs are locally recycled. The crop yield due to its application is variable but is able to match the yield of artificial fertilisers. It results into limited emissions.

This technology is locally available. Information sources include NARO institutes, Makerere University Faculty of Agriculture, NAADS, Codex Alimentarius Guidelines for the production, processing, labelling and marketing of organically produced foods and International Federation of Organic Agriculture Movements (IFOAM).

**Potential Emission Reduction**

Uganda imports a variety of fertilisers with an average emission factor of 0.2 ton Nitrous oxide/ton. The average emission for the last five years for four fertilisers was 824 tons/year.

Organic farming would displace some of these fertilisers. Assume 20 % fertilisers are displaced, this would save 165 tons of Nitrous oxide.

### 4.3.10 Upland Rice Cultivation Technology

#### Technical Aspects

There is need to commercialise this technology so that most farmers cab benefit from it. The cost is low because it does not require irrigation systems. Other benefits are utilization of marginal lands (suitable for poor farmers), conservation of water resources and minimal inputs.

Upland rice cultivation is a low cost variety since only tilling is done. Possibility of Non-tilling exists. The yield is medium compared to the yield from paddy rice.

This technology is locally available from NARO institutes, Faculty of Agriculture, Makerere University and NAADS.

#### Potential Emission Reduction

Upland rice growing would displace paddy rice which causes emissions. It is estimated that 50,000 hectares of paddy rice are cultivated annually. Assuming upland rice growing saves 50% of this land, saving would be from 25,000 hectares. The emission factor for paddy rice is between 0.25 and 0.82 $g/m^2$/ day and swamps are occupied 120 days a year.
The calculation yields a range of 7.5 to 24 Gg of methane.

### 4.3.11 Waste Composting Technology

#### Technical Aspects

There is need to conserve soil especially since land is becoming scarce. The benefits include use of compost manure for soil improvement and does not require skills.

At the local household level, no cost is necessary for composting. However, for improved status of composting, the technology requires up to US$ 50 to set up and train for the required skills. This technology is available and is widely practised in developed agricultural economies.

The technology is locally available.

#### Potential Emission Reduction

Kampala City produces 1200tons/day of garbage. If you consider this production over a year, it becomes 432,000 tons per year. Allowance is made for other towns which have small land fills by doubling garbage for Kampala. It is also assumed that 60% of this garbage is taken for land filing. Fraction of degradable organic carbon (DOC) is estimated to be 0.16. Assuming 50 % of this is composted; methane saved would be about 22,000 tons/year.

### 4.3.12 Waste Recycling Technology

**Technical Aspects**

There is need to reduce on raw materials especially where they are imported. Recycling can save on costs of raw materials while paper recycling can reduce deforestation and promote greater carbon sequestration.

The practice of recycling and reuse can be employed at the source of waste generation, as well as at an advanced level in industry. The simple practice at household level involves minimal effort and costs (say less than US$ 2), but an advanced recycling system may cost millions of dollars, depending on the technology and the output.
The simple recycling systems are locally available but advanced systems have to be imported.

**Potential Emission Reduction**

Estimated methane emission from land fill places was estimated as 44,000 tons per year. Assuming recycling saves 10% of the garbage, this would result into saving of 4400 tons of methane annually.

## *4.4 DESIRABLE CHARACTERISTICS /FEATURES OF KEY TECHNOLOGIES*

The technologies selected should mitigate GHG emissions and also contribute to the national development. However, selection of a technology requires careful consideration of characteristics/features connected with that particular technology. Desirable characteristics/features have been identified as follows:

1. Sourced locally
2. Accessible
3. Low cost
4. Suitable Capacity
5. Detailed specifications
6. Does not need adoption
7. Does not need skills training
8. Does not need expert installation
9. Has operations Manual
10. Has Maintenance Manual
11. Is insurable

The twelve technologies were subject to the above check list of desirable characteristics/features and the results are presented in Table 10.

**Table 10: Technology Characteristics / Features**

| | CHARACTRERITICS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Small Scale Hydropower | Yes | No | No | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes |
| Biogas Technology | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes |
| Solar Energy Technology | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes |
| Improved cement production | Yes | No | No | Yes | Yes | No | Yes | Yes | Yes | Yes | No |
| Improved Road Infrastructure | Yes | No | Yes | Yes | Yes | No | No | No | Yes | Yes | No |
| Ethanol Production | Yes | No | No | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes |
| Stabilised Blocks | Yes | Yes | Yes | Yes | Yes | Yes | No | No | Yes | Yes | No |
| Improved Cook stoves | Yes | Yes | Yes | Yes | Yes | No | No | No | Yes | Yes | No |
| Organic Farming | Yes | Yes | Yes | Yes | Yes | No | No | No | Yes | Yes | No |
| Upland Rice Cultivation | Yes | Yes | Yes | Yes | Yes | No | No | No | Yes | Yes | No |
| Waste Composting | Yes | Yes | Yes | Yes | Yes | No | No | No | Yes | Yes | No |
| Waste Recycling | Yes | Yes | Yes | Yes | Yes | No | Yes | No | Yes | Yes | No |

# 5.0 RECOMMENDATIONS

The TNA carried out under this study has confirmed and identified specific barriers to deployment of technologies that will help mitigate GHG emissions in Uganda. Several policies, strategies and interventions to overcome or minimize these barriers are proposed below. Some of these are specific to the nation and national players whereas some are addressed to the international community.

## *5.1 RECOMMENDATIONS TO THE NATION AND NATIONAL STAKEHOLDERS*

**Institutional Framework**

To address the gaps related to implementation capacity, there is need to strengthen the relevant sector institutions. Within the Ministry of Water, Lands and Environment, the recently established National Steering Committee on Climate Change which is meant to handle matters on the Clean Development Mechanism needs to be strengthened to include issues of global warming.

**Legal and Regulatory Framework**

The legal and regulatory framework to handle climate change and global warming issues needs to be formulated and harmonised with existing but related legislation and regulations.

**Financing of Technology Transfer**

Most of the technologies identified by the TNA will be utilized by individuals and the private sector. Because of the limited financial resources within the private sector to meet the costs of technology transfer, there is need to provide financial and regulatory incentives for investors.

**Capacity Building and Training**

There is need to develop capacity at various levels. These include:

- Programs for sensitisation of the public on many issues of climate change and technologies
- Mechanisms to facilitate development of local experts in developing local mitigation technologies.
- Private sector institutions on the process of identification, sourcing and deployment of mitigation technologies.

**Standards and Codes**

To avoid damping, there is need to develop and enforce relevant standards and codes of the various technologies.

**Grouping/phasing of priority sectors**

Six national sectors have been identified as needing investments and interventions with regards to technologies for mitigation of GHG emissions. In light of limited resources, it is proposed that the six sectors be placed in two groups as follows:

Group I: Energy, Industry, Transport and Agriculture

Group II: Solid Waste and Housing

It is proposed that initially, Group I receive a higher priority. This is because this group contributes greatly to total emissions in Uganda.

**Evaluation of proper costs and risks in the various technologies**

The selection of technologies carried out under this study was based on the AHP tool. This enabled the identification and prioritization of technologies needed. The tool, however, does not handle the costs and risks associated with the individual technologies. It is thus recommended that as a next step each technology should be subjected to a detailed study of the costs/risks through CBA and RBA tools.

**Immediate application of the technologies**

Some of the technologies identified for mitigation of GHG emissions in Uganda can be sourced locally. Elaborate technology transfer mechanisms are therefore not necessary in these technologies. Hence the proposed measures should be applied immediately. Where additional development is essential, various sectors should take up the required development.

## *5.2 RECOMMENDATIONS FOR THE INTERNATIONAL COMMUNITY*

It has been envisaged within the UNFCCC that developing countries experience various barriers in technology transfer. Article 4.5 of the Convention mandates Annex 1 parties and developed parties included in Annex II to take steps to assist parties, in particular developing countries, in the process of technology transfer. The following are the areas in which specific assistance is recommended.

**Financing the Transfer of Mitigation Technologies**

One of the major difficulties regarding transfer of technology is the financial transactions involved. It is proposed that the international community create or facilitate an enabling environment for favourable monetary transactions. This could be in the form of guarantees; both bilateral and multilateral.

**Support to Research, Development and Dissemination**
There is need to continuously carry out research, development and dissemination of technologies. It is recommended that development partners should support efforts towards the development of local capacity to handle mitigation technologies.

## *5.3 RECOMMENDATIONS OF SPECIFIC TECHNOLOGIES*

There are various gaps that are specific to the identified technologies. These are presented below.

**Small and Mini Hydropower Technology**

- Identify and attract private foreign direct investment
- Provide expertise for appropriate training leading to capacity building and development of pilot sites;

**Solar Water Heating**

- Help in exposing local engineering enterprise to modern production techniques and adopting backward integration of the technology for long-term sustenance of the local industry.
- Help in identifying international funding sources for production and use of solar energy.

S**olar Photovoltaic Technologies**

- Set up joint-venture initiatives to fabricate subsystem components such as regulators and assemble PV modules.
- Promote co-operative programs between researchers in local universities, research institutions, public and private sector institutions.
- Provide access to facilities in advanced countries in order to help update and improve skills and consequently strengthen the local capacity.
- Assist Uganda to develop code of installation and practice as well as regulations for the local PV industry.

**Improved Cook Stoves and kilns**

- Provide funding to support construction and demonstration of the Retort stove for the public.
- Provide funding for the construction and demonstration of efficient kilns in rural areas.

**Biofuel Production**

- Provide support for public awareness in the production, use and the potential of biofuels.
- Provide funding for setting up initial infrastructure for ethanol production either through loan guarantees or insurance.

**Waste Composting Technology**

- Provide technology transfer in compost production (e.g. magnetic waste separators and short duration composting technology).
- Assist in capacity building in operation, management and maintenance of composting equipment.

**Afforestation Technology**

- Assist in promoting growth of trees in public areas such as along roads.

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# ANNEXES

## *ANNEX I: TERMS OF REFERENCE*

The Terms of Reference (TOR) for the consultancy services for Technology Needs Assessment (TNA) were stipulated as follows:

1. Organise capacity building workshop for identified sectoral institutions;
2. Define the scope of mitigation technologies;
3. Discussions with stakeholders, include elements of selection criterion;
4. Develop a criterion for selecting required mitigation technologies;
5. Review available technology information on selected technologies and fill technology information gaps;
6. Develop and compile detailed technology information (characteritics and performance) of identified mitigation technologies, including their sources;
7. Identify technology transfer barriers and propose recommendation on addressing the identified barriers – financial (tax barriers, lack of financial resources), legal, and capacity;
8. Facilitate technical discussions of intermediary reports; and
9. Produce final report.

## *ANNEX II: RANKING OF SECTOR TECHNOLOGIES.*

**Table 10: Ranking Matrix for Mitigation Technologies (Template)**

| FACTORS AND INDICATORS | TECHNOLOGY | | |
|---|---|---|---|
| | Technology A | Technology B | Technology C |
| **Economic Development** | | | |
| Job creation | | | |
| Improved livelihood of the poor | | | |
| Sustainable use of natural resources | | | |
| Increased production of marketable goods and services | | | |
| Improved infrastructure development | | | |
| Improvement in land usage | | | |
| **Climate Change Mitigation** | | | |
| Enhancement of $CO_2$ sink | | | |
| Reduction in GHG emissions | | | |
| No GHG emissions | | | |
| No leakage | | | |
| Improvement of waste management practice | | | |
| **Environmental Sustainability** | | | |
| Effect on local environment (land, water and air) | | | |
| **Social Benefit** | | | |
| Social acceptability to the local community | | | |
| Improvement/attraction of social services to community | | | |
| Improvement of food security | | | |
| Development of social infrastructure | | | |
| Promotion of gender equity | | | |
| **Technological Benefits** | | | |
| Capacity of the local community/individual to absorb and manage the technology | | | |
| Replicability | | | |
| Possibility of expansion | | | |
| Human and Institutional capacity development (skills, regulations, laws and policy) | | | |
| Promotion of cleaner production practice | | | |
| Reliability | | | |
| Promotion of energy efficiency | | | |
| Potential for innovation | | | |

| | | | |
|---|---|---|---|
| Occupational health and safety to users | | | |
| **Marketability** | | | |
| Cost effectiveness | | | |
| Commercial availability | | | |
| Durability | | | |
| Low operational and maintenance costs | | | |
| Accessibility | | | |
| Demand | | | |
| | | | |
| **TOTAL** | | | |

**Table 11: Ranking Matrix for the Energy Sector**

| No. | Technology | Number of Panel Votes |
|---|---|---|
| 1 | Improved combustion technologies | 18 |
| 2 | Small hydropower | 16 |
| 3 | Solar thermal | 15 |
| 4 | Solar PV | 14 |
| 5 | Gasification | 12 |
| 6 | Co-generation | 11 |
| 7 | Large hydropower | 10 |
| 8 | Geothermal | 7 |
| | | |

Panel participating votes were 22

**Table 12: Ranking Matrix fort the Industry Sector**

| No. | Technology | Number of Panel Votes |
|---|---|---|
| 1 | Improved combustion technologies | 19 |
| 2 | Improved efficiency of machines | 17 |
| 3 | Eco-design | 15 |
| 4 | Energy conservation technologies | 13 |
| 5 | Waste heat recovery technologies | 12 |
| 6 | Alternative fuel use | 10 |
| 7 | Co-generation | 8 |
| 8 | Materials recycling technologies | 6 |
| | | |

Panel participating votes were 22.

**Table 13: Ranking Matrix for the Agriculture Sector**

| FACTORS AND INDICATORS | TECHNOLOGY | | | |
|---|---|---|---|---|
| | Biogas | Up Rice | Cogeneration | Organic Farm |
| **Economic Development** | | | | |
| Job creation | 1 | 4 | 3 | 1 |
| Improved livelihood of the poor | 0 | 3 | 2 | 4 |
| Sustainable use of natural resources | 4 | 3 | 3 | 4 |
| Increased production of marketable goods and services | 0 | 3 | 4 | 3 |
| Improved infrastructure development | 0 | 2 | 3 | 0 |
| Improvement in land usage | 0 | 4 | 0 | 3 |
| **Climate Change Mitigation** | | | | |
| Enhancement of $CO_2$ sink | 0 | 2 | 0 | 4 |
| Reduction in GHG emissions | 4 | 3 | 1 | 4 |
| Improvement of waste management practice | 5 | 0 | 5 | 4 |
| **Environmental Sustainability** | | | | |
| Effect on local environment (land, water and air) | 4 | 1 | 1 | 5 |
| **Social Benefit** | | | | |
| Social acceptability to the local community | 1 | 4 | 0 | 3 |
| Improvement/attraction of social services to community | 0 | 2 | 4 | 0 |
| Improvement of food security | 2 | 5 | 0 | 2 |
| Development of social infrastructure | 0 | 0 | 1 | 0 |
| **Technological Benefits** | | | | |
| Capacity of the local community/Individual to absorb and manage the technology | 2 | 4 | 1 | 4 |
| Replicability | 1 | 5 | 1 | 3 |
| Possibility of expansion | | | | |
| Human and Institutional capacity development (skills, regulations, laws and policy) | 1 | 3 | 1 | 3 |
| Promotion of cleaner production practice | 4 | 0 | 3 | 4 |
| Reliability | 1 | 4 | 4 | 3 |
| Promotion of energy efficiency | 4 | 0 | 4 | 0 |
| Potential for innovation | 2 | 2 | 3 | 1 |
| Occupational health and safety to users | 1 | 5 | 2 | 5 |
| **Marketability** | | | | |
| Cost effectiveness | 3 | 4 | 4 | 5 |
| Commercial availability | 4 | 4 | 4 | 4 |
| Durability | 1 | 4 | 4 | 4 |
| | | | | |
| **TOTAL** | **44** | **71** | **58** | **73** |

Ranking was : Organic farming, Upland Rice Cultivation, Cogeneration and Biogas

**Table 14: Ranking Matrix for the Transport Sector**

| FACTORS AND INDICATORS | TECHNOLOGY | | |
|---|---|---|---|
| | Technology A | Technology B | Technology C |
| **Economic Development** | | | |
| Job creation | 1 | 3 | 4 |
| Improved livelihood of the poor | 0 | 2 | 4 |
| Sustainable exploitation | 0 | 4 | 0 |
| **Climate Change Mitigation** | | | |
| Reduction in GHG emissions | 4 | 3 | 4 |
| No GHG emissions | 4 | 4 | 4 |
| No leakage | 4 | 4 | 4 |
| **Environmental Sustainability** | | | |
| Effect on local environment (land, water and air) | 1 | 3 | 4 |
| **Social Benefit** | | | |
| Social acceptability to the local community | 3 | 3 | 5 |
| Improvement/attraction of social services to community | 3 | 3 | 4 |
| **Technological Benefits** | | | |
| Replicability | 4 | 4 | 4 |
| Human and Institutional capacity development (skills, regulations, laws and policy) | 3 | 3 | 4 |
| Promotion of cleaner production practice | 3 | 3 | 4 |
| Reliability | 3 | 3 | 4 |
| Promotion of energy efficiency | 3 | 3 | 4 |
| Potential for innovation | 3 | 3 | 5 |
| **Marketability** | | | |
| Cost effectiveness | 4 | 2 | 2 |
| Commercial availability | 3 | 3 | 4 |
| Durability | 4 | 3 | 3 |
| | | | |
| **TOTAL** | **47** | **54** | **63** |

The ranking in the Transport Sector was as follows:

1. Improved infrastructure development (Technology C)
2. Alternative fuel (Technology B)
3. Improved efficiency (Technology A)

**Table 15: Ranking Matrix for the Solid Waste Sector**

| **FACTORS AND INDICATORS** | **TECHNOLOGY** | | | | | |
|---|---|---|---|---|---|---|
| | Comp ost | Minim ise | Sortin g | Recycl e | Aerobi c | Anaerob ic |
| **Economic Development** | | | | | | |
| Job creation | 1 | 0 | 2 | 3 | 2 | 2 |
| Improved livelihood of the poor | 2 | 1 | 2 | 3 | 2 | 2 |
| Sustainable use of natural resources | 4 | 1 | 1 | 4 | 1 | 1 |
| Increased production of marketable goods and services | 2 | 0 | 3 | 4 | 0 | 4 |
| Improved infrastructure development | 0 | 0 | 0 | 1 | 2 | 2 |
| Improvement in land usage | 3 | 4 | 3 | 4 | 2 | 2 |
| **Climate Change Mitigation** | | | | | | |
| No leakage | 4 | 5 | 3 | 2 | 2 | 2 |
| Improvement of waste management practice | 4 | 4 | 4 | 4 | 4 | 4 |
| **Environmental Sustainability** | | | | | | |
| Effect on local environment (land, water and air) | 2 | 4 | 4 | 4 | 2 | 2 |
| **Social Benefit** | | | | | | |
| Social acceptability to the local community | 4 | 2 | 1 | 3 | 3 | 2 |
| Improvement/attraction of social services to community | 0 | 0 | 0 | 2 | 4 | 3 |
| Improvement of food security | 4 | 0 | 1 | 0 | 0 | 0 |
| Development of social infrastructure | 0 | 0 | 0 | 1 | 3 | 3 |
| **Technological Benefits** | | | | | | |
| Capacity of the local community/Individual to absorb and manage the technology | 4 | 3 | 3 | 3 | 3 | 3 |
| Replicability | 4 | 4 | 4 | 4 | 4 | 4 |
| Human and Institutional capacity development (skills, regulations, laws and policy) | 4 | 4 | 4 | 4 | 4 | 4 |
| Promotion of cleaner production practice | 4 | 4 | 4 | 4 | 4 | 4 |
| Reliability | 4 | 1 | 1 | 3 | 4 | 4 |
| Promotion of energy efficiency | 0 | 0 | 0 | 1 | 0 | 4 |
| Potential for innovation | 4 | 3 | 3 | 4 | 4 | 4 |
| Occupational health and safety to users | 3 | 5 | 2 | 1 | 4 | 4 |
| **Marketability** | | | | | | |
| Cost effectiveness relative to other technologies | 4 | 5 | 3 | 4 | 1 | 2 |
| Commercial availability | 5 | 5 | 4 | 4 | 4 | 4 |
| Durability | 5 | 5 | 3 | 2 | 1 | 1 |
| | | | | | | |
| **TOTAL** | **72** | **59** | **54** | **69** | **60** | **67** |

Ranking was as follows: Composting, Recycle, Anaerobic land fill, Aerobic landfill, Minimising and Sorting

**Table 16: Ranking Matrix for the Housing Sector**

| FACTORS AMD INDICATORS | TECHNOLOGY | | | | | |
|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | **F** |
| **Economic Development** | | | | | | |
| Job creation | 1 | 2 | 0 | 1 | 1 | 3 |
| Improved livelihood of the poor | 0 | 1 | 0 | 0 | 0 | 2 |
| **Climate Change Mitigation** | | | | | | |
| Reduction in GHG emissions | 3 | 3 | 0 | 5 | 3 | 4 |
| No GHG emissions | 5 | 5 | 5 | 4 | 4 | 5 |
| No leakage | | | | | | |
| Improvement of waste management practice | 0 | 0 | 0 | 0 | 3 | 2 |
| **Environmental Sustainability** | | | | | | |
| Effect on local environment (land, water and air) | 5 | 3 | 0 | 5 | 3 | 4 |
| **Social Benefit** | | | | | | |
| Social acceptability to the local community | 5 | 4 | 5 | 5 | 3 | 5 |
| Promotion of gender equity | 0 | 3 | 0 | 3 | 3 | 1 |
| **Technological Benefits** | | | | | | |
| Capacity of the local community/Individual to absorb and manage the technology | 3 | 4 | 3 | 5 | 5 | 5 |
| Replicability | 5 | 4 | 3 | 4 | 3 | 4 |
| Human and Institutional capacity development (skills, regulations, laws and policy) | 2 | 4 | 2 | 2 | 5 | 4 |
| Promotion of cleaner production practice | 3 | 3 | 2 | 3 | 3 | 3 |
| Reliability | 4 | 4 | 4 | 5 | 5 | 3 |
| Promotion of energy efficiency | 4 | 3 | 2 | 3 | 3 | 2 |
| Potential for innovation | 5 | 5 | 3 | 3 | 5 | 5 |
| Occupational health and safety to users | 3 | 3 | 4 | 5 | 4 | 3 |
| **Marketability** | | | | | | |
| Cost effectiveness relative to other technologies | 4 | 4 | 3 | 1 | 1 | 3 |
| Commercial availability | 4 | 4 | 4 | 4 | 4 | 4 |
| Durability | 5 | 4 | 5 | 5 | 4 | 4 |
| | | | | | | |
| **TOTAL** | **61** | **64** | **45** | **63** | **65** | **67** |

The ranking in the Housing Sector was as follows:

1. Stabilised soil blocks technology (F)
2. Biogas (E)
3. Improved efficient cookstoves (B)
4. Solar Energy (D)
5. Efficiency Improvements (A)
6. Proper housing design (C)

## *ANNEX III: LIST OF PARTICIPANTS*

**A. INCEPTION WORKSHOP**
FAIRWAY HOTEL: 7th November, 2005

**Table 17: List of Participants at the Inception Workshop**

| No. | NAMES | MAILING ADDRESS | TELEPHONE NUMBERS | E-MAIL ADDRESS |
|---|---|---|---|---|
| 1 | Mr. Stephen Magezi | Dept. of Meteorology | | |
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| | | | | |

## B. CAPACITY BUILDING WORKSHOP

HOTEL EQUATORIA: 28th November, 2005

**Table 18: List of Participants at the Capacity Building Workshop**

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| 3 | Mr. Magezi Akiiki | Dept of Meteorology | | |
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| 8 | Mr. Mark Ochen | MTTI | | |
| 9 | Mr. Fred Kafero | Environment Alert | | |
| 10 | Mr. Patrick Kakaire | ERA | | |
| 11 | Mr. Lakidi F. | MOFA | | |
| 12 | Mr. Oluka Akileng | Forest Inspection Div. | | |
| 13 | Mr. Andrew Kintu | Centre for Development Initiative (CDI) | | |
| 14 | Mr. Akona Alex | Uganda Coalition for Sustainable Development (UCSD) | | |
| 15 | Mr. Akunda Kamba | MOWHC, Plot 63 Old Portbell Road | | |
| 16 | Mr. Atwine Abel | NEMA | | |
| 17 | Mr. Musiime Samuel | NFA | | |
| 18 | Ms. N.Masembe Sarah | Ministry of Justice | | |
| 19 | Ms. Gubya Phoebe | KCC | | |
| 20 | Ms. Nsangi Susan | UCPC | | |
| 21 | Ms. Prossie Kikabi | UIA | | |
| 22 | Mr. Wamembo Paul | UNCCI | | |
| 23 | Mr. Nkalubo M.S.Z | Dept. of Meteorology | | |
| 24 | Ms. Sarah Nakide | Private Sector Foundation | | |
| 25 | Ms. Sekamate Martin | UMA | | |
| 26 | Mr. Magumba Charles | UEGC. | | |
| 27 | Mr. James Bukwamye | UNSCI | | |
| 28 | Eng. Dr. J.K.D. Higenyi | Technology Consults | 0772-404104 | |
| 29 | Dr. B. Kariko-Buhwezi | Technology Consults | 0772-402354 | |
| 30 | Dr. S.B. Kucel | Technology Consults | 0772-302157 | |
| 31 | Mr. F. Nturanabo | Technology Consults | 0752-652026 | |

## C. CONSULTATIVE WORKSHOP

RIDAR HOTEL: 13th – 14th December, 2005

**Table 19: List of Participants at the first Consultative Workshop**

| No. | NAMES | MAILING ADDRESS | TELEPHONE NUMBERS | E-MAIL ADDRESS |
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| 9 | Ms. Gubya Phoebe | KCC | 0712-886637 | |
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| 11 | Mr. Ronald Kawuma | NHCCL | 0772-454629 | |
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| 13 | Mr. Ochan Geoffrey | Fairway | 0772-851300 | |
| 14 | Mr. Akora Alex | UCSD | 0782-563509 | |
| 15 | Mr. Kimuli M. Godfrey | MEMD | 0772-956832 | |
| 16 | Ms. Prossie Kikabi | UIA | 0772-519822 | |
| 17 | Mr. Kamese Geoffrey | NAPE | 0712-850026 | |
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| 23 | Mr. Dragulu Vale | MWLE | 0782-492586 | |
| 24 | Ms. N. Sarah Masembe | MOJCA | 0772-612080 | |
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| 34 | Mr. F. Nturanabo | Technology Consults | 0752-652026 | mpazi@tech.mak.ac.ug |
| | | | | |

## D. CONSULTATIVE WORKSHOP

RIDAR HOTEL: 27 th. April 2006

**Table 20: List of Participants at the Second Consultative Workshop**

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| 11 | Mr. Mayende Musa | Kyambogo University | | |
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| 24 | Mr. Turyahabwe E | MEMD | 0772449080 | |
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