REPUBLIC OF KENYA

TECHNOLOGY NEEDS ASSESSMENT AND TECHNOLOGY ACTION PLANS FOR CLIMATE CHANGE MITIGATION

MARCH 2013

Supported by:

TECHNOLOGY NEEDS ASSESSMENT AND TECHNOLOGY ACTION PLANS FOR CLIMATE CHANGE MITIGATION

This document is an output of the Technology Needs Assessment project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP) and the UNEP Risoe Centre (URC) in collaboration with Environmental Development Action in the Third World (ENDA Senegal) for the benefit of the participating countries. The present report is the output of a fully country-led process and the views and information contained herein is a product of the National TNA team, led by the National Environment Management Authority-Kenya (NEMA-Kenya)

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This Technology Needs Assessment (TNA) and Technology Action Plan for Climate Change Report for Mitigation is an output of the Technology Needs Assessment Project under the United Nations Framework Convention for Climate Change.

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This report has assessed the technology needs for climate change mitigation in Kenya. The report has further prioritized technology needs for mitigation within the energy and waste management sectors using a multi-stakeholder process and a linear additive Multiple Criteria Analysis Framework. A Barrier Analysis and Enabling Framework for the prioritized technologies have been done and measures identified to overcome these barriers. Finally, Technology Action Plans and Project Concepts have been developed. It is my sincere hope that these 4 part report findings will prompt all stakeholders to take timely action in climate change mitigation and that the reports will form an important reference tool to spur all actors to implement the prioritized technologies in order to contribute in addressing climate change in Kenya.

PROF. GEOFFREY WAHUNGU
DIRECTOR GENERAL, NEMA

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List of Acronyms

ASALs	Arid and Semi- Arid Lands
CBO	Community Based Organizations
CFC	Chlorofluorocarbons
CNA	Climate Network Africa
CP	Cleaner Production
DEPOR	Department of Environmental Planning and Research
EAC	East African Community
EE	Energy Efficiency
EST	Environmentally Sound Technologies
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
Gg	Gigagram
GHG	Greenhouse gas
GIS	Geographic Information Systems
GOK	Government of Kenya
GTZ	German Technical Co-operation
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPPs	Independent Power Producers
KAM	Kenya Association of Manufacturers
KEFRI	Kenya Forestry Research Institute
KENGEN	Kenya Electricity Generating Company
KFS	Kenya Forest Service
KIPPRA	Kenya Institute for Public Policy, Research and Analysis
KNBS	Kenya National Bureau of Statistics
KPLC	Kenya Power & Lighting Company
KTDA	Kenya Tea Development Agency
LPG	Liquid Petroleum Gas
MCA	Multi Criteria Analysis
MCDA	Multi- Criteria Decision Analysis
MDGs	Millennium Development Goals
MTP	Medium Term Plan
MW	Megawatt
NCAR	National Centre for Atmospheric Research
NCCRS	National Climate Change Response Strategy
NCST	National Council of Science and Technology
NEAP	National Environment Action Plan
NEMA	National Environment Management Authority
NGOs	Non-Governmental Organizations
NMVOCs	Non Methane Volatile Organic Compounds
NMT	Non- Motorized Transport
NSC	National Steering Committee
PJ	Petajoules
PPP	Public Private Partnership
PSC	Project Steering Committee
PTC	Professional Training Consultants
RE	Renewable Energy
SHS	Solar Home Systems
SME	Small and Medium Scale Enterprises
SOE	State of the Environment Report

SWH	Solar Water Heater Systems
TNA	Technology Needs Assessment
ToE	Tonnes of Oil Equivalent
ULCPDP	Updated Least Cost Power Development Plan
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization

EXECUTIVE SUMMARY

Kenya's economic activities and growth have to continue and therefore emissions of greenhouse gases have to continue. But there are many technological measures that can be undertaken to reduce or avoid the emissions of GHGs and hence contribute to global efforts to slow down the rate of climate change. Kenya like any other developing country does not have adequate technological capacity to effectively mitigate Climate Change. There is therefore the need for transfer and development of appropriate technologies for climate mitigation. In order to do this, Kenya as a country will need to identify out technology needs for climate change in line with the national development priorities. It is for the above reason that Kenya has embarked on a Technology Needs Assessment process that is fully participatory involving many stakeholders including the Government, Private Sector, Civil Society and International Organisations. The objective of technology needs assessment (TNA) is to identify, evaluate and prioritize technological means for both mitigation and adaptation for the purpose of achieving sustainable development.

The TNA process involved review of national development Plans, UNFCCC, workshop with stakeholders, and expert knowledge. The following sectors were identified during the TNA process: Energy, Industrial processes; Agriculture, Forestry and Land-use change and Waste Management.

The sectors were identified and prioritized on the basis of their contribution to overall national economic development and their potential for contribution to climate change mitigation.
As a result, the study identified and prioritized two main sectors for mitigation: namely Energy (including Transport-subsector) and Waste Management.

Finally the study undertook Technology prioritization for the above sectors based on carbon dioxide abatement, costs and their socio economic and environmental benefits by applying the Multi Criteria Analysis (MCA) using Definite Student Model. The Analysis selected the following technologies in the Energy Sector in order of their priority. Solar Home Systems (SHS); Solar Dryers; Non-Motorized Transport (NMT), Mini-hydros, Electric Trains; Mass Transport; and Co-generation. Similarly in the Waste Management Sector, the following Technologies were prioritized as follows: Methane capture from landfills; Plastic waste recycling; Waste paper recycling; Waste composting; Biogas; and Waste re-use.
The following two technologies in the energy sector were selected in order of priority: Solar Home Systems (SHS) and Solar Dryers.

The following two technologies in the Waste management sector were selected in order of priority: Methane capture from bio-digesters and waste paper recycling. These technologies will be analyzed further during the next phase of the TNA process.

The sector and energy prioritization process and prioritized technologies were validated in a stakeholder workshop held on 25th July 2012.

CHAPTER 1: OBJECTIVES OF THE TECHNOLOGY NEEDS ASSESSMENT (TNA)

1.1 Objectives of the TNA

The primary goal of a TNA is to identify technological needs for achieving a country's development priorities in a sustainable manner. The focus is therefore to use environmentally sound technologies (ESTs), which can provide the required development services with low or zero Greenhouse gas (GHG) emissions.

Specifically, the objective of the TNA is to identify, analyze, evaluate, and prioritize technological needs for achieving sustainable development, and identify technologies which reduce emissions of GHGs. If properly conceived and implemented, a TNA can achieve a number of additional desirable ends, namely contributing to enhanced capacity to acquire environmentally sustainable technologies, developing important links among stakeholders to support future investment and barrier removal, and diffusing high priority technologies throughout the sectors of national economy. Hence the purpose of the TNA is to establish a baseline for a portfolio of programmes and projects to facilitate the transfer of and access to ESTs and know how in the implementation of Kenya's economic development programmes.

1.2 National Circumstances

1.2.1 Population

According to 2009 census, the Kenyan population stood about 40 million and is currently projected to be over 41 million. Kenya is a rainbow Nation with over 42 different indigenous ethnic group and other races which have been *Kenyanized/naturalised* over the years through birth and naturalization. In addition almost all nationalities are found in Kenya working for various International Organizations, Private Sector and International NGO's which are based in Kenya. The current constitution divides the country into 47 counties which are basically the Districts which existed before 1992.

1.2.2 Climate

Kenya's climate varies both in time and space on account of the equally variable topography that include large water bodies; high mountain ranges; and the Great Rift Valley among others. The small scale circulation patterns generated by these features interact with the large scale circulation systems mainly the Inter- Tropical Convergence Zone (ITCZ) to influence the weather/ climate patterns. The climate is also influenced by global features such as El- Nino/Southern Oscillation (ENSO) events that are controlled by the sea surface temperature fields of the Pacific Ocean, upper level wind reversals known as Quasi- Biennial Oscillation (QBO), sea surface temperature fields in the adjacent oceans such as the Indian Ocean Dipole (IOD) as well as the south west Indian ocean Tropical Cyclone activities. There are two main rainy seasons followed by long dry periods. The long rains normally occur from March to May while the short rains fall between October and December. The wettest month is usually April with approximately 266 mm of rainfall while the driest month is usually August with about 24 mm of rainfall. On average February is the hottest month with a range of 13^0C to 28^0C while July is the coolest with a range of 11^0C to 23^0C but the regimes are irregular and erratic and the effects of climate change is already affecting the rainfall regimes.

1.2.3 Ecosystems (Agro-Ecological Zones)

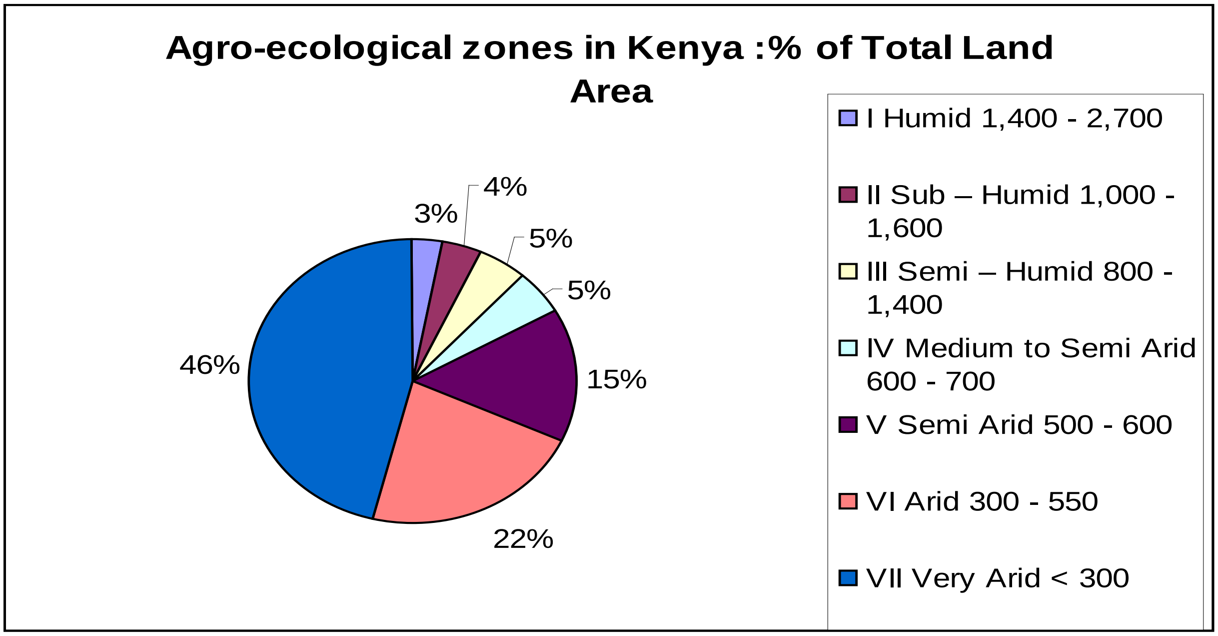
The country is divided into seven agro-ecological zones. These zones are determined by rainfall, temperature and topographical factors. The ecological zones are listed thus:-

i) Afro – Alpine Moorland and grassland or barren land above the Forest line in the mountainous regions.
ii) Forests and derived grasslands and bush lands
iii) Land of High Agricultural Value, and low forest potential

iv) Semi – humid region with average rainfall of 700mm to 850 mm per year
v) Semi – Arid Zone with 500 mm to 700 mm average rainfall per year
vi) Arid lands with 300mm to 500 mm average rainfall and
vii) Very Arid zone with annual rainfall of about 200 mm to 300 mm

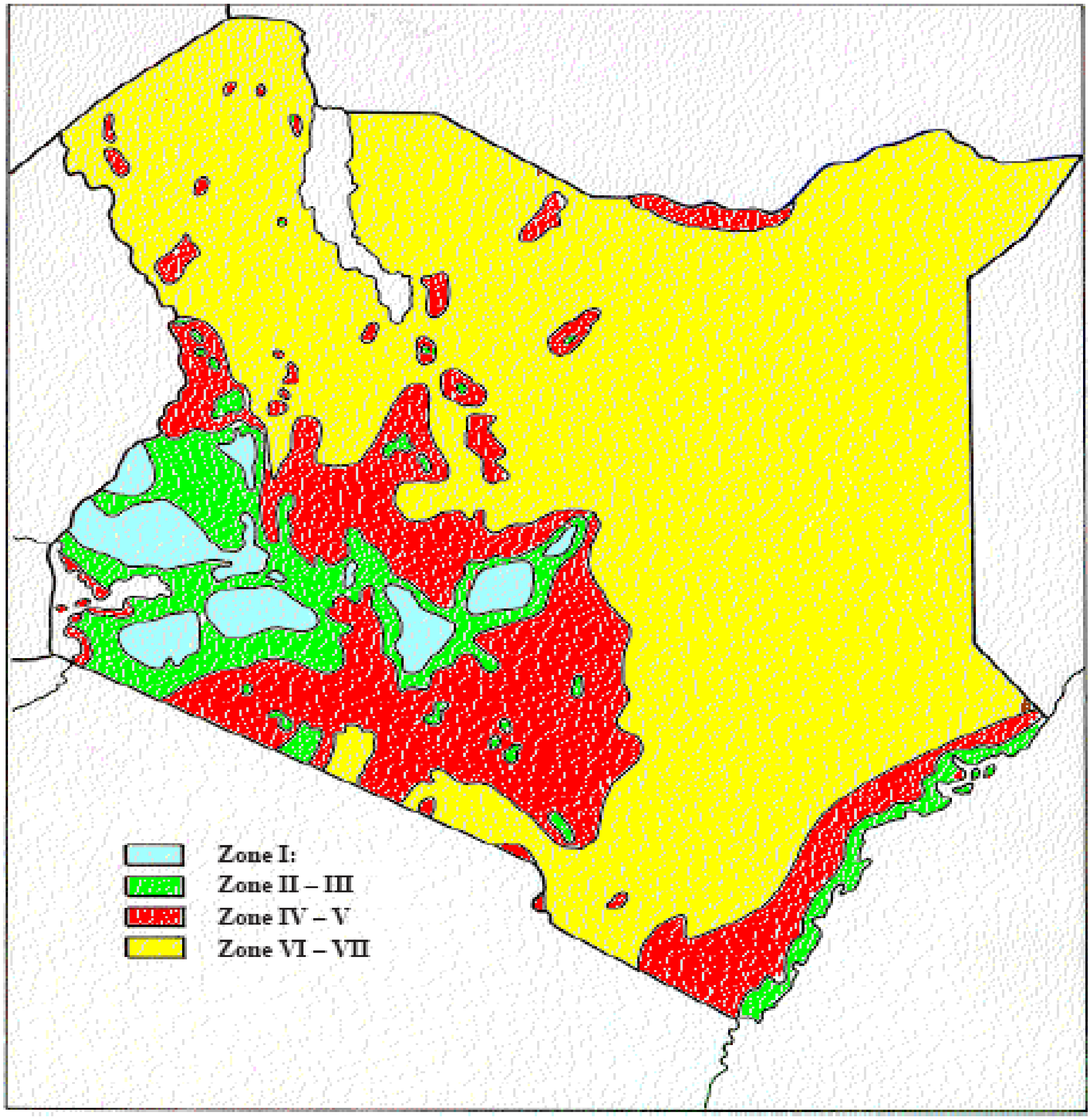
Zones I to IV that cover 16% of total land area, are of high to medium agricultural potential (food crop production, cash crops and dairy farming) and supports about 80% of the country's population. The remaining 20% of the population live in zones V to VII, which comprise 84% of the total land area. These zones have the least potential for agriculture but are rich in wildlife, mineral resources and are therefore important for tourism development and mining (Refer to Figure 1.2 and 1.3).

Fig. 1.1: Percentage of the various agro-ecological zones as a percentage of the total land area



Source: Derived from the NEAP 2009-2013 Report

Fig. 1.2: Agro-Ecological Zones in Kenya

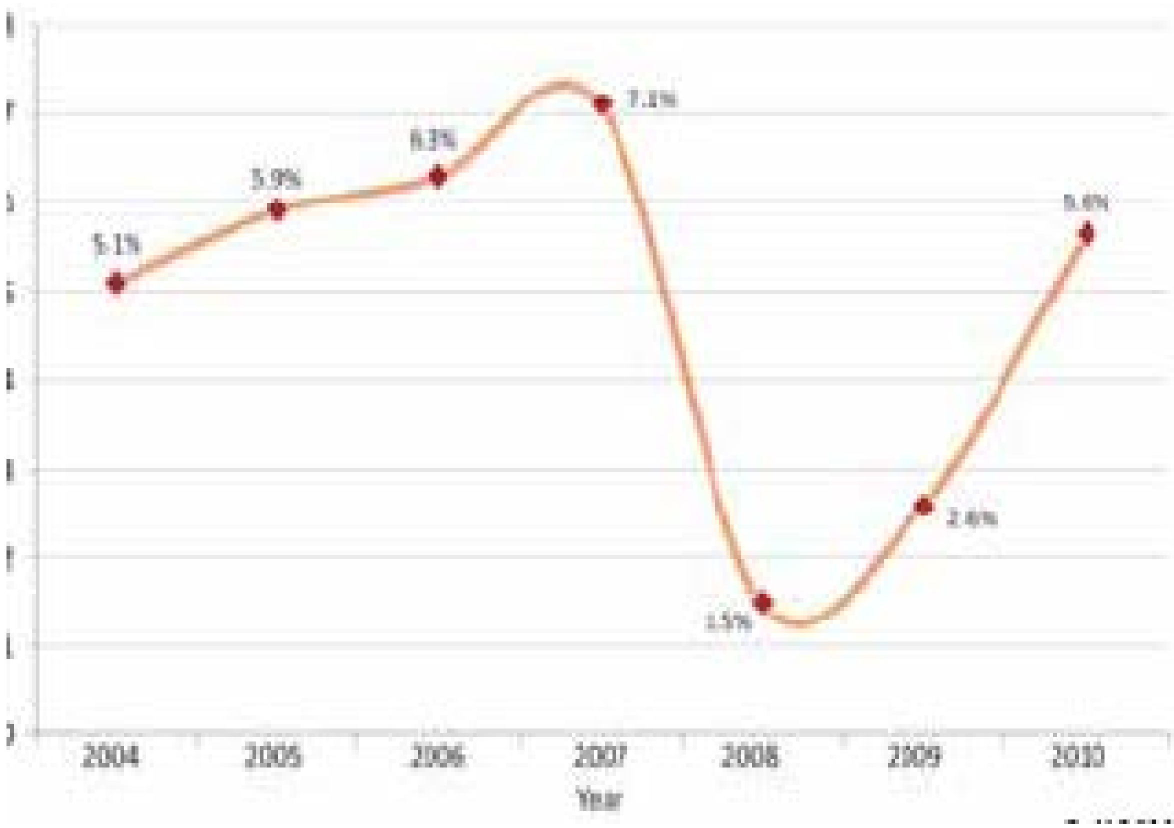


Source: Kenya National Environment Action Plan (2009)

1.2.4 Overview of the Economy

Kenya's real growth of GDP decreased from 7.1% in 2007 to 1.7% in 2008 mainly due to post election violence, poor state of infrastructure, depressed investment, and slump in industrial production, deteriorating terms of trade and increased climatic variations. It rebounded a bit in 2009 to 2.6% due to government's efforts of putting an economic stimulus package and growth in some key sectors such as tourism, building and construction, telecommunications and fishing. The country's GDP rose to 5.6% in 2010 due to micro-economic stability, low inflation, increased credit in the private sector and better weather. According to Kenya's Vision 2030 the economy is expected to grow by 10% per year. This trend was reversed in 2011 due to drought and inflation. Kenya's economic growth rate from 2004 to 2010 is illustrated in the figure 1.4 below.

Fig. 1.3 : Kenya's Economic Growth Rate (2004 to 2010)



1.2.5 Environmental Factors

Kenya has serious environmental problems, which include deforestation, soil erosion and desertification, water shortage and quality, poaching and pollution at both the ecosystem and community levels. Currently Kenya is classified as a water scarce country. In the Forestry Sector productivity has declined due to overexploitation and degradation.

Loss of forest cover aggravates erosion, the siltation of dams and causes flooding resulting in environmental disasters. The government has undertaken mitigation measures in form of legislation, regulations, rules, strategies and action plans as well as programmes.

1.2.6 Poverty and the Environment

More than half of the Kenyan population lives on less than a dollar a day. This state of the national circumstances has resulted in heavy dependence on natural resources for survival, resulting in resource, over utilization and degradation. The country's economy is agriculture based and relies heavily on rain fed agriculture which is very climate sensitive since the rains are irregular and erratic.

1.3 Existing Policies and Plans addressing about Climate Change Mitigation and Development Priorities

1.3.1 National Sustainable Development Strategies

The current Development Plans and Strategies are anchored on Vision 2030 which is Kenya's Blueprint for transforming the country to a newly Industrialized Middle Income Country that is able to provide high quality of life to all its citizens by the year 2030. It runs from 2008-2030. The Vision is based on three (3) pillars i.e. Economic, Social and Political.

- The Economic pillar aims at improving the welfare of all Kenya's through economic programme for the whole Republic. Sectors in this pillar are: tourism, agriculture, manufacturing, business, trade and financial services.
- The Social Pillar aims at building a just and cohesive society and secure environment. Sectors in this pillar are: health; environment; water and sanitation; education and training; housing and urbanization; gender, youth and vulnerable groups.
- The Political Pillar aims at realizing a democratic political system founded on issues based politics that relies on the rule of law and protects the rights and freedoms of every citizen. One important outcome from the political pillar is the **Kenya Constitution 2010.** The promulgation of the Kenya Constitution in 2010 marked an important chapter in Kenya's development. It is hailed as a green Constitution as it embodies elaborate provisions with considerable implications for sustainable development. Chapter V of the constitution is entirely dedicated to land and environment. It also embodies a host of social and economic rights of an environmental character, such as the right to water, food and shelter among others.

In order to realize the benefits of the Vision, its implementation is based on 5-year successive plans. In implementing the Vision 2030 the country will strive also to meet its obligations under the Millennium Development Goals (MDGs) which were approved by the United Nations General Assembly in the year 2000.The target for the MDGs is the year 2015. Currently the country is behind schedule in implementing MDGs.

1.3.2 National Climate Change Response Strategy (NCCRS)

The NCCRS primary focus is ensuring that climate adaptation and mitigation measures are integrated in all government plans and development objectives. This requires collaborative and joint action with all stakeholder including private sector, civil society, NGOs, and communities in tackling the impacts of climate change.

Policy directions, legislation as mitigation and adaptation measures in various sectors are also outlined. The need for technology development, transfer and utilization is also evident as a major action for alleviating the impacts of climate change. The Strategy also identifies several measures for climate change mitigation, thus: efforts that seek to prevent or slowdown the increase of GHG concentrations and enhancing potentials sinks. Some of the recommended mitigation measures in various sectors are outlined in Table 1.1 below.

Table 1.1: Recommended Mitigation Measures per Sector

	Sector	Recommended Mitigation Measures
1.	Forestry	Plant more trees to act as carbon sinks, 10% of forest cover is the FAO recommended cover per country's total land mass
2.	Energy	Use alternative sources such as geothermal, wind and solar technologies
3.	Transport	Use low cost public transport
4.	Agriculture	Use biotechnologies which increase food production Management of agricultural wastes Promotion of agro forestry (Tree based intercropping (TBI))
5.	Carbon trading mechanisms	Promote carbon trading in agriculture and forestry activities

Source: Derived from NCCRS 2010

It is envisaged that Kenya will become a Green Economy by the year 2020.

1.3.3 Relevance of TNA to National Development Priorities

The national development objective for the Kenya Government is to achieve sustainable development through integration of environment, social and economic concerns and enhancing linkages and collaboration across different sectors as well as improving partnerships between the government, private sector, civil society and communities on matters of environmental management and conservation.

This is especially crucial because the main productive sectors are environment and natural resources-based and a significant number of people derive their livelihoods from environmental goods and services. Increased economic activities particularly in agriculture and industry coupled with rising population have adverse impacts on the country's fragile environment; constraining the capacity of the environment to provide for the increasing needs. The key economic sectors are also sensitive to climatic conditions.

National development plans and programmes have stated that climate change is not only an environmental phenomenon but also a development issue. It is imperative to address climate change concerns if sustainable development is to be realized. The government's development strategies aim at addressing the duo problems of poverty and environmental conservation. These directly and indirectly integrate climate change adaptation and mitigation into development planning, programmes and budgeting.

There are however, challenges that hinder the integration of climate change into the development programmes and process. Some of these challenges are summarized below:

- Capacity to integrate environment and climate change issues has not been adequately factored into most of the sectors of the country's economy including Government development policies and plans.
- Inadequate capacity and technology in terms of finance, human, institutions, technical and political goodwill to mitigate climate change hinders the achievement of Vision 2030 and MDGs resulting in underdevelopment.
- Weak coordination of climate change activities hinders development of climate proof socio-economic development anchored on low-carbon path.

These challenges therefore call for technologies for climate change mitigation to enable the country to effectively mitigate climate change.

CHAPTER 2: INSTITUTIONAL ARRANGEMENT FOR THE TNA AND STAKEHOLDERS INVOLVEMENT

2.1 National TNA Team

The TNA process is a national project involving various ministries, NGOs and the private sector. Table 2.1 below summarises the main institutions involved in the process:

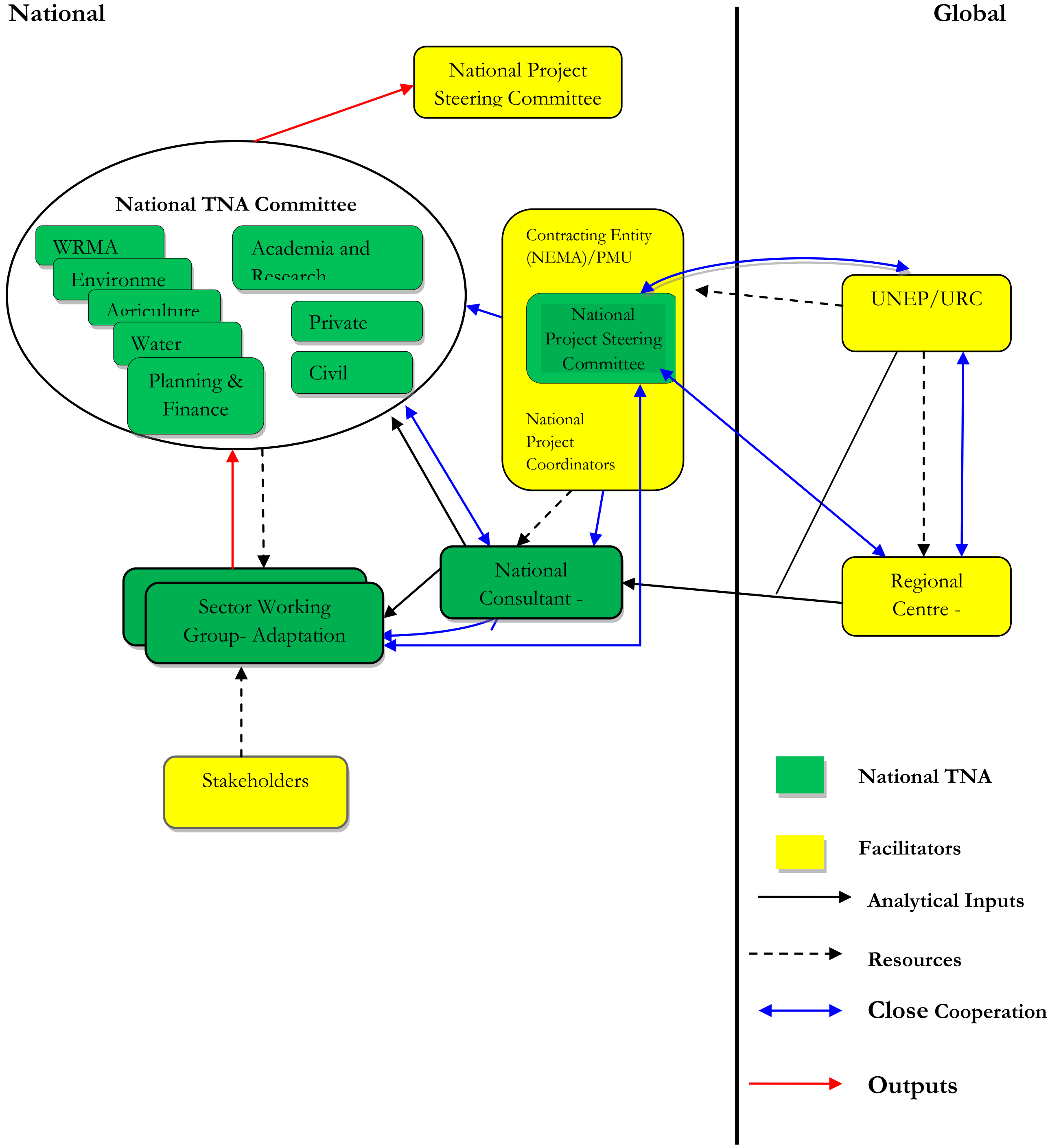
Table 2.1: TNA Institutional Arrangement

ORGANIZATION STRUCTURE	COMPOSITION	MAIN FUNCTIONS
UNEP RISOE/ ENDA	Department and Unit dealing with climate change	Technical and financial support
National Project Steering Committee	Ministries of Energy, Local Government, Finance, MEMR, Forestry and Wildlife, Agriculture, Water, Public Health, National Council for Science and Technology (NCST)	Policy & Supervisory roles
NEMA – National Coordinating Institution	National Project Coordinator (Anne Nyatichi Omambia PhD – Climate Change Desk Officer NEMA)	• Overall Coordination link between UNEP and Consultants • Link between PSC and Consultants • Administration & day to day running of Project
Project Management Unit	The Department of Environmental Planning and Research(DEPR) at NEMA in collaboration with all other NEMA Departments, line ministries, representatives from private sector Kenya Association of Manufacturers and National Council Science and Technology	To coordinate with and support the national consultants to ensure that all the objectives of the TNA project are met and project is successfully completed
Consultants	Professional Training Consultants(PTC)	Technical Inputs
Main stakeholders	Ministry of Environmental and Mineral Resources Ministry of Energy Ministry of Forestry and Wildlife Ministry of Agriculture Ministry of Finance Ministry of National Planning and Vision 2030 Kenya Electricity Generating Company Kenya Power and Lighting Company Ministry of Transport Ministry of Local Government Climate Network Africa (CNA) Kenya Clean Production Centre Kenya Industrial Research Institute University of Nairobi Kenya Meteorological Dept. City Council of Nairobi Chloride Exide Ltd Kenya Association of Manufacturers (KAM)	Validation of Project Outputs and Consensus Building

ORGANIZATION STRUCTURE	COMPOSITION	MAIN FUNCTIONS
Sector Working Groups	Ministry of Energy	Policy formulation and co-ordination
	Kenya Tea Development Authority	Tea processing Energy Consumer
	Climate Care	Climate Change experts
	Chloride Exide	Manufacture of batteries
	Kenya National Cleaner Production Centre	Cleaner Production focal point
	Nairobi City Council	Waste Management
	Ministry of Environment and Mineral Resources	Environmental policy formulation and co-ordination
	University of Nairobi	Research and development on climate change mitigation
	Kenya Association of Manufacturers	User of climate change mitigation technologies
	Ministry of Finance	Policy formulation and co-ordination on taxation and fiscal matters
	Office of the Prime Minister	Co-ordination of climate change
	Kenya Electricity Generating Company	Power generation and regulation
	National Council for Science and Technology	Clearing house for technology development

Source: NEMA per com

Fig. 2.1: Institutional Structure of the TNA Project (Adopted from Dhar et al, 2010)



2.2 Stakeholder Engagement Process followed in TNA

Stakeholder engagement process followed in the TNA is outlined below:

2.2.1 Stakeholder Identification and Analysis

Stakeholder analysis was undertaken to help in the identification of stakeholders and their roles in the TNA process. This was in consultation with the Client (NEMA). Detailed analysis was necessary to enable the TNA process to be undertaken in participatory and consultative process in order to incorporate the views and interests of the major stakeholders in climate change mitigation in the country. Stakeholders are central to the TNA process because they will be intimately involved not only in the process itself but also in the implementation of the resulting technologies.

For the purpose of this study, Stakeholders are institutions that are in one way or another involved or have interests in climate change technology development, promotion, transfer or application as well as individuals who have taken keen interest in climate change related activities.

a) **Government Institutions**
These are the institutions that have the responsibility for policy formulation and regulation in the various priority sectors identified for technology needs assessment. They include Government Ministries, Departments and parastatals.

b) **Private and Public Industries, Association and Distributors**
These are institutions involved in the provision of GHG emitting services or are vulnerable to climate change impacts

c) **Electric Utilities and Regulators**
These are institutions that are involved in power generation, supply, and regulation.

d) **Technology Development Suppliers**
These are institutions that are engaged in climate change technology development transfer, promotion and application. They include both private and public institutions.

e) **The Finance and Investment Community**
These are institutions that are likely to provide the capital for technology project development and implementation.

f) **Technology End Users**
These include households, communities, small businesses, farmers and will be using technologies, and that would experience the effects of climate change.

g) **Non- Governmental Organizations**
These are institutions that are involved in advocacy, and promotion of environmental and social objectives.

h) **Support Institutions**
These are institutions that will provide technical support to both the government and industries. Examples of these are Universities, Industry R & D, and consultants.

i) **Awareness Creation Institutions**
These include labour unions, consumer groups and the media.

j) **International Organization Participating in Climate Change Mitigation Programmes**
These are international organizations that participate in programmes that participate in climate change mitigation at global or regional level. Some of them could act as financiers to climate change programmes.

The stakeholder analysis report was presented and enriched at the inception workshop held on June 2011. NEMA used this list to identify institutions invited for TNA workshops and the Consultant also used stakeholders identified to engage on one to one basis mitigation issues. Detailed list of institutions identified under each category are shown in (**Annex 2.1 of this Report).**

2.2.2 Stakeholder Involvement

Stakeholder engagement for the TNA process were through NEMA Project Management Unit, consultation with key institutions on a one to one basis (mainly the use of structured questionnaire) and workshops held. The whole process of stakeholder involvement is summarized on the Table 2.2 below

Table 2.2: Summary of Stakeholder Involvement and Input in the TNA Process

	TNA Activities	**Activities**	**Date**
i)	Inception Workshop	Sectors and technologies were identified during inception workshop, questionnaire responses and stakeholders meeting at NEMA. Discussed with the Project Management Unit and enriched at the Inception Workshop **(see Annex 2.3 for attendance list)**	21st June 2011
ii)	Sector Identification and Prioritization	Technologies were identified through literature review, questionnaires a structured questionnaire and stakeholders meeting at NEMA where consensus on sector and technology prioritisation was reached MCA involving stakeholders (**see Annex 2.2 for names of stakeholders engaged on one to one basis**.)	June 2011 – July 2012
iii)	Technology Prioritization	Stakeholders reviewed and validated priority sectors and prioritized technologies	22nd February 2012
iv)	Sector and Technology Prioritization Validation	Stakeholders did the following: i) Sector Identification, prioritization and selection ii) Consequently the stakeholders validated technology identification and prioritization and the final technologies selected for next TNA process. iii) Stakeholders were introduced to barrier identification analysis and measures to overcome barriers. iv) The stakeholders undertook initial barrier identification and analysis exercise.	25th July 2012

CHAPTER 3: SECTOR SELECTION

The following sectors as identified under IPCC guidelines are considered and described under mitigation. These sectors are as follows:

i) Energy
ii) Industrial Processes
iii) Agriculture
iv) Forestry and Land-use change and
v) Waste Management

3.1 Overview of Sectors and GHGs Emissions

3.1.1 Energy Sector

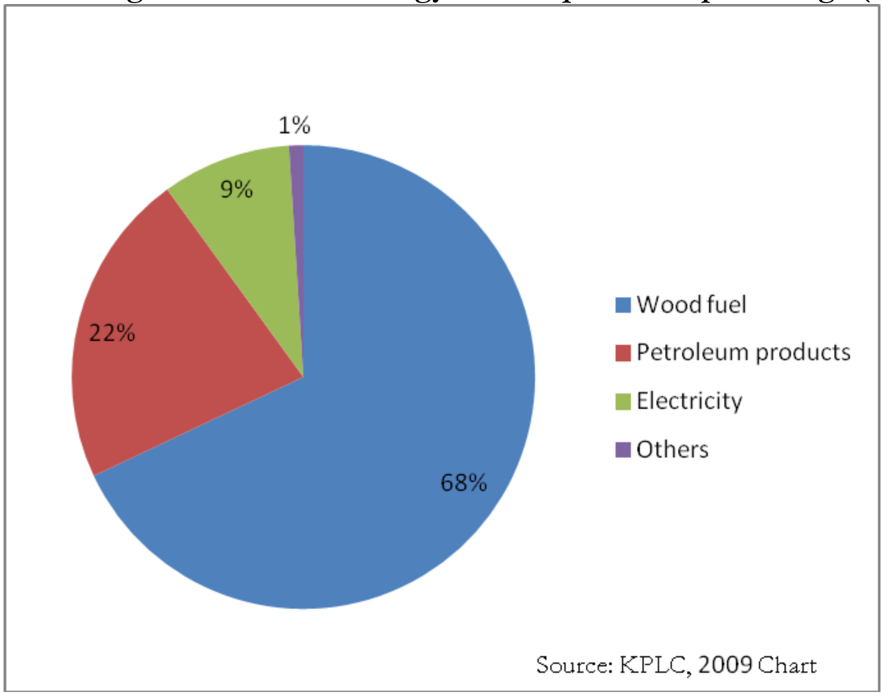
This chapter presents an overview of sectors and the GHG emission status and trends of the different sectors.

Energy is one of the infrastructural "enablers" of the three pillars of Kenya's Vision 2030. The sector is a source of energy for domestic, industry and commercial use besides being the driver of the economy. This is because the level and intensity of commercial and industrial energy use in the country is a key indicator of the degree of economic growth and development. The government in collaboration with the private sector has initiated programmes to ensure that the country is energy sufficient by 2020 (Table 3.2 and Fig 3.3).

Energy is sourced from a variety of renewable and non-renewable sources such as hydropower, biomass, solar, wind, petroleum, and geothermal (Tables 3.2 and 3.3 and figures 3.2 and 3.3). Fossil fuels are the major source of energy used by commercial and industrial establishments. Electricity is the third most used source of energy in Kenya after biomass and fossil fuels (fig. 3.1). About 80% of Kenya's population depends on wood-fuel for its domestic energy needs. The scarcity of fuel-wood and the impact of its escalating prices are acute at the household level because of poverty and limited alternatives.

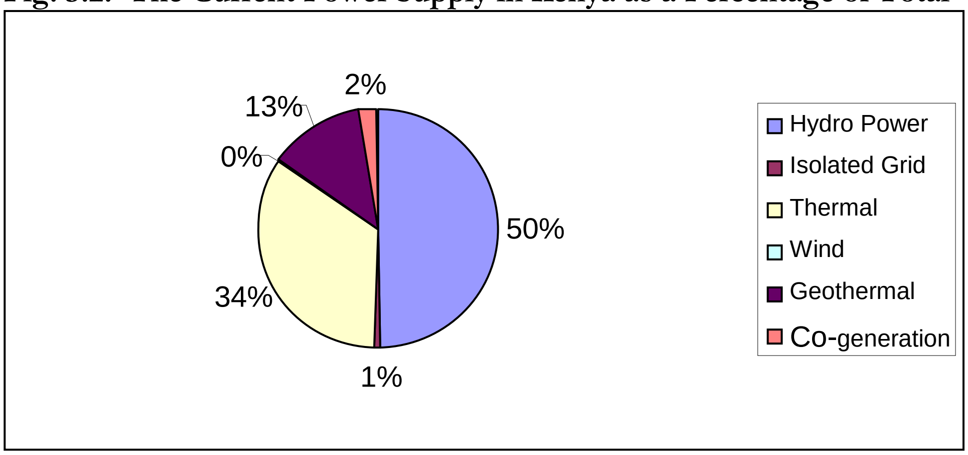
Electricity contributes 10% of the country's energy demand. So far, about 20% of the 40 million of population have access to commercial electricity. The main sources of commercial electricity in Kenya are hydro, geothermal and fossil fuel fired generators (Fig. 3.2 and 3.3 and Tables 3.2 and 3.3). The installed capacity of the interconnected system is 1,533 MW comprising 761 MW hydro, 198 MW geothermal, 5.4 MW wind, and 525 MW thermal. Several isolated mini-grids make up a total of 18 MW. The National Energy Policy advocates for the provision of adequate, reliable, cost effective and affordable energy to meet Kenya's development needs while protecting and conserving the environment.

Fig. 3.1: National Energy consumption as a percentage (%) of total



Source: KPLC (2009)

Fig. 3.2: The Current Power Supply in Kenya as a Percentage of Total



Source: Ministry of Energy (2012)

Table 3.1: Projected Energy Demand up to 2020

Energy Form	**Demand in 2003**	**Projected Demand 2020**
Biomass	36 Million tonnes of wood	53.41 Million tonnes
Electricity	1172 MW of electric power	2839 MW
Petroleum	2.3 Million tonnes of petroleum	3.5 Million tonnes

Source: NEMA (2005)

Table 3.2: Installed and Projected Electricity Capacity by type

Project	Type	Capacity MW	Commissioning Date
Thermal Plant-Kipevu	Diesel	120	Dec. 2010
Eburu	Geothermal	2.5	Jan. 2011
Songoro	Hydro	21	Dec. 2011
Raising of Masinga Dam	Hydro	15	April 2012
Ngong 3	Wind	14	July 2012
Kindaruma 3rd Unit	Hydro	25	Oct-2012
Olkaria IV	Geothermal	140	Jan-2013
Olkaria 1 Units IV and V	Geothermal	140	July 2013
Mombasa Coal	Coal	300-600	July 2013
Rabai	Diesel	88.6	Sept. 2009
Mumias	Co-generation	26	Sept-2009
Iberafrica	Diesel	52.5	Sept-2009
Aggreko Embakasi 3	Diesel	80	Sept-2009
Aggreko Suswa	Diesel	60	Oct-2009
Iberafrica 3	Diesel	30	Jan-2012
Athi River Power Plants	Diesel	240	July-2012
ARM	Coal	19	July-2012
Lake Turkana	Wind	300	July-2013
Osiwo Wind	Wind	50	July 2013
Aeolus	Wind	60	July 2013
Orpower 4	Geothermal	50	Jan-2014
Small Hydros	Hydro	25	2011-2015
Ethiopia	Import	200	2015

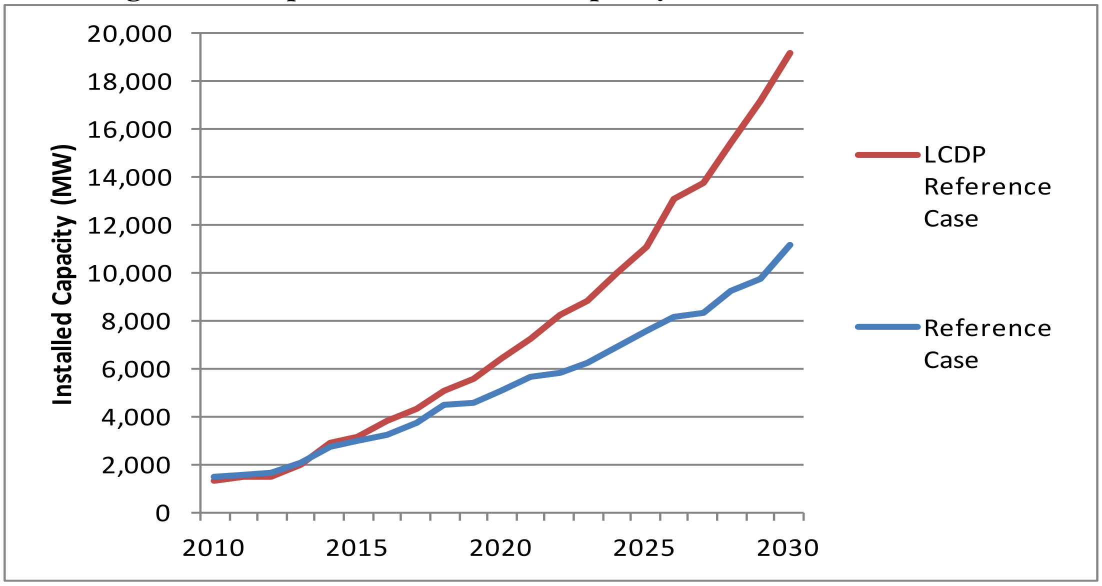
Sources: KPLC (2009)

Table 3.3: Installed Electricity Capacity by KENGEN

Name	Type	Capacity (MW)
Kamburu Power Station	Hydro	92
Kindaruma power Station	Hydro	44
Kiambere	Hydro	144
Gitaru Power Station	Hydro	80
Masinga Power Station	Hydro	40
Turkwel Power Plant	Hydro	106
Sondu Miriu	Hydro	60
OlKaria I Power Station	Geothermal	45
OlKaria II	Geothermal	70
OlKaria III	Geothermal	48
OlKaria IV	Geothermal	1.8
JBE Kipevu	Gas	30

Sources: KPLC (2009)

Fig. 3.3: Comparison of installed Capacity between 2010 and 2030



Source: Cameron et al. (2012)

a) Electricity Generation

Electricity generation in Kenya is dominated by hydropower, diesel generation and geothermal which together make up almost 99% of electricity connected to the national grid. In recent years thermal sources such as diesel and gas (see figure 3.2) have made up the largest portion of new capacity added in the last decade due to their ability to be rapidly deployed to meet emergency demand despite the available renewable energy resources which are generally readily available in Kenya especially geothermal power, wind and solar.

The energy sector has been dominated by a large public utility company (KenGen), that has developed the vast majority of electricity generation plants to date, complemented by a small, but growing number of independent power producers (IPPs) that play a substantial role in electricity generation and particularly in proposing new renewable energy projects for development.

After Energy Sector liberalization, four Independent Power Producers (IPPs) are now in operation providing 186 MW mostly from thermal sources using diesel. Three of these namely, Iberafrica, Westmont and Tsavo Power Plant are thermal-based injecting 174 MW while or Power 4 is a geothermal plant providing 50 MW (table 3.3). The Independent Power Producers contribute 16% of energy consumption.

i) Renewable Energy Sources

Renewable Energy (RE) is most often defined as energy derived from inexhaustible sources - the sun, the wind, and the Earth. Kenya is endowed with significant amounts of renewable energy sources, which, inter alia, include hydro, geothermal, solar, wind. Methane from municipal landfills can be termed renewable if a sustainable supply of the required raw materials can be assured. Other renewable energy sources include power alcohol, biogas, bio-fuels (bio-ethanol and bio-diesel).

Uncertainty about the future of the hydro power as a renewable energy resource under climate change is a key issue for the energy sector. The Government recognizes that alternative renewable energy sources hold tremendous potential, especially for reducing heavy dependence on woody biomass. Renewable energy resources in Kenya comprise the following:

- **Wind power**

Wind energy remains largely under-developed and under-exploited. A study in 2002 found there is the potential for about 0.6 per cent of total energy to come from community wind energy Government of Kenya (GOK) 2002. Wind energy applications, especially those related to mechanical functions, have a long history in Kenya. In 1986, there were over 200 working windmills, of which about 100 were in Lamu and Mombasa districts. Local expertise for building windmills, especially for water pumping, is still available in the private sector. The Ministry of Energy developed a National Wind Energy Resources Atlas for Kenya in 2003. It provides useful information to facilitate both public and private sector investment in this important energy sub-sector.

- **Hydropower**

Hydro-power (Tables 3.2 and 3.3 and figure 3.2) constitutes around 60 per cent of the total electricity generated in Kenya and is the leading source of electrical energy, with an installed capacity of 761MW. However, hydropower is obtained from the countries major rivers whose water volume is dependent on rainfall which is sensitive to climate variability. Therefore, during drought period, the country suffers from reduced energy generation from hydropower and therefore reverts to emergency thermal generation which leads to emissions of CO_2.

- **Solar energy**

About 1.6% of Kenyan households use solar energy, and its adoption has been slow due to the high initial installation costs (KNBS 2007 and Ikiara 2009). It is estimated that Kenya receives 4-6 $kW/m^2/day$ of solar energy, on average, which translates into about 1.5 billion tonnes of oil equivalent, making it a major alternative for energy. Although Kenya is a leader in installation of solar home systems (SHS) in Sub-Sahara Africa, solar energy is currently under-exploited although it is widely regarded as a plausible option to stimulate rural electrification. To date, it is being exploited in Kenya for lighting (photovoltaic)-solar home systems, water pumping (mechanical), refrigeration, and solar water heating. The solar market is currently estimated to be worth over US$ 4 million per year. A solar photovoltaic policy framework and strategy is being developed under the power sector re-organization programme.

- **Biomass**

Biomass energy is the principal source of energy for most Kenyans, particularly in the rural areas. Firewood remains the predominant fuel for cooking in rural areas. Nationwide 68.3% and 13.3% of Kenya's household population utilize firewood and charcoal for cooking respectively thereby exerting enormous pressure on the environment as much of it is obtained from unsustainable sources.

In general there are two main approaches to using plants for energy production: growing plants specifically for energy use, and using plant residues from others use. The best approaches vary from region to region according to climate, soils and geography.

Ethanol can be used as a fuel for vehicles in its pure form, but it is normally used as a gasoline additive to increase octane and reduce vehicle emissions. Bio-ethanol is produced by several sugar companies in Western Kenya

Biodiesel is made from vegetable oils, animal fats or recycled greases. Bio-diesel can be used as a fuel for vehicles in its pure form, but it is normally used as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles. Jatropha is being promoted as source of bio-diesel in the coast province.

- **Geothermal Power**

Kenya has registered significant progress in exploring geothermal energy for power generation. It has an installed capacity of 198 MW, equivalent to about 13% of the country's installed electricity generation capacity which is fed into the national grid from three plants located at Olkaria by 2030.

Kenya is one of the leading producers of geothermal energy in Africa although the current production at approximately 198 MW is still fairly small yet the full potential is said to be in the range of 3000-5000 MW.

ii) Non Renewable Sources

Coal, diesel and gas constitute sources of fossil fuel energy in Kenya.

- **Coal**

The recent discovery of coal resources in Mui Basin in Kitui County is expected to play a large part in Kenya's long-term electricity sector planning. Athi River Mining Company is proposing to generate 30MW of electricity from coal by 2012.

- **Diesel**

Kenya has installed several power plants to generate electricity from diesel power. Most of the diesel power plants are supported by Independent Power Producers (IPPs) (table 3.2). Kipevu I Diesel plant generates 120 MW. The proposed Athi River Power plants have potential to generate 240 MW before end of 2012.

- **Gas**

Kipevu I Gas Turbine Power Plant in Kenya is located at Mombasa and generates 30 MW. Fossil fuel sources provide about 34% of Kenya's power supply (Table 3.2).

b) Energy Consumption/Demand

i) Transport Sub-Sector

The Transport Sub- Sector comprises five major types: road, rail air, sea/lake and pipeline with the road transport dominating. Transport plays a crucial role in the country's development and integration. The Transport Sub-Sector is crucial in the promotion of socio-economic activities and development. An effective efficient and reliable transport system is a mainspring for rapid and sustained development in terms of national, regional and international integration, trade facilitation, poverty reduction and improvement of welfare of citizens. Roads freight transport embraces domestic and international conveyance of goods by lorries, trucks, heavy vans, trailers and fuel tankers.

Road transport covers both public and private passenger movement on roads using buses, mini-vans (locally referred to as matatus), taxis, tour vehicles, light delivery vehicles, private motorcars and motorcycles.

The sub-sector accounts for 56% of the fossil fuels consumed nationally. This is likely to rise in future due to the rapidly rising demand for motorized transport.

The main modes of transport in Kenya include:

- **Road transport**

Kenya has extension network of paved and unpaved roads. These include International Trunk Roads, National Trunk Roads, Primary Roads, Secondary Roads, Special Purpose Roads and Unclassified Roads. There are well over one million cars in the Kenyan roads with additional rate of about 10,000 per year. The heavy commercial vehicles number over 120,000.

- **Railways**

The railway system is very important as it links the nation's ports and major cities and connects Kenya with neighbouring Uganda and Tanzania. There are proposals to link Kenya to Juba in South Sudan. Fossil fuels are used to power locomotives used by the railways.

- **Pipeline transport**

The main objective of setting up The Kenya Pipeline Company and constructing the Pipeline System was to ensure efficient, reliable, safe and cost effective means of transporting petroleum products from Mombasa to the hinterland. In pursuit of this objective, the company constructed a pipeline system for the transportation, storage and distribution of white petroleum products. The pipeline system was intended to reduce the number of vehicles transporting petroleum fuels from Mombasa to the hinterland.

Pipeline transport hinges on its ability to offer least-cost transportation of fuel and its ability to attract traffic (tankers) away from roads. This is because pipeline transportation is a faster and more economical mode for transportation of petroleum fuels than road or rail.

The pipeline transport system though the most environmentally sound mode of moving petroleum fuels, it is associated with risks of spillage and fires with severe environmental consequences. The country lacks adequate contingency plans to deal with such risks and the consequences thereof.

ii) Industry Sub-Sector

Energy is the main driver of Kenya's industrial production.
Kenya Vision 2030 was conceived to be implemented by way of 5-year rolling plans known as the Medium Term Plans (MTP). The first of such MTP covers the period 2008-2012. Industry is an enabler of the economic pillar of Kenya's Vision 2030. Many industries use fossil fuels and electricity to power their operations.

In 2007, manufacturing contributed 10% of GDP, 12.5% of exports and 13% of formal employment. Industrial and manufacturing sub-sector are significant contributor to Kenya's economy (Government of Kenya (GOK), 2007).

iii) Agriculture Sub-Sector

The level of mechanization in the agriculture sub- sector is fairly low. Consequently GHG emissions from fuel consumption in the sector are negligible.

iv) Forestry and Land Use Sub-Sector

As a sub-sector of the energy sector, forestry and land-use in Kenya is of less significance in that most forestry activities are labour intensive and therefore less mechanized.

v) Residential/Commercial Sub-Sector

Residential/Commercial sub-sector comprises households, schools, colleges, hospitals, hotels and restaurants, private offices, and government institutions among others. All these institutions use different forms of energy in one way or another whether it is for cooking, lighting or heating.

Biomass is the most commonly used fuel for cooking in rural areas (mostly wood fuel) and accounts for about 68 percent of the total primary energy consumption (while 13.3% of the population use charcoal for cooking), followed by petroleum at 22 per cent, electricity at 9 per cent and others at about less than 1 per cent. In rural areas, the reliance on biomass is over 80 per cent. In 2005, 39,157,452 tonnes of wood fuel were consumed (Government of Kenya (GOK), 2005).

Only approximately 20 percent of Kenyans have access to grid electricity. Access to affordable modern energy services is constrained by a combination of low consumer incomes and high costs. In the rural areas where only about 5 percent of the population has access to electricity, the scattered nature of human settlements further escalates distribution costs and reduces accessibility (Shell, 2010).

The majority of Kenyans live in rural areas where traditional biomass has remained the leading source of energy (both for cooking, and at times for lighting and heating). The potential of biomass has not been effectively utilized in the provision of modern energy for a variety of reasons. One is the failure to exploit the opportunities for transforming wastes from agricultural production and processing into locally produced modern energy. High incidence of poverty is another constraint to shift from traditional to modern biomass energy utilization. Continued over-dependence on unsustainable wood fuel and other forms of biomass as the primary sources of energy to meet household energy needs has contributed to uncontrolled harvesting of trees and shrubs with negative impacts on the environment. In addition, consumption of traditional biomass fuels contributes to poor health among users due to incomplete combustion and smoke emissions in the poorly ventilated houses common in rural areas. Biogas is an energy technology that has the potential to counteract many adverse health and environmental impacts connected with traditional use of biomass energy in Kenya.

For the last fifty years, biogas technology has been promoted by the Government, international organizations and NGOs who have trained Kenyan technicians resulting in building of hundreds of biogas digesters in the country.

The use of Liquid Petroleum Gas (LPG) in homes, educational and health institutions has risen from slightly over 40 thousand metric tonnes in 2003 to 80 thousand metric tonnes in 2008. Some households and institutions use methane gas derived from biogas plants (KIPPRA, 2010).

Kerosene is the most popular fuel used by households for lighting and cooking. About 300 thousand cubic metres of kerosene was used in 2008 as compared to 200 thousand cubic metres used in 2003.

3.1.2 Industrial Processes Sector

The industrialization policy projects GDP growth at an average rate of 5.9% between 1997 and 2020. Faster economic growth relies on agriculture and industry. In 2007, manufacturing contributed 10% of GDP, 12.5% of exports and 13% of formal employment (KAM, 2007). During the same period, agro-processing sub-sector accounted for 70% of manufacturing production turnover, 18.4% of export earnings. Food products contributed 73% of production turnover in the sub-sector.

Formal manufacturing sub-sector employs about 254,000 people while the informal sector employs about1 400,000 people. Majority of manufacturing work in the industrial sector in involve processing of agricultural products.

In Kenya, the main industrial processes emission sources are releases from processes that chemically or physically transform materials such as cement, lime and soda ash where these processes release significant amounts of GHGs such as CO_2, CH_4, N_2O, hydro-fluorocarbons, and per-fluorocarbons. Charcoal production also emits CO_2 into the atmosphere.

3.1.3 Agriculture Sector

Agriculture Sector is identified as one of the key sectors of the economic pillar in the Vision 2030 and MTPs with an annual growth rate of 5-7%.

Agriculture continues to be a significant sector of Kenya's economy and plays a leading role towards national economic development. The country's agriculture is characterized to some extent by subsistence farming and is operated by small holder farmers using relatively low farm inputs. Crop production and productivity are generally low and average yield of major grain crops grown in the country is about 1.0 tonnes per hectare due to a number of factors including low crop husbandry practices with resultant low production levels. Agriculture production is predominantly undertaken under rain-fed with irrigation accounting for only 1.7% of the total land under agriculture (Government of Kenya (GOK), 2010)

Agriculture is the mainstay of the Kenyan economy and currently represents 24% of GDP, 65 % of total exports and accounts for 18% of total formal employment in the country (Vision 2030, 2007). Agriculture provides the means of livelihood of most of Kenya's rural population with an estimate of about 80% of the population deriving their livelihood from agricultural activities.
Agriculture also contributes to the national food security, foreign exchange earnings and stimulates off-farm income generating activities and is a key sector for tackling hunger, and reducing poverty in a country like Kenya.

Livestock production is the dominant activity in the Arid and Semi-Arid Areas of Kenya (ASALs). The ASALs though supporting 25% of the human population support over half of the country's livestock production (Government of Kenya (GOK), 2010). Although ASALs have enormous livestock development potential, development in these areas has been low compared to other areas due to shortage of pasture, water and inadequate livestock extension services (Government of Kenya (GOK), 2010). The key livestock types in Kenya are beef and dairy cattle, camels, pigs, sheep and goats. In addition, the country is endowed with natural resources that can be used for fisheries and bee keeping.

It is estimated that 89% of the land mass in Kenya is used for agriculture and livestock. About 12% of the surface of Kenya is regarded as high potential agricultural land, 8% as medium potential and the rest as Arid and Semi-Arid Lands (ASALs).

Livestock contributes 7% of the rational GDP and accounts for 30% of the farm gate value of agricultural commodities. The livestock sub-sector employs and accounts for 50% of the agricultural labour force. With 80% of Kenya's land area being ASAL where livestock production is best suited, livestock remains one of the sectors with the highest potential to contribute to poverty alleviation.

The livestock sub-sector faces many challenges and constraints that have had negative impact on the rate of livestock development including among others weak policy and legal framework, low livestock productivity, and erratic and unpredictable weather conditions. The sub-sector has a high degree of vertical links with upstream and downstream industries. It is a major use of products from feeds, drugs, vaccines and equipment manufacturing industries while on the other hand it is major supplier of raw material for agro-processing industries.

3.1.4 Forestry and Land Use Sector

Kenya's forests rank high among the most important national assets. Forests are an important global source of valuable market goods and environmental services and need to be sustainable managed to ensure sustainable supply of these goods and services for the welfare of mankind.

Kenya's forests cover stood at about 12% of the country's land surface area at independence in 1963 but now stands below 2%. The drastic reduction in forest cover has been attributed to conversion of forests to other land uses including among others agricultural production, human settlement and infrastructure development. Lesser drivers of deforestation include illegal logging, wildfires and natural disasters such as droughts, pests and diseases. In order to restore the country's forest cover to the internationally recognized benchmark of 10%, the country has put in place long and medium term plans. In the long term timeframe, Kenya's Vision 2030, the country's long – term development blue print aims at attaining at least 10% forest cover by 2030 through intensification of tree growing and management in farmlands and dry-lands, restoration of degraded forests in the five water towers as well involvement of communities in the management of public forests.

In the medium timeframe, the First Medium Term Plan, 2008-2012 aims to increase the forest cover to 4% by establishing 4.1.million hectares of new forests during the plan period.

The National Climate Change Response Strategy (NCCRS) is the first national initiative to comprehensively address the challenges and opportunities posed by climate change to the forest sector. The strategy recognizes the forest sector among the ones to spearhead the national effort on climate change mitigation.

Kenya's Forest Development priorities are enshrined in the Draft National Forest Policy (2012) and Kenya Forest Services Strategic Plan 2010 – 2014.The overall strategic goal is to increase the country's forest and tree cover to 4% over the plan period.

Although Kenya's forest cover is less than 2% of the country's land surface area, they contribute immensely to the national economy through provision of wood and non-wood products for commercial and domestic use, and environmental services for sustenance of human and other forms of life. A large proportion of the goods and services supplied by the forest sector does not enter the cash market and as such the section's contribution to the Gross Domestic Product (GDP) is not well articulated in the national accounting system.

Environmental services provided by forests such as catchment conservation, soil conservation, habitat for wildlife, biodiversity conservation and amelioration of the climate are yet to be assigned monetary value and therefore are not captured in the national accounting. In addition some non-wood forest products such as herbal medicine and honey, although traded in the market, their value has not been quantified to be factored in the sectors contribution to GDP.

Wood remains the major forest product traded in the market. Before the ban on harvesting in 2000, Kenya's forests produced a total of 1 million cubic meters of round wood to sustain the country's wood based industries, (Kagombe et. al. 2005). Wood fuel is the other forest product of significant importance in the market. It is estimated that 75% of Kenyans use wood fuel either as firewood or charcoal as source of energy with a combined annual consumption of 15.3 million tons (FAO 2005).

The 2005 Economic Review gives the forest sectors contribution to the GDP as 1.1% which translates to 16.4 billion Kenya Shillings. It is estimated that the sub-sector employs over 50000 people directly and another 300,000 indirectly (KFS 2009). In addition, an estimated 1 million households living 5 kilometres from forest reserves depend on forests for grazing, herbal medicine and non-wood products.

3.1.5 Waste Management Sector

Wastes have potential to have negative impacts on human and animal health and plant life depending their types and quantities.

They also reduce the beauty of landscape depending on their dumping sites.

Waste management sector is important to the country's economy for the following reasons:

- It contributes to the protection of human and animal health and plant life.
- It creates employment in manufacturing factories
- It creates opportunities for income generation especially for youth groups
- It leads to generation of cheap and clean energy for low income rural households and contributes to improved livelihoods
- It leads to manufacturing of products which are cheaper than those made from new raw materials
- It leads to energy saving
- It has potential to attract new and improved technologies

Major types of solid wastes found in Kenya include the following:

i) Municipal Waste

These wastes are generated by domestic and commercial activities in residential areas and institutions located in urban centres.

They include:

- Plastic and paper wastes that are used as containers or wrapping materials and then discarded
- Organic (biomass) wastes that are generated from foods in residential and commercial operations including institutions.

ii) Industrial Waste

These are wastes generated by manufacturing industries.

They include:

- Wastes resulting from by-products of manufacturing of industrial goods. They include plastics, papers, polythene and other solid wastes.
- Sugar cane wastes also known as bagasse that is generated from sugar production.
- Coffee wastes also known as coffee husks that are generated from coffee milling.
- Rice wastes also known as rice husks that are generated from rice mills.

iii) Agricultural Waste

These are agricultural residues that are left after crop harvesting and animal wastes.

They include:

- Livestock wastes mainly cow dung and manure.
- Crop residues such as maize, bean wastes and others.
- Weeds that are generated during cultivation.

3.2 GHG Emission Status and trends of different sectors

3.2.1 Energy Sector

The energy sector is a major contributor of GHG emissions that cause global warming and the resultant climate change. A study conducted by the Stockholm Environment Institute (SEI) on the economic impacts of climate change in Kenya in 2009 found the country's current GHG emissions, both total and per capita to be relatively low (National Climate Change Response Strategy, 2010 a).

a) Energy Generation

A substantial amount of electricity in Kenya is generated from thermal sources i.e. diesel and gas (table 3.2 and 3.3). Most of the energy generated from thermal sources is sponsored by independent power producers and is especially used to meet energy demand when the country is experiencing drought conditions. Energy generation sub-sector uses diesel, and gas to produce electricity. These sources of energy are associated with emissions of carbon dioxide into the atmosphere.

Proposed green technologies in the energy generation subsector include solar, wind, geothermal, hydros and clean coal technologies.

An emission baseline for the energy generation sub-sector is developed by estimating the total fossil fuel consumption of different generation technologies and then multiplying the total consumption by appropriate emission factors. This method is the same as the Tier 1 approach used in the 2006 IPCC Guidelines (IPCC, 2006) for stationary combustion sources and employs the following equation:

GHG Emissions from the Energy Sector.

$$Emissions_{GHG,fuel} = \sum_{tech} Fuel\ Consumption_{fuel} \times Emission\ Factor_{GHG,fuel,tech}$$

$Emissions_{GHG,\ fuel}$ = emissions of a given GHG by type of fuel (kg GHG)
$Fuel\ Consumption_{fuel}$ = amount of fuel combusted (TJ).
Fuel Consumption for the electricity sector is estimated by multiplying the total generation (GWh) by the average conversion efficiency of the technology (%) by the conversion factor 3.6 GWh / TJ.
$Emission\ Factor_{GHG,\ fuel}$ = default emission factor of a given GHG by type of fuel (kg gas/TJ)
Total generation by technology type is estimated by multiplying the installed capacity (MW) of each technology by an average capacity factor (hours per year).

b) Energy Consumption/Demand

i) Transport sub-sector

The main GHG from the transport sub-sector are carbon dioxide (CO_2), Non-Methane Volatile Organic Compounds (NMVOCs), NO_x and Nitrous Oxide (N_2O).
Motorized transport is by far the most dominant and major source of pollution and emitter of GHGs, especially in the urban areas. All the vehicles in the country are powered by fossil fuels mainly petrol. The current use of diesel in the rail transport system is a major contributor of GHG emissions. The change therefore from diesel motive power to electric powered locomotives will result in considerable reduction or elimination of emission of Greenhouse Gases, so long as the electricity is generated from renewable sources.

ii) Industry sub-sector

The industrial sub-sector is a consumer of fossil fuels in food industry (meat; fish; dairy; edible oils; and fruits and vegetables processing) and mining. Cement production requires heating of the kilns by fossil fuels such as heavy oil or coal. These activities result in GHG emissions such as CO_2 into the atmosphere.

The sector also consumes electric energy some of which is generated by fossil fuelled power plants.

iii) Agriculture sub-sector

Kenya first national communication to UNFCC gave the sub-sectors emissions of methane in 1994 as 576 Gigagrams of methane. Emissions from other agricultural activities were considered to be low. The level of mechanization in the agriculture sub-sector is fairly low and consequently carbon dioxide emissions from fossil fuel consumption is negligible.

iv) Forestry and Land Use sub-sector

Forestry and land-use in Kenya is of less significance in terms of GHG environment that most of the forestry activities are labour intensive and therefore less mechanized.

v) Residential/Commercial sub-sector

The residential/commercial sub-sector mainly uses biomass, fossil fuels (kerosene), Liquefied Petroleum Gas (LPG) and biogas as source of energy either for cooking, heating and lighting. Usage of fuel wood (charcoal and fire wood) as sources of energy has impact on both human health and environment since they produce smoke and carbon dioxide. Biogas as a source of energy releases methane into the atmosphere.

3.2.2 Industrial Processes

Industrial processes that result in emissions of greenhouse gases in Kenya include production of cement, lime, soda ash, beer and spirits, pulp and paper.

Carbon Dioxide is the major gas emitted during production of cement and soda ash.

Production of pulp and paper, beer and spirits, sugar and bread results in the emission of Non-Methane Volatile Organic Compounds (NMVOCs) and carbon monoxide (CO). Cement production is the one industrial process that results in the highest emission of carbon dioxide in the country because for every tonne of clinker produced through heating about 612 Kilograms of the gas is emitted.

3.2.3 Agriculture

The agricultural sector is currently the largest source of GHG emissions of all analysed in Kenya (IISD, 2012). More than one-third of total national emissions are from the agricultural sector. The main sources of GHG emissions from the agriculture include the following:

i) Methane Emissions from Enteric Fermentation and Wastes from Livestock

In Kenya domestic livestock is mainly reared on the range. Therefore GHG emissions from animal wastes is negligible compared to that from enteric fermentation

ii) Emission from Rice Production

About 90% of rice grown in Kenya is by flooded paddies. About 15,000 hectares are generally under continuous paddy rice production and therefore this is a significant methane emission source.

iii) Emission of Nitrogen Oxide from Fertilizer Use

In Kenya the use of synthetic fertilizer is low being on the average at 25 kilograms per hectare per year. It is therefore considered to be an insignificant GHG emission sources.

iv) Emissions from Burning of Agricultural residues

In Kenya some of the agricultural residues are used as animal feeds others re-incorporated in the soil where they support crop growth. The estimate therefore is that only about 25% of the residues are burned on the field. Burning of crop residues emits CO_2 into the atmosphere.

3.2.4 Forestry and Land Use

According to Kenya's first National communication to UNFCCC, the forest sector is a net carbon dioxide sink absorbing about 28,262 Gigagrams CO_2. However, there are indicators that the sink capacity could be decreasing due to rapid land use changes and increased deforestation that surpasses afforestation. According to 2005 FAO State of the Forests, Kenya lost about 12,000 hectares of forests annually between 2000 and 2005. In addition, Kenya's land use is changing rapidly due to high population growth and economic expansion. The combination of these activities has potential for increasing greenhouse gas emissions in the sector.

3.2.5 Waste Management

It is estimated that about 4000 tonnes of solid wastes are generated in the major urban areas of Kenya (KBS- 2010). The bio-degradable wastes undergo aerobic and anaerobic decomposition thereby emitting carbon dioxide and methane gases. A lot of the wastes are also burned resulting in the emission of large quantities of carbon dioxide. The plastic, paper and other solid wastes are similarly transported and dumped in the dumping sites. The wastes are then subjected to burning with resulting emissions of GHGs such as CO_2**.** The main GHG emitted in landfills is methane.

3.3 Process, Criteria and Results of Sector Selection

The process for sector selection was based on the following:

a) Detailed literature review and use of expert knowledge

A detailed literature review of the national development plans, programs and strategies; past and current documents and activities with respect to climate change mitigation; sectoral reports, plans and strategies and IPCC documents and other climate change related reports. With information from the review and use of expert knowledge, the consultants identified among other things:

- National development priorities
- Key economic sectors and their contribution to the national economic development. The following sectors were identified energy; industrial processes; agriculture; forestry and land use; and waste management
- The sector's relationship to climate change mitigation potential of GHGs.

b) Involvement of stakeholders on the basis of sector interests through meetings, workshops, one to one engagement and questionnaire administration (see Annex 3.0 for questionnaire used).

c) In consultative forums of sector Working Groups for mitigation, the following sectors were identified and ranked in order of priority through brain storming and consensus building approaches as follows:

i) Inception Workshop held involving key stakeholders on 21st June 2011.
ii) Analysis of responses from the questionnaires between January and February 2012
iii) NEMA Sector Working Group meeting held on 22 February 2012.
iv) TNA Sector Selection and Technology Prioritization Workshop held on 25TH July 2012 (Annex 2.5)

The criteria used for sector selection were: i) Contribution to the national economy ii) Contribution to climate change mitigation.

The following Sectors for mitigation were identified and ranked in order of priority as follows:

- Energy
- Waste Management

- Industrial Processes
- Agriculture
- Forestry and Land Use.

As a result, energy and waste management sectors were selected for further analysis in the following chapters.

CHAPTER 4: TECHNOLOGY PRIORITIZATION FOR THE ENERGY SECTOR

Energy is the major driver of socio-economic development in the country. There are numerous sources of energy in the country including both renewable and non-renewable sources. There are also several technologies for energy generation some of which are associated with emissions of GHGs into the atmosphere. Technology prioritization in the energy sector was based on the concept which leads to low carbon emission development path in the country.

4.1 Existing Technologies and Greenhouse Gas (GHG) Emissions in the Energy Sector

The existing technologies in the energy sector comprise hydropower; thermal power; geothermal power; wind power; biomass; and solar energy-Solar PV.

4.1.1 Hydro Power

Hydro-power constitutes around 50 per cent of the total electricity generated in Kenya and is the leading source of electrical energy, with an installed capacity of 761 MW. Most of hydro-power stations are located in the country's big rivers such as Tana, Sondu Miriu and Kerio Valley.

Small hydropower refers to hydroelectric power plants below 10MW installed capacity. Hydroelectric power plants are power plants that produce electrical energy by driving turbines and generators, thanks to the gravitational force of falling or flowing water. Through the natural water cycle mainly evaporation, and rain, the water is then brought back to its original height. It is thus a renewable form of energy. Small-scale hydro power may be a useful source for electrification of isolated sites and may also provide an extra contribution to national electrical production for peak demand.

4.1.2 Thermal Power (Fossil Fuels)

Coal , diesel and gas constitute important sources of thermal energy in Kenya. The recent discovery of coal resources in Mui Basin in Kitui County is expected to play a large part in Kenya's long-term electricity sector planning. Kenya has installed several power plants to generate electricity from fossil fuels diesel power. Most of the diesel and gas power plants are supported by Independent Power Producers (IPPs). Kipevu II Gas Turbine and Kipevu III Diesel Power Plants in Kenya are located at Mombasa and generate 60MW and 120 MW respectively.

Several other diesel thermal sources of electricity exist in other parts of the country. These include Iberafrica (30 MW by January 2012), Aggreko (140 MW), Iberafrica (30MW) and Thika Power Ltd (88MW).

4.1.3 Geothermal Power

Geothermal energy is generated using natural steam tapped from volcanic-active zones in the Rift Valley. Geothermal energy originates from the high-temperature aquifers inside the Earth's crust at depths of between one and four kilometres. These aquifers are surrounded by porous, soft rocks and/or sand and are heated by the Earth's heat. Hot water or steam within the aquifers could reach temperatures of over 300°C. This heat can be used for heating of buildings and/or production of electricity (http://www/geo-energy.org/aboutGE/basic.asp)

Geothermal power is very cost-effective in the Great Rift Valley of Kenya, East Africa. Kenya was the first African country to build geothermal energy sources. Kenya is one of the leading producers of geothermal energy in Africa although the current production at approximately 198 MW is still fairly small yet the full potential is said to be in the range of 3000-5000 MW. Plans are to increase geothermal production capacity by another 576 MW by 2017, covering 25% of Kenya's electricity needs, and correspondingly reducing dependency on imported oil.

4.1.4 Wind Power

Large scale wind generation is a technology that generates electricity from wind energy. The Ministry of Energy developed a National Wind Energy Resources Atlas for Kenya in 2003. It provides useful information to facilitate both public and private sector investment in this important energy sub-sector.

A limited number of wind generators for use in remote missions, farms and rural health centres (i.e. Olesseus of capacity 1-5kW) have been installed and are working in various places in Kenya. There are to-date a number of well established companies (Kenital, Telesales, Solagen, Chloride Oxide, Ecogen and Sollatek Ltd.) that import and sell small wind generators ranging from 300-1000W. In September 2010, the Government of Kenya commissioned a 5.1 MW wind power project in Ngong Hills and expects installed capacity to more than double in the next three years (KENGEN, 2010.)

The Lake Turkana Wind Power Project (LTWP) that is under development aims to provide 300MW of reliable, low cost wind power to the Kenya national grid, equivalent to approximately 20% of the current installed electricity generating capacity. The Project is of significant strategic benefit to Kenya, and at a cost of Ksh75 billion (€582 million) will be the largest single private investment in Kenya's history. The wind farm site, covering 40,000 acres (162km^2), is located in Loyangalani District, Marsabit West County, in north-eastern Kenya, approximately 50km north of South Horr Township. The financing was targeted for completion in March 2012 followed by the first 50 to 90MW to be commissioned in December 2013 and full operations of 300MW scheduled for late 2014.

4.1.5 Biomass Energy

Biomass energy is the principal source of energy for most Kenyans, particularly in the rural areas. Firewood is the predominant fuel for cooking in rural areas. Nationwide 68.3% and 13.3% of Kenya's household population utilize firewood and charcoal for cooking respectively thereby exerting enormous pressure on the environment as much of it is obtained from unsustainable sources.

4.1.6 Improved Cook-stoves

The Kenya Ceramic Jiko (KCJ) is among the most widely used models of improved cook-stoves. It is a portable metal stove with ceramic lining in its top half where the charcoal is placed. At the bottom, there is a box for collection of ashes. The ceramic lining guarantees an improved heat retention thus improving stove efficiency.

KCJ reduces charcoal by three times. Due to its design, it remains very cool on the outside, preventing injury to small children who often accompany their mothers in the kitchen. Another major benefit of this stove design is that it minimizes smoke production, reducing harmful side effects to users. Most importantly, however, the stove can be produced locally. The materials and skills to create these jikos are abundant in Kenya and, when harnessed correctly, will create a sustainable solution to the economic and health crisis the traditional stove has been causing.

4.1.7 Solar Energy Technologies

Solar electricity is the electric power generated from sunlight using devices called solar cell modules. Photovoltaics is the direct conversion of light into electricity at the atomic level. Some materials exhibit a property known as the photoelectric effect that causes them to absorb photons of light and release electrons. When these free electrons are captured, and electric current results that can be used as electricity. The technology is slowly gaining popularity in Kenya since the prices of other electric energy sources rise as the prices of solar photo-voltaics (PV) fall. Solar electricity can replace small applications of petroleum-fuelled generators, grid power and dry cell batteries. Solar electric systems are being sold to end users in Kenya through a competitive and growing free market network. The following are some key solar technologies that are being promoted in Kenya.

i) Solar Home Systems (SHS)

Solar Home Systems (SHS) provides households lights, and electrical power for televisions, cassette players and small appliances. This forms the bulk market for photovoltaics in Kenya. Solar electricity if adopted fully in the country could be widely used in rural Kenya to power wireless communications technologies that are linked to processes of economic integration and greater rural-urban connectivity.

ii) Solar Water Heater Systems (SWHS)

Solar Thermal Water Heating is a simple, reliable, and cost-effective technology that harnesses the sun's energy to provide for the hot water needs of homes and businesses.

It is estimated that 7000 solar water heaters in the country have been installed mainly by institutions (hotels, hospitals and colleges) and the upper urban market relieving the national grid of 20MW. In most domestic scenarios, water heating constitutes over 50% of the power bill. The initial costs of installing solar energy equipment are high.

iii) Solar Cookers

A solar cooker, or solar oven, is a device which uses shortwave solar radiation to cook food, heat food, and water or sterilize it. Solar cooking is a form of outdoor cooking and is often used in situations where minimal fuel consumption is important, or the danger of accidental fires is high.

The solar kitchen is a technological breakthrough in solar cooking that makes it possible for cooking to be carried out indoors for communities of up to 500 persons. High temperature solar dish systems are a series of parabolic 'fixed - focus –tracking 'dish/collector configurations that represent the technological solution to high temperature solar applications. This arrangement allows the focus of the concentrated heat to be stationary throughout, and can therefore be situated indoors for cooking, water heating and commercial and industrial applications like steam raising and absorption refrigeration etc. in the power range of 2 - 24kW (thermal) in single systems applications.

iv) Solar Dryers

Direct solar drying (i.e. laying products out in the sun to dry) has traditionally been important for preserving food, crops and other products. Drying involves the removal of moisture from produce so as to provide a product that can be safely stored for longer periods.

The solar drying method uses indirect solar radiation. The principle of the solar drying technique is to collect solar energy by heating-up the air volume in solar collectors and conduct the hot air from the collector to an attached enclosure.

In Kenya, GTZ has played a key role in introducing the technology. Most of the work was with simple direct, lowest cost type solar dryers. Such "simple" designs use frames made of wood, inside which screen trays are laid. A UV resistant plastic film is used as a cover.

The Kenya Industrial Research and Development Institute (KIRDI) is actively working with institutions and women's groups in developing improved dryers for processing of fruits, vegetables, cereals and legumes on a commercial basis.

4.1.8 Co-generation

Sugar factories have the potential to co-generate power using bagasse as the raw material. Co-generation would reduce the use of thermal power stations in western Kenya and make sugar production cheaper in the local and international market.

Co-generation technology is being implemented in several sugar factories in Western Kenya especially in Mumias Sugar Factory. The factory is currently generating 26 MW of electricity which has been connected to the national grid with bagasse being the main raw material.

4.2 GHG Emission in the Energy Sector

Kenya's Initial National Communication to the United Nations Framework Convention on Climate Change outlined the sources of greenhouse gas emissions in the Energy Sector as energy production and consumption.

The energy sector is among the largest contributor of GHG emissions in the country. According to Kenya's First National Communication to UNFCCC, the most significant GHG emitted from the energy sector was CO_2 amounting to 4522.45 Gigagrammes. Much of emissions from this sector come from fossil fuel consumption by motor vehicles, locomotives, motorcycles and industry. With the increase growth especially in motor vehicle industry which has so far registered 1.4 million vehicles and 400,000 motorcycles the GHG emissions from this sector are expected to have grown significantly. Energy generation from fossil fuel sources of energy such as diesel, gas and coal results in emissions of GHG. Emissions of GHG in the sector are estimated at 18 million tonnes CO_2 equivalent (Cameron et.al. 2012).

4.2.1 Electricity Generation Sub-sector

35% of electric generation in Kenya is from fossil-fuel sources. Burning of fossil fuels is the most important source of greenhouse gas emissions. Although Kenya's GHG emissions from the energy sector are low by global standards, they are rising quickly and are estimated to have increased by as much as 50% over the last decade (National Climate Change Response Strategy, 2010). Stiebert et.al (2012) have estimated that GHG emissions from energy generation to be about 2.2 million tonnes.

4.2.2 Transport sub-sector

The main GHG from the transport sub-sector is carbon dioxide (CO_2). Road and rail transport are principal sources of GHG. Road transport is a major generator of greenhouse emissions (30% of the total energy sectors emission; Cameron et al. 2012 b).

4.2.3 Industry Sub-sector

Consumption of energy in the industry sub-sector releases GHGs into the atmosphere. These gases include carbon dioxide and methane. GHGs in this sub-sector are associated with consumption of fossil fuels in food industry (meat; fish; dairy; edible oils; and fruits and vegetable processing), manufacturing of steel, cement production and mining among other industries

4.2.4 Residential/Commercial sub-sector

The residential/commercial sub-sector mainly uses biomass, fossil fuels (kerosene, liquefied petroleum gas (LPG)) and biogas as source of energy either for cooking, heating and lighting. Usage of fuel wood (charcoal and firewood) as sources of energy has impact on both human health and environment since they produce smoke and carbon dioxide. Biogas as a source of energy releases methane into the atmosphere. Methane is a GHG.

4.3 An Overview of possible Mitigation technology options in the Energy Sector and their Mitigation Benefits

There exists a wide range of possible mitigation technology options in the energy sector (See fact sheets Annex 1.1). These include the following:

a) Hydro-Electric Power

Hydro-power constitutes around 50 per cent of the total electricity generated in Kenya and is the leading source of electrical energy, with an installed capacity of 761 MW. Most of this power is generated from Tana, Sondu Miriu and Kerio rivers. There is scope for electric power generation from micro-hydro-power stations in the country.

The Kenya Tea Development Agency (KTDA) intends to implement a US$ 14.5 million mini-hydro project aimed at constructing 10 mini-hydro power plants with a total production of 20 MW in the next years. This amount of power is more than KTDA's factories can consume and the excess power will be supplied to the Kenya national electricity grid through a power purchase agreement. At present KTDA obtains its electricity supply from the Kenya national grid. The mini hydro power will thus lead to emissions reductions by replacing electricity that would have otherwise been supplied by thermal power plants connected to the Kenya national grid.

Hydro capacity can replace fossil fuel generation capacity. Based on this, the mitigation potential is in the order of 1,100 ktCO2/year in 2030 (Cameron et al., 2012 c).

b) Solar Energy Technologies

About 1.6% of Kenyan households use solar energy for both heating and electric generation, and its adoption has been slow due to the high initial installation costs (KNBS, 2007). It is estimated that Kenya receives 4-6 kW/m2/day of solar energy, on average, which translates into about 1.5 billion tonnes of oil equivalent, making it a major alternative source of energy. Solar energy is currently under-exploited although it is widely regarded as a plausible option to stimulate rural electrification.

i) Solar Home Systems (SHS)

Solar Home Systems (SHS) provides households lights, and electrical power for televisions, cassette players and small appliances. This forms the bulk market for Photovoltaics in Kenya. Solar electricity if adopted fully in the country could be widely used in rural Kenya to power wireless communications technologies that are linked to processes of economic integration and greater rural-urban connectivity.

It is estimated that over 200,000 rural households in Kenya have solar home systems. This limited success has been largely due to private sector activity. But as shown in table 4.1 below the uptake of the technology has been slow mainly because of the high cost, low awareness of the potential opportunities and economic benefits of the SHS.

SHS technology has potential to replace fossil fuel sources of energy and therefore contribute to reduction of emissions of GHGs.

Table 4.1: Trade and Production of Solar PV Parts and Component in Kenya (Annual Mean 2004-2008)

Short Description	Units	Imports	Production	Consumption
Static converters [e.g. rectifiers and inductors and inverters for converting dc power to ac power]	Number	305,995	-	305,690
Photovoltaic system controller [charge controller for voltage not exceeding 1000 V]	Number	185,171	-	114,113
Photovoltaic cells, Modules and Panels	Number	118,322	-	112,908
Other lead-acid accumulators [Deep discharge (solar)]	Number	173,740	<50,000	1112,015

Source: Ikiara (2009)

ii) Solar Water Heater Systems (SWHS)

SWHS technology uses the process in which solar radiation is absorbed and converted into heat energy which raises the temperature of the water.

SWHS technology reduces demand for fossil fuels generated electricity for heating water in institutions. It also reduces demand for charcoal and fuel-wood and therefore contributes to conservation of forests. As a renewable energy source, SWHS has potential to lead to reduction in GHG emissions and therefore contribute to climate change mitigation.

iii) Solar Cookers

Solar cookers technology is being promoted to help reduce fuel costs for low-income people, reduce air pollution and slow deforestation and desertification, caused by use of firewood for cooking. Solar cookers can therefore replace the use of wood-fuel and LPG for cooking and hence contribute to mitigation of emissions of GHGs.

iv) Solar Dryers

The principle of the solar drying technique is to collect solar energy by heating-up the air volume in solar collectors and conduct the hot air from the collector to an attached enclosure.

Solar dryers technology can replace the use of fossil fuels and biomass for drying cereals, legumes, tea leaves, fruits and vegetables. This has potential to reduce GHG emissions.

c) Improved Cook-stoves

The Kenya Ceramic Jiko (KCJ) is a portable metal improved stove. The KCJ is the result of research on stove design, efficiency, and patterns of usage initiated in the 1970's and actively continued through the 1980's by KENGO (a local NGO).

Due to its efficiency the use of KCJ can lead to emission reductions of roughly 30 to 50 per cent per stove and hence contribute to substantial GHG emissions. Assuming that 35% of the feedstock is biomass, a total abatement potential of 5.6 Mt CO_2 in 2030 could be realized (Saidi et. al. 2012).

d) Wind Power

On average, the country has an area of close to 90,000 square kilometres with wind speeds of 6m/second and above which has not been translated into technical or economically viable potentials.

Wind energy can replace fossil fuels for generation of electric power. The Updated Least Cost Power Development Plan of Kenya forecasts over two Gigawatts of wind generation in 2030. On this basis, the mitigation potential is estimated at 1360 ktCO_2 per year by 2030 (Cameron et. al 2012).

e) Nuclear Energy

Nuclear energy originates from the splitting of uranium atoms in a process called fission. At the power plant, the fission process is used to generate heat for producing steam, which is used by a turbine to generate electricity

Development projects recommended under Vision 2030 will increase demand on Kenya's energy supply. To meet this demand, various power generation options, including nuclear power have been considered, with the first nuclear plant planned for commissioning in 2022.

Generation of electricity from nuclear energy has potential to replace energy generated from fossil fuels and will have GHG mitigation potential.

f) Geothermal

Kenya is one of the leading producers of geothermal energy in Africa although the current production at approximately 198 MW is still fairly small yet the full potential is said to be in the range of 3000-5000 MW. Geothermal energy is generated using natural steam tapped from volcanic-active zones in the Rift Valley.

Geothermal capacity can replace the need for additional fossil fuelled generation capacity. Plans are to increase geothermal production capacity by another 576 MW by 2017, covering 25% of Kenya's electricity needs, and correspondingly reducing dependency on imported oil. Every 100 megawatt equivalent capacity can mitigate in the order of 600 kt/CO2/year (Cameron et. al., 2012 e).

g) Biodiesel/Jatropha

Bio-diesel is made from vegetable oils, animal fats or recycled greases. Bio-diesel can be used as a fuel for vehicles in its pure form, but it is usually used as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles. Jatropha is being promoted as source of bio-diesel in the Coast Province of Kenya.

Use of biodiesel leads to almost zero net emissions of CO_2 because the carbon dioxide that is emitted during combustion of biodiesel is absorbed during regrowth of Jatropha and it is therefore a mitigation option since it replaces use of fossil fuels.

h) Ethanol

Ethanol was introduced in Kenya as a fuel blend for gasoline in 1983. However, due to management and pricing problems, its use was discontinued in 1993. This fuel blend had a volume composition of 65% super petrol, 10% alcohol, 25% ordinary or regular petrol. The octane number of the blend was 93. The government of Kenya has in its plan to reintroduce power alcohol as a motor fuel in its long-term policy to enhance security of supply and redress the trade imbalance arising from petroleum imports.

Use of power alcohol results in almost zero net emission because the CO_2 that is emitted is absorbed during regrowth of plants and it is therefore mitigation option since it replaces use of fossil fuels.

i) Co-generation

In Western Kenya several sugar factories are using bagasse as a raw material to generate electricity. Mumias Sugar Factory is generating 26MW of electricity which has been connected to the grid.
Co-generation is a climate change mitigation option as it reduces Kenya’s dependence on fossil fuel based sources of energy.

4.4 Criteria and process of Technology Prioritization

The technologies were selected on the basis of their economic, environmental benefits and their CO_2 abatement potential. The importance of the technologies to the society was included in social and economic benefit analysis.

The technologies were further selected using a consultative process based on the following criteria:

i) Technology has not been successfully implemented in the country
ii) Technology is innovative
iii) Technology is facing barriers in its implementation

iv) The technology has potential to formulate fundable projects

Technology fact sheets were developed for each selected technology.
Technology fact sheets (see Annex 1.1) were prepared through the following process:

i) Intensive literature review
ii) Inception workshop with stakeholders held on 21st June 2011
iii) Analyses of responses from questionnaires done between January and February 2012
iv) NEMA Meeting with Sector Working Groups on 22nd February 2012.
v) TNA sector and technologies validation Workshop held on 25th July 201(annex 2.5)

The criteria used for prioritization of technologies in the energy sector were as follows:

i) Contribution to national development
ii) Adaptation to local conditions: This comprises acceptability by the community, sustainability and poverty reduction
iii) Contribution to poverty reduction
iv) Contribution to climate change mitigation

4.5 Results of Technology Prioritization with MCA

Technology prioritization was conducted by the consultant in collaboration with all stakeholders (see chapter 4.4). The tool used for technology prioritization is Multi Criteria Analysis (MCA) using Definite Student computer based model.

MCA is a decision support tool used in case of decisions involving several actors with different and often conflicting objectives. The MCA was conducted in several steps on the basis of existing documentation synthesis for priority technologies in the energy sector. The MCA helps in doing assessment based on monetary and non-monetary criteria. The following steps were followed.

i) Identification of technologies
ii) Identification of criteria for the prioritized technologies
iii) Grading of technologies based on the criteria
iv) Standardization and ranking of the technologies
v) Ponderation/weighting of the criteria

The Criteria used were as follows:

i) Contribution to national development
ii) Cost of implementing the technology
iii) Contribution to climate mitigation
iv) Adaptation to local conditions

Grading of Technologies/scores

Using the above mentioned criteria, the technologies were allocated grades with respect to selected criteria.

Standardization and Ranking

Values of criteria were expressed in values in the same unit. This was followed by calculation of the average of scores for each option and then ranking.

Weighting the criteria

Important criteria were allocated different weights based on their importance

Uncertainties

i) Uncertainties arise from various sources such as the following:
ii) Analysis of inputs from previous studies: databases, expert advice and participatory approach

iii) Uncertainties on the selection of criteria and the choice of options
iv) Uncertainty about the data: evaluation of the qualitative data ranges
v) Uncertainty of judgements, qualitative data and scale scores

For the energy sector, the following climate mitigation technologies were subjected to MCA using Definite Student computer model:

Co-generation; Solar Home Systems (SHS); Non-Motorized Transport (NMT); Electric Trains; Mass Transport; Solar Dryers; and Mini-hydros.

Table 4.1: MCA – Assigned scores

Criteria	Unit	Solar Home Systems	Solar Dryers	Mini-hydros	Co-generation	Non-Motorized Transport	Electric Train	Mass Transport
Contribution to national development 1-10	Range 1-10	10	8	6	3	7	6	5
Contribution to climate change mitigation	Range 1-10	9	8	4	2	10	5	3
Adaptation to local conditions	Range 1-20	20	18	15	6	15	5	10
Contribution to poverty reduction	Range 1-10	6	10	9	2	5	4	4

Contribution to national development with respect Solar Homes Systems (SHS) was given highest score because of its potential for use in rural households and institution not connected to the national grid. About 80% of Kenyans are not connected to the grid. Again adaptation to local conditions was awarded highest score of 20 for the same reason. Application of SHS has potential to reduce ailments related to indoor pollution resulting from use of kerosene for lighting while at the same time contributing to reduction of GHGs emissions.

Table 4.2: MCA – Standardized Table

Criteria	Unit	Solar Home Systems	Solar Dryers	Mini-hydros	Co-generation	Non-Motorized Transport	Electric Train	Mass Transport
1. Contribution to national development	Range 0-1	1.0	0.71	0.43	0.00	0.57	0.43	0.29
2. Contribution to climate change mitigation	Range 0-1	0.88	0.75	0.25	0.00	1.00	0.38	0.13
3. Adaptation to local conditions	Range 0-1	1.00	0.87	0.67	0.07	0.67	0.0	0.33
4. Contribution to poverty reduction	Range 0-1	0.5	1.0	0.88	0.00	0.38	0.25	0.25

Table 4.3: Weighting Interval Scale

Weighting / Criteria	Minimum	Maximum	Weighting	
1. Contribution to national development	3	10	10	0.417
2. Contribution to climate change mitigation	2	10	7	0.292
3. Adaptation to local conditions	5	20	2	0.083
4. Contribution to poverty reduction	2	10	5	0.0208

Fig. 4.1: Technology prioritization for the energy sector

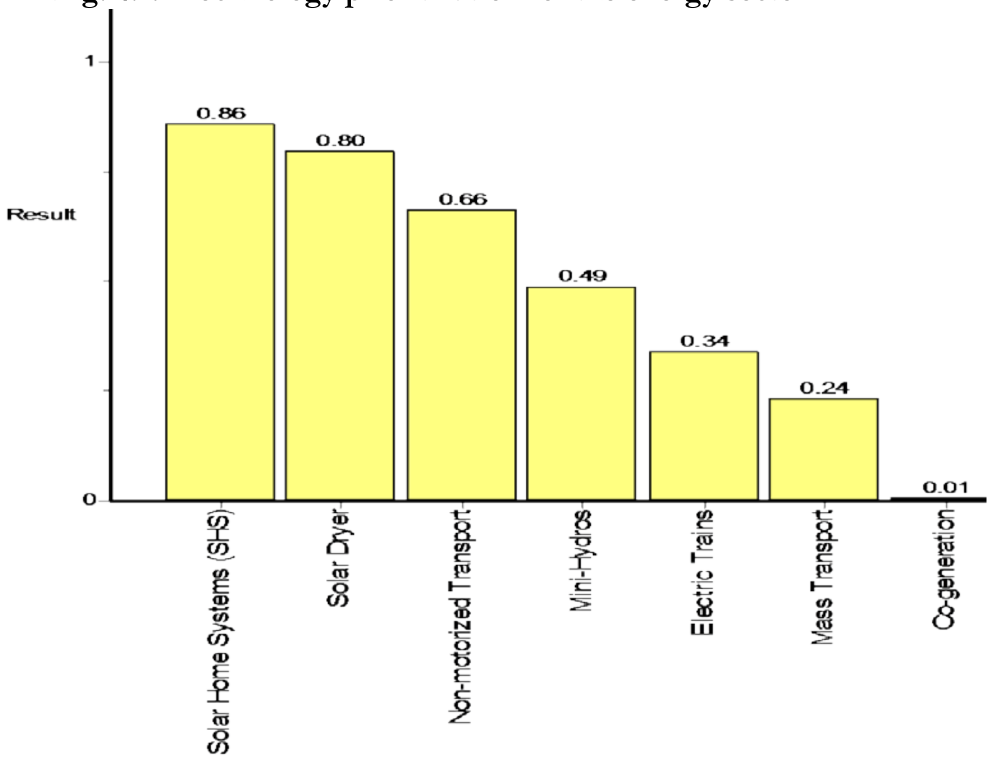
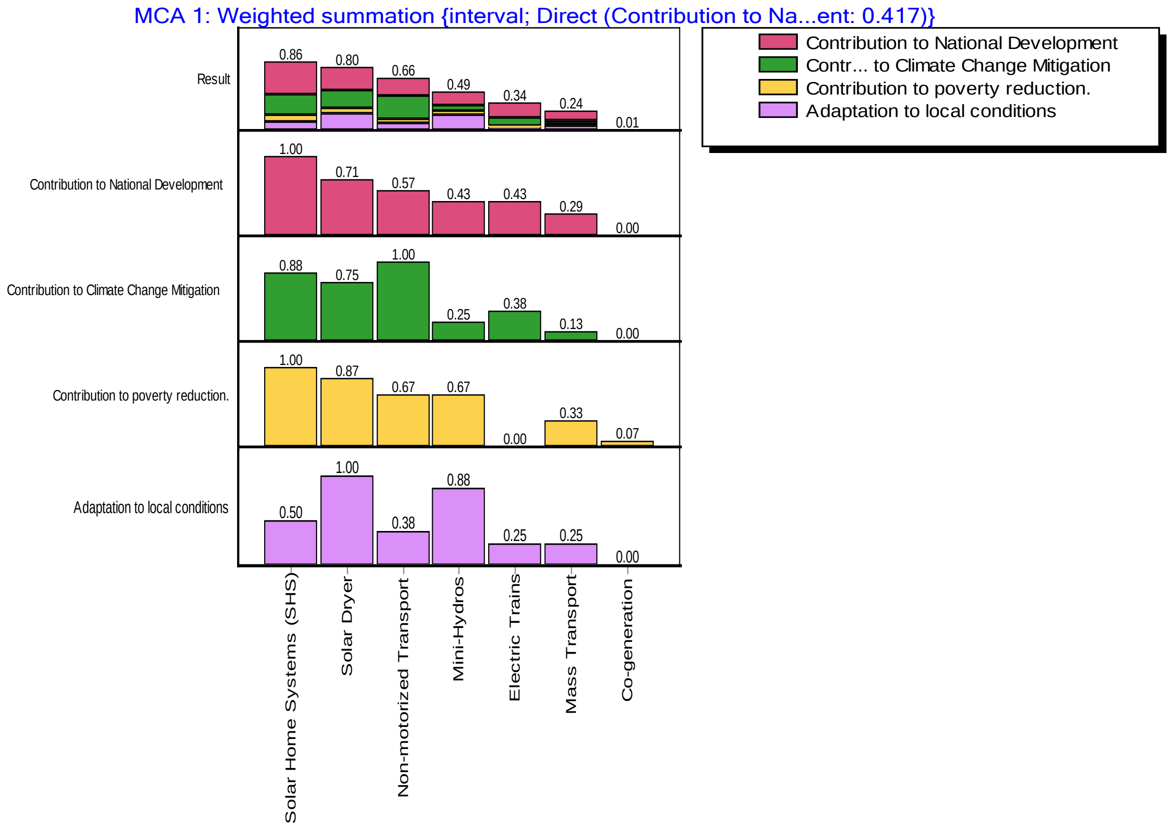


Fig. 4.2: Influence of different criteria on each other



Results of MCA technology prioritization for the energy sector were as follows:

- Solar Home Systems (SHS)
- Solar Dryers
- Non-Motorized Transport (NMT)
- Mini-hydros
- Electric trains
- Mass transport
- Co-generation

The first two ranked technologies in the energy sector namely: Solar Home Systems; and Solar Dryers were identified for further analysis with respect to overcoming barriers to transfer and diffusion of climate technologies.

Justification for SHS

The SHS technology has potential to provide electric power in the rural areas where about 95% of the population is not connected to the grid. Currently only about 200,000 households have Solar Home Systems in place. As Solar Home System is the appropriate technology for lighting and for powering small appliances in the rural areas. There is a large potential (about 7,000,000households) for its diffusion in the country. There is additional potential of SHS technology to provide electricity to the already grid connected households in both the urban and rural areas as a measure to ensure continuous power supply in view of frequent power outages. The uptake of SHS has been slow (see table 4.1) due to various reasons such as relative high cost of the technology and low awareness on the potential socio-economic and environmental benefits of the technology among others.

Justification for the Solar dryers

The main economic activity in Kenya is agriculture that entails production of cereals which include maize, wheat, rice, sorghum, millet and other produce such as beans and peas etc. The export market is dominated by cash crops such as tea, coffee and a range of horticultural products.

Traditionally most small scale farmers still rely on open air drying to process and preserve their products including vegetables, fruits and other foods by laying products in the sun to dry. However for large scale farmers and commercial farms, this method is not effective. They therefore rely heavily on the National Cereals and Produce Board of Kenya whose dryers use diesel in all its over 45 stations in the country. From common knowledge these diesel powered dryers emit enormous amounts of carbon dioxide into the atmosphere.

65 tea factories in the county rely on drying their products by use of fuel wood, thus resulting in massive destruction of our forests. So far only one tea factory in Kenya has installed a solar dryer which has enabled it to realize 50% savings on energy use.

Adoption of solar dryers technology by family units, medium scale farmers, large tea factories, cooperative societies and large scale application for large commercial farming operations all over the country will assist in energy saving and increase Kenya's contribution to global efforts to mitigate climate change through reduction of emissions of greenhouse gases and enhanced conservation of forests which act as carbon sinks.

CHAPTER 5: TECHNOLOGY PRIORITIZATION FOR WASTE MANAGEMENT SECTOR

Technology prioritization in the waste management sector was based on the concept which leads to low carbon emission development pathway in the country (Annex 1.2)

5.1 Existing Technologies and Greenhouse Gas Emissions in the Waste Management Sector

5.1.1 Existing Technologies for Solid Waste Management Sector

The following are the existing waste management technologies

5.1.1.1 Methane Capture

This technology involves collection of bio-degradable agricultural and municipal wastes and subjecting them to bio-digestion in anaerobic process resulting in production of methane that is then used for electricity generation, cooking and lighting.

The technology can be applied in large landfills or by construction of bio- digesters some of which could be compact enough to be portable.

5.1.1.2 Solid Waste Reduction

These technologies involve proper selection of process technologies that reduce generation of wastes

5.1.1.3 Solid Waste re-use

This technology involves selection of high quality raw materials and production procedures that result in high quality goods that can be re-used without degradation of the required quality.

5.1.1.4 Waste Plastic Recycling

This technology involves collection, separation and use of solid plastic items as raw material for manufacture of new products.

5.1.1.5 Waste Composting

This is the decomposition of biodegradable organic matter to compost manure for use in agriculture production. It involves collection and separation of organic waste before decomposing it aerobically into manure.

5.1.2 Greenhouse Gas Emissions in the Waste Management Sector

The main source of greenhouse gas emissions in the Waste management sector is anaerobic decomposition of biodegradable organic matter to produce methane gas in waste disposal sites such as waste dumps. Anaerobic decomposition of biodegradable organic matter proceeds well in deep disposal sites where oxygen is in limited quantities or absent. In Kenya such sites are very rare as most of the waste is disposed in shallow unmanaged and uncontrolled sites. Consequently the rate of generation of methane gas is quite low due to the high rate of oxidation associated with their open nature.

5.2 Overview of Possible Mitigation Technologies in Waste Management

5.2.1 Methane Capture

Methane capture technology involves collection of bio-degradable agricultural, domestic, institutional or municipal wastes and subjecting them to bio-digestion in anaerobic process resulting in production of methane that is then used for electricity generation, cooking and lighting.

The technology can be applied in large landfills or by construction of bio- digesters some of which could be compact enough to be portable.

The biogas technology helps to provide fuel for domestic and institutional uses and helps clean the environment of methane gas among other pollutant gases.

Biogas technology has been promoted by the Government, international organizations and NGOs who have trained Kenyan technicians resulting in building hundreds of biogas digesters in the country. However for some reason, the penetration rate of biogas technology in the country remains very low. It is estimated that up to 2000 units have been installed in total, though it is impossible to estimate what percentage remain in working condition due to the dispersed and sometimes uncontrolled and informal nature of installations (SHELL, 2010).

The use of biogas as an alternative energy source comprises part of climate change mitigation measures. Use of biogas energy minimizes the emission of methane into the atmosphere and reduces the demand for biomass for energy and therefore contributes to conservation of forests resulting in enhanced carbon sinks.

5.2.2 Incorporation of agricultural waste into the soil

This technology involves spreading the wastes on the soil surface and undertaking deep cultivation. The technology has two advantages namely:

i) Enhancing nutritional status of the soil and
ii) Increasing sequestration of carbon into the soil and hence mitigating climate change.

5.2.3 Solid waste reduction

These technologies involve:

- Proper selection of production technologies that reduce generation of wastes.
- Proper selection of raw materials so that almost all of them can be utilized for production of goods.

5.2.4 Solid waste re-use

This technology involves selection of high quality raw materials and production procedures that result in high quality goods that can be re-used many times without degradation of the required quality.

5.2.5 Plastic waste recycling

Plastic wastes which are not bio-degradable can be recycled through manufacture of usable materials such as containers, poles and other products using appropriate technologies. There several local companies involved in plastic waste recycling in Kenya.

Waste recycling contributes to climate change mitigation in that the technology requires less energy and hence reduces emissions of greenhouse gases. The technology also contributes to conservation of the resources especially raw materials

5.2.6 Waste Paper Recycling

The technology involves turning waste paper into new paper products. It has been practised in Kenya since 1958. Currently there are three paper recycling mills that produce about 62,000 tonnes of recycled paper (www.chandaria.com, 2012). But the recycling plants are concentrated around Nairobi and its environs.

Waste paper in the other towns away from Nairobi ends up in landfills as it is expensive to transport it to the recycling plants. Setting up recycling plants in towns like Kisumu, Mombasa and Eldoret will reduce the amount of waste paper going to landfills and create additional employment.

Waste paper recycling avoids production of methane gas that would have resulted from anaerobic decomposition of the paper. Waste paper recycling also avoids use of virgin paper thereby reducing deforestation that would have taken place had the same amount of virgin paper been produced. It therefore contributes to conservation of forests and hence mitigation of climate change.

5.2.7 Waste Composting

This is the decomposition of biodegradable organic matter to compost manure for use in agricultural production. In Kenya waste composting is taken at both commercial and household levels.

5.3 Criteria and Process of Technology Prioritization in Waste Management

The technologies were selected on the basis of their socio-economic and health benefits and CO_2 abatement potential and their socio-economic and environmental benefits. The importance of the technologies main uses to the society was included in social and economic benefit analysis.

The technologies were further selected using a consultative process based on the following criteria:

i) Technology has not been successfully implemented in the country
ii) Technology is innovative
iii) Technology is facing barriers in its implementation
iv) The technology has potential areas to formulate fundable projects

Fact sheets were prepared for each selected technology.

Technology fact sheets (see Annex 1.2) were prepared through the following process:

i) Intensive literature review
ii) Inception workshop with stakeholders held on 21st June 2011
iii) Analyses of responses from questionnaires done between January and February 2012
iv) NEMA Meeting with Sector Working Groups on 22nd February 2012.
v) TNA sector and technologies validation Workshop held on 25th July 2012(annex 2.5)
vi) TNA Barrier Identification and Validation Workshop 29th November 2012

The criteria used for prioritization of technologies in the waste management sector were as follows:

i) Contribution to national development
ii) Adaptation to local conditions.
iii) This comprises acceptability by the community and hence sustainability
iv) Contribution to poverty reduction
This includes contribution to GDP through employment creation and income generation and aspects of foreign exchange earnings
v) Contribution to climate change mitigation

5.4 Results of Technology Prioritization with MCA

Technology prioritization for the waste management sector was conducted by the consultant in collaboration with all stakeholders. The tool used for technology prioritization is Multi Criteria Analysis (MCA) using Definite Student computer based model (see 4.4).

For the Waste management sector, the following climate mitigation technologies were subjected to MCA using Definite Student computer model:

Waste composting; Biogas; Waste re-use; Methane capture from landfills; Plastic waste recycling; and Waste paper recycling.

Waste Management Sector

Table 5.1 MCA Scores

Criteria	Unit	Methane capture from bio-digester	Waste recycling-plastic	Waste – re-use	Waste Compositing	Waste recycling paper	Biogas
1. Contribution to climate change mitigation	Range 1-20	10	7	3	5	6	4
2. Contribution to national development	Range 1-20	20	8	7	12	15	10
3. Adaptation to local conditions	Range 1-10	9	1	4	4	5	6
4. Contribution to poverty reduction	Range 1-10	10	7	2	6	7	5

Methane capture from landfills was awarded the highest scores due to its potential to create opportunities for employment in urban areas and reduction of emissions of GHGs.

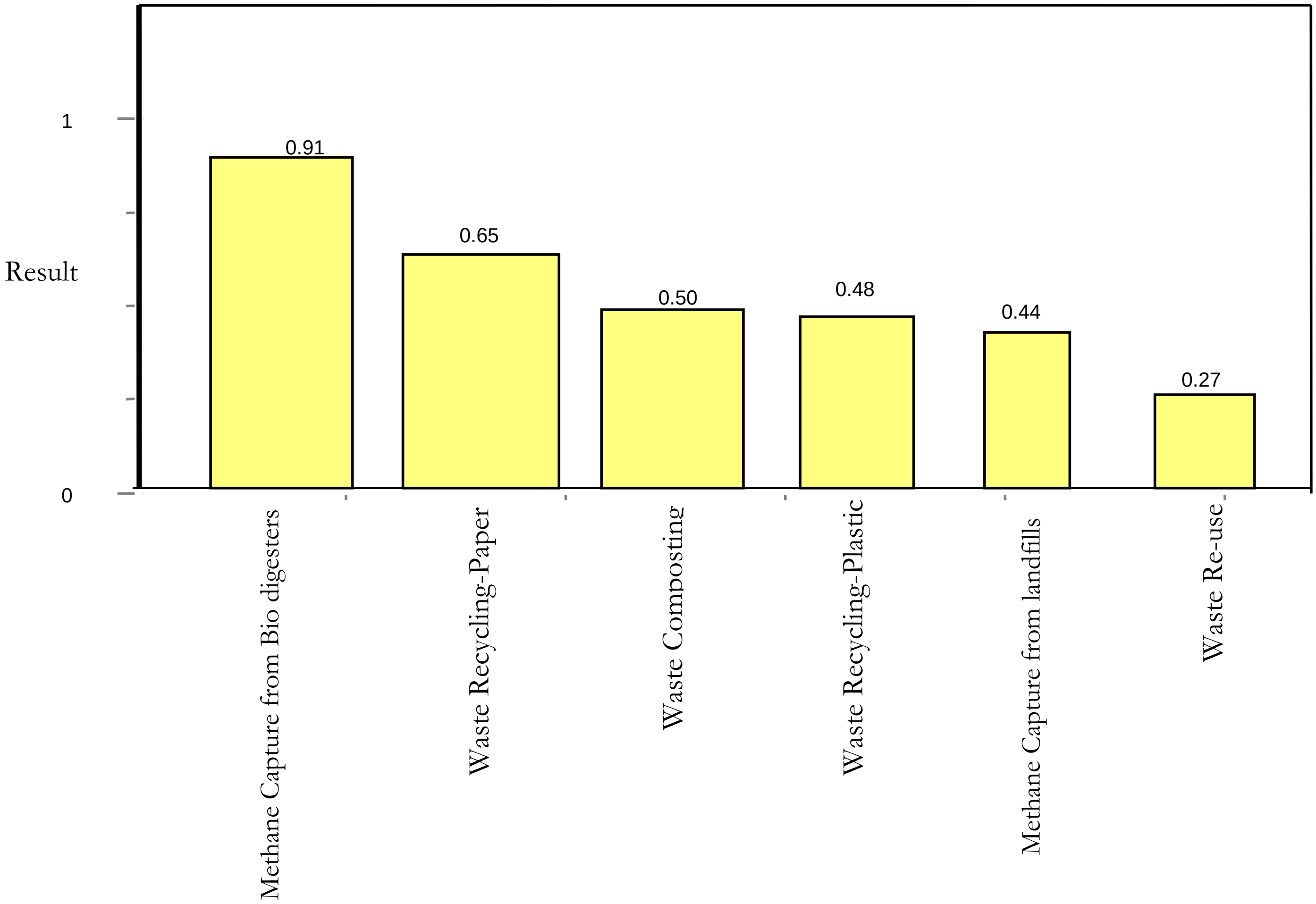
Table 5.2: Standardized Table

Criteria	CB	Unit	Methane capture from bio-digester	Waste recycling-plastic	Waste – re-use	Waste Compositing	Waste recycling paper	Biogas
Contribution to national development	+	1-20	10	7	3	5	6	4
			1.00	0.57	0.00	0.29	0.43	0.14
Contribution to climate change mitigation	+	1-20	10.00	8.00	7.00	12.00	15.00	10.00
			0.67	0.53	0.47	0.80	1.00	0.67
Adaptation to local conditions	+	1-10	9	1	4	4	5	6
			1.00	0.11	0.44	0.44	0.56	0.67
Contribution to poverty reduction	+	1-10	10	7	6	6	7	5
			1.00	0.70	0.60	0.60	0.70	0.50

Table 5.3: Relative Weighting

	Minimum	Maximum	Assigned Weights	Weight
1. Contribution to national development	3	10	10	0.40
2. Contribution to climate change mitigation	0.00	15	7	0.280
3. Adaptation to local conditions	0	9	5	0.200
4. Contribution to poverty reduction	0	10	3	0.120

Fig. 5.1: MCA results for technology prioritization



Results of MCA technology prioritization for the waste management sector were as follows:

i) Methane capture from bio-digesters
ii) Waste recycling-paper
iii) Waste composting
iv) Waste recycling-plastic
v) Waste re-use

The first two ranked technologies in the waste management sector were methane capture from bio-digesters and waste paper recycling. These two technologies will be subjected to further analysis in the next phase of the TNA process.

i) Methane Capture from bio-digesters was given to priority because it provides clean energy for rural household for cooking and lighting. It boosts crop production at lower costs and reduces indoor air pollution. It also reduces deforestation and hence enhances carbon sinks.
ii) Waste paper recycling was selected because it provides products for consumers at lower prices, reduces deforestation and reduces energy consumption during manufacturing.

CHAPTER 6: SUMMARY AND CONCLUSIONS

There are many technological measures that can be undertaken to reduce or avoid the emission of GHG and hence slow down the rate of Climate Change. Kenya like any other developing country does not have adequate technological capacity to mitigate climate change effectively. Therefore, there is need to transfer and develop appropriate technologies for climate change mitigation.

It is for this reason that Kenya has undertaken Technology Needs Assessment to identify, evaluate and prioritize technological means for climate change mitigation on the low carbon development path to achieving sustainable development.

The Technology Needs Assessment study identified and prioritized a number of sectors which included Energy, Agriculture, Forestry and Land Use, Industrial Process and Waste Management. It eventually settled on Energy (including Transport - subsector) and Waste Management for Mitigation.
Through the Multi Criteria Analysis the Study finally selected Solar Home Systems and Solar Dryers in the Energy Sector and in the Waste Management Sector selected methane capture from landfills, and Waste paper recycling.

The selection of Solar Home System gains credence by the fact that the country lying in equatorial belt has very high potential for solar energy. The solar electricity produced would therefore be widely used by households, schools, hospitals, hotels etc in the rural areas as well as urban centres not connected to the grid. In addition, the technology would greatly contribute to better health conditions, improvement in education and creation of employment. Most important is that the technology would replace the use of fossil fuel and therefore drastically cut down on emission of GHG.

Solar Dryers also rely on the high potential for solar energy to process and preserve food, vegetable, fruits and other crops such as tea and coffee. The technology could therefore replace use of fossil fuels and thermal electricity thereby cutting down on emission of GHG. It could further benefit the famers by increased income, reduced volume for transport, increased food security and nutritional conditions.

Methane Capture from bio-digesters is strongly recommended especially in rural areas where the capacity for waste management is very low. As bio-degradable wastes decompose in the bio-digesters, methane and carbon dioxide are emitted into the atmosphere. This technology would therefore capture the methane and contribute to improvement on health of the population, promote environmental quality and provide support to economic productivity.

Waste paper recycling technology responds to the demand for paper in the country which is unsatisfied. It entails turning waste paper into new products. The recycled paper reduces the amount of waste that would otherwise go to landfills. The technology saves forests by avoiding deforestation that would have taken place had the same amount of virgin paper been used.

In Kenya, waste paper recycling is undertaken in Nairobi and its environs. Waste paper in other towns far from Nairobi end up in landfills and contributes to the problem of managing waste. Thus if the technology is spread to other towns, it will not only protect the environment but will also create additional jobs in collection, separation and processing of the recycled paper.

All the above technologies have yet to get wide acceptability and application in the country especially in rural areas and hence need for their promotion. The next phase of the TNA will therefore focus on barrier analysis for each technology and measures to address the barriers.

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ANNEXES

ANNEX 1.0: TECHNOLOGY FACT SHEETS

Annex 1.1: Energy Sector

The following are fact sheets for the Energy sector

i) Solar Home Systems (SHS)
ii) Solar Dryers
iii) Non-Motorized Transport (NMT)
iv) Mini-hydros
v) Electric trains
vi) Mass transport
vii) Co-generation

i) Technology Fact Sheet: Solar Home Systems (SHS)	
Introduction	Kenya lies along the Equator. Solar energy resources are available in many areas of the country in quantities that are commercially viable. Solar Home Systems provide households lights, and electrical power for televisions, cassette players and small appliances. In addition, small scale systems for households and institutions such as schools, hospitals in especially in isolated rural areas not connected to the grid can be developed for local community utilization. Solar electricity if adopted fully in the country could be widely used in rural Kenya to power wireless communications technologies that are linked to processes of economic integration and greater rural-urban connectivity.
Technology Characteristics	Solar electricity is the electric power generated from sunlight using devices called *solar cell modules*. Electric devices transform solar energy into electricity for lighting, pumping water, powering radios, etc.
Country Specific Applicability and Potential	Solar Home Systems has very high potential given the fact that the country is located on the Equator
Status of technology in country	Solar Home Systems is yet to get wide acceptability and application in the country especially in rural areas not connected to the grid due to high initial costs of investment and insecurity of solar panels (Table 4.1). As one of the largest unsubsidized markets for solar home systems (SHSs) in the world, Kenya represents a promising model for rural electrification based on private purchases of clean decentralized photovoltaic technologies.
Benefits to economic/Social and environmental development	Employment creation Social and health benefits include: i) Better health as the technology does not emit any pollution as opposed to use paraffin lamps ii) Good learning opportunities for students in the evenings iv) Improved health. Traditionally families in rural areas use paraffin candles and lamps as source of light. These candles and lamps produce fumes which are harmful to human health
Climate change mitigation benefits	SHS can replace use fossil fuels for lighting and powering electrical appliances

Financial requirements and costs	On average costs about US$ 625 to install a Solar Home Systems with a 100W panel
ii) Technology Fact Sheet: Solar Dryers	
Introduction	Solar drying involves the removal of moisture from produce so as to provide a product that can be safely stored for longer periods. The solar drying method uses indirect solar radiation. The principle of the solar drying technique is to collect solar energy by heating-up the air volume in solar collectors and conduct the hot air from the collector to an attached enclosure. Drying is an important step in the food production process. The main argument for food drying is to preserve the food for longer periods of time. However, it is important to note that the process is not just concerned with the removal of moisture content from the food. Additional quality factors are influenced by the selection of drying conditions and equipment: • Moisture Content. It is essential that the foodstuff after drying is at moisture content suitable for storage. The desired moisture content will depend on the type of food, duration of storage and the storage conditions available. The drying operation is also essential in minimizing the range of moisture levels in the batch of food as portions of under-dried food can lead to deterioration of the entire batch. • Nutritive value. Food constituents can be adversely affected when excessive temperatures are reached. • Mould growth. The rate of development of micro-organisms is dependent on the food moisture content, temperature and the degree of physical damage to the food. • Appearance and smell of the food. For example, the colour of milled rice can be adversely affected if the paddy is dried with direct heated dryers with poorly maintained or operated burners or furnaces.
Technology Characteristics	The solar dryer is a relatively simple concept. The basic principles employed in a solar dryer are: • Converting light to heat: Any black layer on the inside of a solar dryer will improve the effectiveness of turning light into heat. • Trapping heat: Isolating the air inside the dryer from the air outside the dryer makes an important difference. Using a clear solid, like a plastic bag or a glass cover, will allow light to enter, but once the light is absorbed and converted to heat, a plastic bag or glass cover will trap the heat inside. This makes it possible to reach similar temperatures on cold and windy days as on hot days. Moving the heat to the food: Both the natural convection dryer and the forced convection dryer use the convection of the heated air to move the heat to the food.
Country Specific Applicability and Potential	Kenya lies along the equator and receives enough sunshine during the year. There is potential for applying solar dryers to dry cereals such as maize, wheat and rice after harvesting. These cereals are

	widely grown in the country both by small households and in large farms
Status of technology in country	In Kenya, GIZ has played a key role in introducing the technology. Most of the work was with simple direct, lowest cost type solar dryers. Such "simple" designs use frames made of wood, inside which screen trays are laid. A UV resistant plastic film is used as a cover. KIRDI is actively working with institutions and women's groups in developing improved dryers for processing of fruits, vegetables and cereals on a commercial basis.
Benefits to economic/Social and environmental development	Solar drying is not simply a method for substituting fossil fuels by solar energy, but it is a technological process of drying agricultural products to the required quality. The country will save on foreign exchange used to import fossil fuel.
Climate change mitigation benefits	Solar dryers have potential to replace use wood-fuels to dry tea leaves in tea factories and hence contribute to climate change mitigation.
Financial requirements and costs	Most of the work is with simple direct, lowest cost type solar dryers. Such "simple" designs use frames made of wood, inside which screen trays are laid
iii) Technology Fact Sheet: Non-Motorized Transport (NMT)-Bicycles	
Introduction	Non- motorised Transportation (also known as active transportation and human powered transportation) includes walking and bicycling and variants such as small- wheeled transport (cycling rickshaws, push scooters and hand- carts) and wheelchair travel. These modes provide both recreation and transportation in urban areas.
Technology Characteristics	These include: • Improved sidewalks, paths, bicycle lanes. • Bicycle parking. • Security concerns for pedestrians and cyclists • Safety education, law enforcement and encouragement programs
Country Specific Applicability and Potential	Non- motorized transport is available in some of the urban centres in the country and has a high potential for further development and improvement. The new highways and roads are making provision for non-motorised transport but this is yet to be expanded to cover other towns in the country.
Status of technology in country	Non- motorised transport is available in some of the urban centres but at a very low scale
Benefits to economic/Social and environmental development	i) NMT decongests roads ii) Provides opportunity for people to do physical exercise iii) It is eco-friendly as it does not pollute the environment
Climate change mitigation benefits	NMT has potential to mitigate GHS emissions from road transport in the range of 116 t CO_2/year (IISD, 2012)
Financial requirements and costs	Non- motorized transportation is one of the cheapest modes of transport that can be afforded by the great majority of the population especially the poor of the society
iv) Technology Fact Sheet: Mini Hydro-Power	

Introduction	Mini- hydropower technology is the development of hydroelectric power on a scale that serves a small community or an industrial plant. The size of a mini- hydropower varies but a generating capacity of up to 277 kW
Technology Characteristics	Mini- hydro-power is mostly of the run-of-river power plants which use the flowing water to generate electricity without the need to change the river flow. After use, the water used in mini-hydropower generation is returned to the natural course. The amount of power that can be produced by a mini- hydropower plant is determined by the head (the height of power drop) and the flow rate. The higher the head, the smaller the flow rate needed to produce the same amount of electricity. Mini- hydro power plants are best suited for isolated locations where there is no electricity grid. Off-grid power plants need local load controlling to stabilize frequency and voltage supply.
Country Specific Applicability and Potential	About 95 % of rural based Kenyans do not have access to electric power as most of the population is located in isolated and remote areas that are not accessed by the national grid. Development of mini- hydropower power plants will therefore contribute to the rural electricity supply. Kenya is endowed with a rich mini-hydropower potential of about 3,000 megawatts and only about 20 megawatts have been developed. In Kenya mini- hydropower is especially suited to micro-enterprises especially agro- processing industries as well as to health and indoor lights.
Status of technology in country	Mini- hydropower plants existed in Kenya in pre- independence days but were outpaced by the diesel engine especially in maize milling and pumping water. Today improved technology makes mini- hydro economically viable in many situations. However, the country lacks adequate capacity for installation and repairs.
Benefits to economic/Social and environmental development	Expansion of mini- hydropower generation in Kenya could result in great socio- economic and environmental benefits. Mini-hydropower generation technology is by and large pollution free and ecological friendly. Mini hydros usually have minimal reservoirs and civil construction works. They therefore have relatively low environmental impacts compared to other electricity generation technologies.
Climate change mitigation benefits	Depending on the forms of energy use the mini- hydro powered system substitutes will decrease air pollution and greenhouse gas emissions. Mini- hydropower plants are practically carbon free. Mini-hydros can replace fossil fuel generation capacity. In this regard, the mitigation potential is in the order of 13 $ktCo_2$/year by 2030
Financial requirements and costs	The capital requirements for mini- hydropower plants depend on the effective head, flow rate, geological and geographical features, the equipment and the required civil engineering works. Making use of existing constructions such as weirs dams etc. can reduce environmental impacts and costs. In general, sites with low heads and high flows need greater capital outlay

v) Technology Fact Sheet: Electric Train	
Introduction	An electric train locomotive is powered by electricity from overhead lines
Technology Characteristics	The advantage of electrification is the lack of carbon dioxide emission, has higher performance, lower maintenance costs and lower energy costs. The source of power can be renewable e.g. geothermal power, hydroelectric power, solar power and wind turbines. Electric locomotives are also quiet compared to diesel locomotives since there is no engine and exhaust noise and less mechanical noise.
Country Specific Applicability and Potential	Electric locomotive have a high potential for development in Kenya. Currently diesel locomotives are in use. The electric locomotives will be ideal for commuter rail services in the urban centres. They could also be used for high speed lines to link the major cities.
Status of technology in country	Trains in Kenya are diesel powered. Plans are now underway to replace them with electric powered systems.
Benefits to economic/Social and environmental development	Electric trains do not emit carbon dioxide, have high performance, lower maintenance costs, have no engine and exhaust noise
Climate change mitigation benefits	As mentioned above, electric trains do not emit carbon dioxide to the atmosphere. A recent study by CES, 2011 indicated reductions of 6,020ktCO_2/year-equivalent per year for a light rail system in Nairobi
Financial requirements and costs	**The chief disadvantage of electrification is the cost of infrastructure (overhead power lines**
Technology Fact Sheet: Mass Transport	
Introduction	In Kenya many people use mini buses/Matatus or private vehicles to go to work. Modern mass transit is an outgrowth of industrialization and urbanization.
Technology Characteristics	• Shared transportation open to all. • Rapid transit • Saving in Energy • High passenger load
Country Specific Applicability and Potential	Mass transport has high potential in Kenya as the concept has just taken off in the city of Nairobi where roads and highways are being widened to cater for more lanes, for example the Nairobi- Thika highway with eight lanes. This has drastically reduced traffic congestion between Nairobi and Thika with hundreds of public vehicles now moving with a lot of ease. The concept should be extended to other cities and towns in the country.
Status of technology in country	As mentioned above this technology is just taking off in parts of Nairobi City and has the potential to be extended to the other urban centres.
Benefits to economic/Social and environmental development	Mass transport is a shared system that caters for thousands of passengers at a go. It moves faster and results in energy saving.

Climate change mitigation benefits	Mass transport has the overall result of reducing Greenhouse gas emission to the atmosphere. A recent study feasibility study by (IISD, 2012) indicated reductions of between 4,832 to 5,696 ktCO_2 per year in Nairobi depending on how traffic is controlled.
Financial requirements and costs	Initially the cost of mass transit may be high but in the long run the overall effect is reduction in cost.
vii) Technology Fact Sheet: Co-generation	
Introduction	Co-generation also known as combined heat and power (CHP), is the simultaneous production of electricity and heat from a single fuel source, such as natural gas, biomass, biogas, coal, waste heat, or oil. By installing a CHP system designed to meet the thermal and electrical base loads of a facility, CHP can greatly increase the facility's operational efficiency and decrease energy costs. Co-generation for Africa project http://cogen.unep.org is an innovative clean energy regional initiative funded by the Global Environment Facility (GEF) through UNEP which aims to assist a number of industries to become self-sufficient in power generation and consumption. Kenya is one of the beneficiary countries for this project.
Technology Characteristics	Co- generation uses both electricity and heat and therefore can achieve an efficiency of up to 90% giving energy savings between 15- 40% when compared with the separate production of electricity from conventional power stations and of heat from boilers. It is the most efficient way to use fuel. The heat produced by co-generation can be delivered through various mediums, including warm water (e.g. for space heating and hot water systems) steam or hot air (e.g. for commercial and industrial use).
Country Specific Applicability and Potential	There is potential to generate electricity from agricultural wastes such as rice husks, bagasse in sugar and rice production industries in Kenya.
Status of technology in country	Co-generation technology is being implemented in several sugar factories in Western Kenya especially in Mumias Sugar Factory. The factory has initiated a 26 MW electricity generation project with bagasse being the main raw material.
Benefits to economic/Social and environmental development	Co- generation helps save energy costs, improves energy security and creates jobs. The country also saves on foreign exchange for importing fossil fuel.
Climate change mitigation benefits	Has high potential to reduce GHG emissions. Mitigation potential is in the order of 381 ktCO_2/year in 2030 (IISD, 2012).
Financial Requirements and costs	High investment costs. The Mumias Sugar Factory project will cost US $ 20million for a 26 MW plant.

ANNEX 1.2: Waste Management Sector

i) Technology Fact Sheet: Methane capture from landfills	
Introduction	Municipal Solid Waste (MSW) is waste generated by commercial and household sources that is collected and either recycled, incinerated, or disposed of in MSW landfills. The primary target of MSWM is to protect the health of the population, promote environmental quality, develop sustainability, and provide support to economic productivity. LFG is created as solid waste decomposes in a landfill. Methane capture from landfills entails the recovery and use of landfill gas (LFG) as an energy resource. This gas consists of about 50 percent methane (the primary component of natural gas), about 50 percent carbon dioxide (CO_2), and a small amount of non–methane organic compounds. Solid Waste Management in Kenya is the responsibility of Local Authorities. In Nairobi, the MSW are managed Nairobi City Council. The Largest municipal landfill in Nairobi is located at Dandora. Nairobi City generates about 2400 tonnes of waste per day.
Technology Characteristics	LFG capture projects aim at preventing emissions of methane and other pollutants from landfills. LFG is extracted from landfills using a series of wells and a blower/flare (or vacuum) system. This system directs the collected gas to a central point where it can be processed and treated depending upon the ultimate use for the gas. From this point, the gas can be flared, used to generate electricity, replace fossil fuels in industrial and manufacturing operations, or upgraded to pipeline–quality gas where the gas may be used directly or processed into an alternative vehicle fuel.
Country Specific Applicability and Potential	There is potential for methane gas capture in municipal landfill in cities like Nairobi, Mombasa and Kisumu among others. The captured methane gas will be used for electric generation.
Status of technology in country	Feasibility study has been done for use of methane gas from MSW although there are no concrete plans for implementation. Initial studies suggest that up to 64 MW of generation capacity in Nairobi (IISD, 2012).
Benefits to economic/Social and environmental development	**Economic benefits** i) Waste management is a business opportunity with potential for job creation ii) Poverty reduction iii) Boosts the economy **Environmental benefits** i) Reduction in self ignited random fires ii) Reduced health risk from infectious and respiratory diseases iii) It directly reduces air pollution by offsetting the use of non-renewable resources
Climate change mitigation benefits	GHG Reduction. The mitigation potential of the methane capture from landfills is estimated to be 1,116 $ktCO_2$/year in 2030 (IISD, 2012)
Financial requirements and costs	Initial costs for installation of methane capture are quite high.
ii) Technology	**Waste Paper Recycling**
Introduction	Waste paper recycling is the process of turning waste paper into new paper products. The process involves waste paper collecting, sorting

	and mixing it with chemicals to break it down. The final process is chopping it up to make pulp
Technology characteristics	Paper recycling is the recovery of waste paper products and reprocessing them into new products. The paper recycling process involves collection of waste paper, sorting it out into categories, pulping the waste paper, which feeds back into the paper making process. The rationale behind paper recycling is to recover the valuable raw materials and recycle it to create new paper.
Country specific applicability and potential	In Kenya waste paper account for about 12% of the municipal solid waste (Kasozi, 2009). In Nairobi, where approximately 80-90% of the municipal waste is landfilled available space is getting filled up fast. Waste paper recycling therefore presents an option to address the landfill site shortage. Waste paper also presents a source of cheaper raw material than virgin paper.
Status of technology in the country	Waste paper recycling has been practised in Kenya since 1958. Currently there are three main paper recycling mills that produce a total of about 150,000 tonnes of paper annual (www.chandaria.com2012). This production is not enough to meet Kenya's demand resulting in importation of finished paper.
Benefits to social economic and environmental development	Expansion of waste paper recycling in Kenya would result in creation of additional jobs in collection, separation and processing of recycled paper. The recycled paper would substitute imported paper and conserve foreign exchange earnings. The recycled paper reduces the amount of waste that would go to landfills thus prolonging the life of landfill sites.
Climate Change Mitigation	Recycling of waste paper avoids production of methane gas that would have resulted from anaerobic decomposition of waste paper thus contributing to climate change mitigation. In addition waste paper recycling significantly reduces energy use as the recovered pulp uses this energy than virgin pulp thus conserving energy
Financial Requirement	Paper recycling plants are major investments that require large capital outlays. However, as demand for paper in the country remains unsatisfied, the investment will be recovered in the long term.

iii) Technology	Waste Compositing
Introduction	Compositing is the decomposition of biodegradable organic matter to produce compost. Waste water decomposition is facilitated by aerobic bacteria under controlled environment. Compositing can be divided into home compositing and industrial compositing. Essentially, the same biological processes are involved in both scales of compositing. Different materials are suitable for decomposition, but carbon and nitrogen containing materials are normally preferred. These include green plant material, dry straw, leaves, paper and wood chips.
Technology characteristics	Generally there are two major approaches to compositing. Active and passive. **Active (hot)** compositing is compositing close to ideal conditions allowing aerobic bacteria to thrive. To achieve good results the composite material must be kept warm, insulated and moist. **Passive** composition is compositing in which the level of physical intervention is kept to a minimum. Most industrial compositing operations use active compositing techniques while home compositing operations use passive techniques. Waste compositing involves, waste collection, segregation/sorting, piling and sprinkling with water.
Country specific applicability and potential	In Kenya, waste compositing can be undertaken at both commercial and home levels as compostable material is found in large quantities in both rural and urban setting. In urban areas about 60% of municipal waste is of organic origin while in rural setting, most of the agricultural waste is available for compositing. With the current clamour for organic farming in the country, waste compositing has a wide application nationally.
Status of technology in the country	Waste compositing has been practised in Kenya for a long time.
Benefits to social economic and environmental development	Waste decomposting in Kenya could result in great social economic and environmental benefits. In rural setting waste collection, segregation and transport could go a long way in poverty reduction as these activities are labour intensive. Waste collection itself results in cleaner environment. In addition, the composite manure so produced is a cheaper alternative to imported chemicals fertilisers that consume large sums of the country's scarce foreign exchange.
Climate Change Mitigation	Waste compositing replace natural decomposition which takes place under anaerobic conditions that would result in emissions of methane gas. The carbon dioxide that is emitted during the de-compositing process is of lower global warming potential than methane and therefore contributor to climate change mitigation
Financial Requirements and Costs	The capital requirement for waste compositing depends on the scale of operations. At home compositing, the operation can be undertaken through household labour thereby minimising costs. Commercial compositing can be undertaken at small scale or medium scale. Most operators use basic equipment that do not require large capital outlay.

iv) TECHNOLOGY: PLASTIC SOLID WASTE RECYCLING		
A.1	**Introduction**	Municipal Solid Waste (MSW) is waste generated by commercial and household sources that is collected and either recycled, incinerated, or disposed of in MSW landfills. The primary target of MSWM is to protect the health of the population, promote environmental quality, develop sustainability, and provide support to economic productivity.
A.2	**Technology Characteristics**	Recycling refers to the separation and collection of wastes and their subsequent transformation or remanufacture into usable or marketable materials. Recycling, including composting diverts potentially large volumes of material from landfills and combustors.
A.3	**Country Specific Applicability and Potential**	Plastic poles in Kenya are used as electric poles, for fencing properties and national parks among others.
A.4	**Status of technology in country**	There are several other private entities in Kenya who are actively engaged in municipal solid collection and sell the same to the waste recyclers who make plastic poles.
A.5	**Benefits to economic/Social and environmental development**	**Economic benefits** i) Creation of jobs and poverty reduction ii) Minimizes **Environmental benefits** i) Energy conservation and preservation of biodiversity ii) Prevents the unnecessary waste of natural resources and raw materials
A.6	**Climate change mitigation benefits**	Reduction of greenhouse gas emissions from burning of plastic wastes
A.7	**Financial requirements and costs**	This technology requires high initial investment costs being in the region of 300,000 Euros
v) TECHNOLOGY FACT SHEET:METHANE CAPTURE FOR BIO-DIGESTERS		
A.1	**Introduction**	For the last fifty years, biogas technology has been promoted by the Government, international organizations and NGOs who have trained Kenyan technicians to build hundreds of biogas digesters in the country. However for some reason, the penetration rate of biogas technology in the country remains very low. Major constraints to biogas technology dissemination include: • High initial investment costs compounded with lacking credit schemes • Negative image caused by failed biogas plants • Limited private sector involvement • Lack of awareness of their social economic benefits
A.2	**Technology Characteristics**	Biogas is most commonly used for cooking and lighting. Residue Slurry is largely used as manure and is appreciated by the users. The most widely disseminated technology in Kenya is the floating drum. Biogas technology is a cost-effective investment if plants are properly constructed, effectively operated and well maintained.
A.3	**Country Specific Applicability and Potential**	Only an estimated 25 % of the installed biogas units in Kenya are operational, giving the technology a negative image. The potential is limited to agricultural areas with high population densities and is further restricted to farmers who can afford the high initial costs associated with biogas plants and have continuous supply of wastes. A minimum of two cows is necessary to start a biogas plant.

A.4	**Status of technology in country**	The use of biogas in homes, educational and health institutions has risen from slightly over 40 thousand metric tonnes in 2003 to 80 thousand metric tonnes in 2008 (KIPPRA, 2010). . It is estimated that up to 2000 units have been installed in total, though it is impossible to estimate what percentage remain in working condition due to the dispersed and sometimes uncontrolled and informal nature of installations (SHELL, 2010).
A.5	**Benefits to economic/Social and environmental development**	Savings on fire wood and charcoal purchases Reduced indoor air pollution Provide enriched fertilizers through waste residue slurry Reduces deforestation
A.6	**Climate change mitigation benefits**	Replaces use of firewood for cooking in rural areas. Abatement potential is high in that it enhances carbon sinks
A.7	**Financial requirements and costs**	Initial high investment costs. It costs about US$ 800 to start a biogas plant.
vi) Technology Fact Sheet: Wastes Reuse		
A.1	**Introduction**	In practice, wastes reuse involves the use of manufactured goods for the same purpose for which they were made or for a different and equally beneficial purpose
A.2	**Technology Characteristics**	Technically, although the goods were manufactured for specific use, their quality and characteristics are such that they can be used for a different purpose or can be used repeatedly for the original purpose without modification.
A.3	**Applicability and Potential**	In Kenya, goods such as bottles wrapping, materials and box containers are being reused for storage of similar substances in households or individual levels. The main requirement is that the quality of the container is such that it is suitable for the intended reuse.
A.4	**Status of technology in Kenya**	Beer bottles are manufactured from glass materials and are returned to the breweries for reuse. Soft drinks and bottled water and milk containers are made of plastic and are disposable and have limited reuse. Most plastic and paper containers and wrapping materials are reused only to a limited scale. There are opportunities for manufacturing higher quality containers which can be reused effectively.
A.5	**Benefits**	Containers that are reused will lead to lower cost of goods that they carry resulting in lower cost of living. It will also lead to cleaner environment.
A.6	**Climate change mitigation benefits**	Manufacturing of glass, plastic and papers consume energy with the associated emissions of greenhouse gases. Reuse of containers will result in lower energy use and hence reduced emissions of the gases.
A.7	**Financial requirements and costs**	In general, financial requirements fro recycling are low.